Uses of Tropical Grain Legumes

International Crops Research Institute for the Semi-Arid Tropics

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Leading scientists from 21 countries working on legume quality and utilization participated in this meeting. Its objectives were to: review the current uses of grains of chickpea, pigeonpea, and groundnut with emphasis on diversification of end uses; identify areas that require further research and development; develop research ideas to provide novel and alternative uses of these legumes; recommend areas for future collaborative research; and identify training requirements for further progress.

This meeting, the first of its kind held at ICRISAT Center, covered in detail the food products and uses of chickpea, pigeonpea, and groundnuts in different regions of the world. Uses of other legumes were also discussed, along with proposals for novel end uses. Market requirements and ideas for potential commercial utilization of legumes were also presented. These proceedings contain 39 papers, reports of discussions, and recommendations on research priorities.

Référence : ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) 1991. Les utilisations des légumineuses à grain tropicales : comptes rendus d'une Réunion de consultants, 27-30 mars 1989, Centre ICRISAT, Inde. Patancheru A.P. 502 324, India : ICRISAT.

Des chercheurs importants de 21 pays travaillant sur la qualité et l'utilisation des légumineuses ont participé à cette Réunion dont les objectifs étaient : l'examen des utilisations actuelles des grains de pois chiche, de pois d'Angole et d'arachide avec l'accent sur la diversification des utilisations finales; l'identification des domaines nécessitant davantage de recherche et de développement; la mise au point des idées de recherche permettant des utilisations nouvelles et diversifiées de ces légumineuses; la recommandation des thèmes pour la recherche collaborative future; l'identification des besoins en matière de formation en vue des progrès soutenus.

La première de son genre tenue au Centre ICRISAT, cette réunion a traité en détail des produits alimentaires et des utilisations du pois chiche, du pois d'Angole et de l'arachide dans différentes régions du monde. La réunion a également étudié les utilisations des autres légumineuses tout en examinant les propositions pour leur diversification. Les besoins du marché et les idées pour une utilisation commerciale potentielle des légumineuses étaient aussi présentés. Ces comptes rendus comportent 39 communications, rapports de discussions, ainsi que des recommandations sur les priorités de recherche.

Citación: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) 1991. Los usos de legumbres granosas tropicales: Actas de una Reunión de Especialistas, 27-30 Marzo de 1989, Centro ICRISAT, India. Patancheru A.P. 502 324, India: ICRISAT.

Científicos principales procedientes de 21 países investigando sobre la cualidad y la utilización de las legumbres participaron en esta reunión cuyos objetivos eran los siguientes: Examinar los usos actuales de los granos de garbanzo, guandul y maní (cacahuete) con énfasis sobre la diversificación de sus usos finales; identificar áreas que requieren mayor investigación y desarrollo; elaborar ideas de investigación a fin de proveer usos nuevos y alternativos de esas legumbres; recomendar áreas para investigación colaborativa en el futuro; e identificar las exigencias del entrenamiento para asegurar más progreso.

Esta reunión, la primerísima de este tipo para ser celebrada en el Centro ICRISAT, abarcó en grandes detalles los productos comestibles y los diversos usos de garbanzo, guandul y maní en las distintas regiones del mundo. La Reunión también se ocupó de los usos de otras legumbres asi como de la propuestas para nuevos usos. De la misma manera, se presentaron las necesidades del mercado y las ideas sobre la potencial de la utilización comercial de las legumbres. Estas Actas incluyen 39 ponencias, informes de las discusiones y las recomendaciones sobre las prioridades investigativas.

Uses of Tropical Grain Legumes

Proceedings of a Consultants Meeting

27-30 Mar 1989

ICRISAT Center

India

Sponsoring Organizations

ICARDA

International Center for Agricultural Research in the Dry Areas

FAO

Food and Agriculture Organization of the United Nations

and

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

ICRISAT

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Contents

Session IV

General

Session I

Welcome

Y. L. Nene[1]

As many of you undoubtedly know, the Consultative Group on International Agricultural Research (CGIAR) supports 13 international agricultural research centers around the world, with the primary aim of increasing world food production, and improving the standard of living of people, mainly in the developing countries. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was established in 1972 here at Patancheru. One of ICRISAT's mandates is to improve the productivity and quality of five different crops, three legumes - groundnut, chickpea, and pigeonpea, and two cereals - sorghum and pearl millet. Our focus has been, and will continue to be, on small farmers who cultivate their crops in rainfed situations in the semi-arid tropics of the world, mainly in Asia, Africa, and Central and South America.

During the last 15 years, a group of more than 30 ICRISAT scientists have worked hard to understand the causes of low productivity and production of pulses, and have made substantial progress in making available to national programs varieties that have higher productivity, and technologies that should ensure higher production.

In groundnuts, our scientists have evolved high-yielding, disease-resistant, pest-tolerant, and drought-tolerant varieties; varieties that are less susceptible to the aflatoxin-producing fungus, *Aspergillus flavus* have also been identified.

In chickpeas, our scientists have evolved short-duration kabuli and desi varieties, that are resistant to diseases such as wilt, root rots, and ascochyta blight, and pests such as pod borers. These cultivars give high yields on residual soil moisture. Very soon we should have short-duration, cold-tolerant varieties that will escape the onslaught of several biotic and abiotic stresses that reduce the yields of traditional, long-duration cultivars.

In pigeonpeas, our progress has been spectacular indeed, and we are proud of it. Our scientists have evolved high-yielding, photoperiod-insensitive varieties that mature in 3-4 months, in contrast to traditional cultivars that mature in 6-9 months and are subjected to several stresses. These short-duration varieties are proving very popular with farmers, particularly because they now have more options to fit pigeonpeas into varied and non-traditional cropping systems. Similarly, hybrid pigeonpeas evolved by ICRISAT scientists are increasingly being cultivated, and today we seem to be on the threshold of breaking the so-called "yield barrier" in pigeonpeas.

Through our Legumes On-Farm Testing and Nursery (LEGOFTEN) unit we have demonstrated improved production technologies to get two to three times the yields of these crops. To reach our goals, we at ICRISAT believe in joining hands with other

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international agricultural research centers and with the concerned national programs. We work closely with ICARDA on kabuli chickpeas. Through our programs in West and Southern Africa, we are working with countries of those regions to increase groundnut production. We will soon initiate similar research activities in eastern Africa. Through our Asian Grain Legumes Network (AGLN), we are working in 10 different countries in South and Southeast Asia. Together with the International Rice Research Institute (IRRI), we organized a workshop on varietal improvement of pigeonpeas, chickpeas, and other legumes in South and Southeast Asia, with particular reference to rice-based cropping systems in Nepal.

I have gone into these details to indicate to you that the chances of increasing production of legumes in many countries in the next 5-10 years are very bright. However, we are concerned that when this happens, the small farmers may not be remunerated for their produce. To protect farmers from such an eventuality, it is important that new, alternative, and innovative uses of these legumes are worked out soon. This is the main reason we are holding this Meeting, with 32 consultants from 21 countries as participants. To learn from the experiences gained on other legumes, we have invited experts who have worked on such other crops as soybean, mung bean, faba bean, and lentils.

At ICRISAT we take things seriously, sometimes too seriously. For example, our organizing committee spent over an hour discussing whether the title of this meeting should include the word: "utilization", or "uses", and finally the majority favored the word "uses". We will not be able to allot that much time for all your deliberations, but sufficient time has been provided. We are looking for ideas, and we will seriously study all your recommendations. We will initiate new research projects, and make necessary changes in our ongoing research projects. Your help will be timely because we are presently preparing our strategic plan for the next decade and beyond.

Welcome

J. I. Cubero[1]

On behalf of the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and Food and Agriculture Organization of the United Nations (FAO) I welcome you all to this meeting. My statement of welcome will be very short, but I would like to comment very briefly on the title of this meeting: "Consultants Meeting on Uses of Grain Legumes". All of us are aware that legumes are important crops, but they have a rather low profile when compared to cereals. They are more important now than they were when man began to cultivate land. They are good companions of cereals both on the table and in the fields, and they provide important proteins for everyone - both humans and animals. They are also useful as rotation crops that improve soil fertility, and are increasingly vital for sustainability of yield. So, legumes are a very important part of our agricultural system, and they will gain in importance if we want to maintain soil structure and fertility.

Until recently legumes have been mainly used for human consumption as a very cheap source of protein. Many people around the world live on a staple diet of cereals and legumes, without consuming any animal meat. We are in a country that has historically demonstrated this. However, in the 20th Century, many more uses for legumes have been discovered. Developed countries have been able to produce new uses for several legumes such as soybean and groundnut. The industrial extraction of oil, which still leaves a very protein-rich material for animal feed and many other purposes, is one of the most successful treatments of legumes that have been developed in this Century. Some other legumes have also been successful, in the sense that new uses have been found for them by developed countries, notably in the canning or freezing industries. Many other legumes such as chickpea and pigeonpea, are still awaiting breakthroughs in nontraditional uses. Traditional agriculture, particularly subsistence agriculture, utilized these legumes for direct consumption on the farm. We need to extend the scope of legume utilization not only to maintain the nutritional values of diets, but also to provide higher incomes for the farmers. In these modern times, subsistence not only means food, or being maintained on a very low protein or food profile: as human beings we need other things, like schools for children; so we need to widen the perspectives of farmers to higher incomes. This can only be achieved if we discover new uses for grains, so that extra production on the farm can be exported or used in one form or another by food processing industries. This meeting should help increase farmers' incomes in the developing world.

Finally, this kind of meeting is popular in the Consultative Group on International Agricultural Research system. It is not only a meeting with long papers, long academic

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papers, with a lot of scientific data, but also, basically it is a meeting to exchange opinions and ideas. It is a meeting not just to speak about what we do in our own Centers, but to learn from other people's work. I am highly appreciative of the invitation of the Organizing Committee to address you on behalf of ICARDA, but I feel I can also speak on behalf of ICRISAT. I started my relationship with international centers at ICRISAT soon after it was created when a similar meeting on pulses was held in 1975. I enjoyed visiting the old conference room where we held our meetings on chickpea and other pulses, and marvelled at the difference the intervening years have made- a difference for the better! On behalf of the three co-sponsors, I welcome you to this Meeting. Enjoy it, and learn a lot from it.

Inaugural Address

L. D. Swindale[1]

First let me say how pleased I am that the Chairman of the International Center for Agricultural Research in the Dry Areas (ICARDA) Board, Dr. Cubero, has joined us for this meeting. It is indeed a real pleasure, both because he represents a sister IARC with which we have close cooperative relationships, and also because he has come to ICRISAT as a scientist. We are very grateful that he has taken the time to do this, and we hope he will participate in our discussions.

I would like to add my welcome to all of you who are here for this Consultants Meeting. Several of you may find opportunities for cooperative research in areas other than those you will discuss in this meeting, and we hope that you will exploit these opportunities.

This is, I think, the first meeting at ICRISAT where uses of legumes will be exclusively discussed. The meeting, therefore, represents quite a challenge and an opportunity to suggest new and different options. It is also easy for a group or organization such as ours to get into a rut, to stay there, to keep thinking the same thoughts, and to do the same things. So we ask you, our Consultants, to help jolt us out of any such routine that we may have fallen into, and to help us look at what the world is doing with legumes, and what we at ICRISAT and ICARDA can do with the ones that appear in our mandates.

It's a great challenge to the centers of the Consultative Group on International Agricultural Research (CGIAR) and to everybody involved with development, to help provide sufficient food to meet the needs of the people. Food production must keep pace with world population, which in many developing countries will double early in the next century. Food production must also keep pace with rising incomes and expectations in countries with growing economies, as is true in most of Asia. A panel of the World's Commission on Environment and Development reached the following conclusion: "The next few decades present a greater challenge to the world's food systems than they may ever face again. The effort needed to increase production in pace with an unprecedented increase in demand while retaining the essential ecological integrity of food systems, is collosal in both its magnitude and complexity. Given the obstacles to overcome, most of them man-made, it can fail more easily than it can succeed". (World Commission on Environment and Development 1987).

The CGIAR, the parent body of the international agricultural research centers, is concerned about this challenge and recently it adopted a new goal statement. That statement reads as follows: "Through international research and related activities, to contribute to increasing sustainable food production in developing countries in such a way that the nutritional level and general economic well-being of low-income people are improved". There are phrases in that goal statement that relate to the purpose of this meeting, and the obvious one is the nutritional level. In several developing countries, the practice of judiciously mixing cereals and legumes to provide a good quality diet was in vogue long

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before we were able to understand and appreciate, through the use of modern science, the basis for this practice. We now know that legumes are excellent sources of protein containing almost double the quantity found in such common cereals as wheat and rice. According to the recent FAO Production yearbook (FAO 1987, p. 246, 248), only a small fraction of total calories, and about 20% of total protein intake, comes from animal sources in the developing countries. In the developed countries, almost 30% of total calories and more than 50% of the protein consumed comes from animal products.

It is a well known fact that legumes are a much cheaper source of protein than poultry, meat, or fish. For example, in Hyderabad, in March 1989, to obtain the same quantity (100 g) of protein from different sources one had to spend for legumes—Rs. 4.74, for beef—Rs. 8.85, for chicken—Rs. 11.58, for mutton—Rs. 24.32, and for fish—Rs. 24.69. It is of course appreciated that the quality of the different proteins would vary.

Another phrase in the CG goal statement is general economic well- being of low-income people. In the CG today, this phrase is being interpreted to mean increasing incomes of farmers and other rural people, and it is being given greater emphasis. Legumes are higher value crops than cereals. Other things being equal, substituting legume production for cereal production should lead to increased incomes. There is great scope for such substitution, particularly in the deltas of the great rivers where two to three crops of rice are no longer necessary. But attempts to increase legume production, particularly of the pulses, is likely to be constrained by demand, unless we can find new and better ways to make use of them.

Legumes may be consumed as immature green grains, or the whole or dehulled grains may be boiled, parched, roasted, germinated, fermented, or cooked in different ways to suit specific tastes. Many of the processes were developed long before we knew about their scientific merits. Even today, we do not completely understand all the changes that occur in a grain during the course of processing, or how this may affect its nutritive value. But many of these traditional/mechanical methods of processing and cooking have largely been confined to specific regions, and there has been little attempt to try new methods where established methods exist for utilizing a crop.

Take for example chickpea. In India, chickpea is used in many different ways. I would like you to think of the possibility of these products finding acceptance in other regions or countries. Last year, in cooperation with FAO, we held a training course here at ICRISAT on quality and utilization of legumes with participants from Bangladesh, Indonesia, Nepal, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam. I am informed that some of the legume products were so much appreciated by the participants that they were consumed as rapidly as they were prepared, and very little was left for the taste panelists. Also, it was the first time that some people tasted *tempeh* made from pigeonpea, and they found it quite acceptable.

Today you represent a much wider region, and bring with you great knowledge and expertise. However, we ask that you keep one objective of this meeting in your minds: Can we find new or alternative uses for ICRISAT mandate legumes-chickpea, pigeonpea, and groundnut? This is particularly important for pigeonpea, which is not widely used except in India, and in some countries where it is produced largely to meet the needs of people of

Indian origin. Therefore, I would like you to be bold in suggesting new areas where you think ICRISAT can venture, and to identify new or alternative ways of crop utilization. It would be greatly appreciated if you and your colleagues could help us by testing some of the products in your native countries and recording the responses of local consumers to them. I understand that you have been requested to bring to this meeting recipes of important products of pigeonpea, chickpea, and groundnut that are popular in your region. Although information may be available for each region separately, it will be useful if these recipes are assembled so that we can all understand the global pattern of utilization of legumes.

We should not be limited by tradition in thinking about what we can do with our crops. For example, they can be used as fodder. Groundnut is already important for that purpose, with the residue after oil extraction being used as feed cake, and the haulms used for hay in some parts of the world. Pigeonpea is used directly as a feed and as a forage, and can be used as a substitute for soybean in some products. In India, at least in the past, and in Thailand, certainly in the present, pigeonpea is used as a host plant for lac insects.

Crop improvement and protection are increasing the possibilities for rapid increases in production. The need to do the same for uses is equally obvious. I would like to ask you to develop long lists of possible uses for legumes through your brain-storming meetings in the working groups, and put them into some rough order of priority for further study and research. Please don't be limited by the number of entries. When we have many consultants, we expect much advice. We will be able to use future opportunities to trim the lists down to manageable proportions.

Help us also, if you can, to describe the specifications for use. At present, groundnut is the only one of the three ICRISAT mandate legumes that has well-defined quality standards in both local and international markets. Two of our colleagues from ICRISAT, Drs Gowda and Dwivedi, returned recently from the Philippines with listed specifications for groundnut to be used in making a whole variety of commercial products, including peanut butter. Such information is very useful to us and perhaps to many of you. Do we know what the list of specifications for pigeonpeas should be? It would be important to know. We welcome the advice of those representatives from industry who are present at this meeting.

Finally, once again, I hope you will enjoy your stay at ICRISAT, and help us to do a better job with our mandate crops for the benefit of people in developing countries.

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World Commission on Environment and Development 1987. Food 2000: Global Policies for Sustainable Agriculture: A Report to the WCED. Geneva, Switzerland: WCED.

Objectives of the Meeting

The purpose of holding the Consultants' Meeting on Uses of Grain Legumes was to discuss current utilization aspects of the grains of chickpea (*Cicer arietinum*), pigeonpea (*Cajanus cajan*), and groundnut (*Arachis hypogea*) with emphasis on diversification of end uses. Invited experts assessed the latest developments and the application of various techniques in the field to formulate immediate and long-range plans to improve the uses of ICRISAT's mandate legumes.

The objectives of the meeting are:

- To review existing knowledge on the uses of chickpea, pigeonpea, and groundnut grain.
- To identify:
  - areas which require further research and development;
  - research ideas which provide novel and alternative uses of these legumes to help structure future research thrust;
  - areas for collaborative research; and
  - training needs.

Nature, Composition, and Utilization of Grain Legumes

J.H.Hulse[1]

Abstract. *Legumes are grown on poorer land and given less attention than the more profitable cereal grains. Cereals have been converted both domestically and industrially into a greater variety of edible products than legumes, soybeans being the only possible exception. Investigations on the nutritional quality of legumes do not suggest that any exceptionally new or unexpected knowledge or concepts have come to light during the last 15 years. Postharvest storage of legumes is influenced by temperature, moisture, and oxygen content. Feasible modifications of established storage systems in villages would be more efficient and economic than imported expensive technologies. More efficient and effective postproduction systems that are complementary integrated with sustainable production systems are needed. Integrated pest management both pre- and postharvest, coupled with a fundamental biochemical approach to entomological and mycological taxonomy would provide further insight and facilitate control of postproduction losses.*

There are many references in the literature to the functional properties of soybean proteins but relatively little on chickpea and pigeonpea. The functional properties of importance inelude water-binding capacity, solubility, gel formation, lipid binding, and foam formation. Processing of legume flour by such methods as agglomeration, extrusion, and protein concentration, offer scope for finding new uses as well as supplementary uses in existing food products. A better understanding of the essential biophysical and biochemical structures of grain legumes are needed if innovative technologies are to yield products of broader application and greater variety than are presently available.

A better appreciation of the functional properties of these important legume components is essential if future genotypes are to be utilized and processed in the most advantageous manner. Insensitivity to, and inability to determine what constitutes consumer acceptability is a primary cause of failure in the introduction of both unfamiliar crops and new food products.

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However, sustainable progress will not be realized if research and development is confined to academic institutions and government laboratories. The early involvement of the commercial sector, whether private or parastatal is essential, particularly in market research and development and in establishing realistic standards of product quality and process control. This would also ensure that genotypes developed by the international agricultural research centers will be fully utilized in improving the quality and variety of human diets, thereby generating employment in the agro-industrial sector.

The Leguminosae are one of the three largest families of flowering plants, and are composed of 690 genera and 18 000 species. They are characterized by butterfly- or keel-shaped flowers and pod-shaped fruits. Of the three main subfamilies, the Papilionoideae are the most important and contain more than 12 000 tropical, subtropical, and temperate species. Many are cultivated, each capable of symbiotic interaction with soil bacteria that infect the root nodules, and of reducing atmospheric nitrogen to a chemical form the plant can utilize in tissue synthesis and maintenance.

Legumes: Nature and Origin

Broadly speaking legumes can be classified into those relatively low and high in edible lipids, the latter often described as oilseeds. Many of both classes may be eaten raw or cooked as green vegetables, but the former are more often harvested as dried pulses. A third class of legumes of agricultural importance includes many species of pasture, cover and fodder crops, and green manures.

The most widely cultivated legumes are the two principal oilseeds: soybean and groundnut that represent roughly 50% and 16% respectively of the total world production of grain legume crops, chickpea providing only 7% and pigeonpea slightly less than 2%.

Grain legumes are known to have been cultivated at least since neolithic times. Phaseolus beans carbon-dated to before 4000 BC have been found in Mexican caves, and peas of similar age were discovered in neolithic excavations in Switzerland, in predynastic Egyptian tombs, and in ruins around Troy. Chickpea seems to have originated in the fertile crescent of the Mediterranean, though some ethno-botanists report early finds in the Himalayas. Recipes for chickpeas are recorded in some of the earliest known Roman cookbooks: "De Re Coquinaria" by Apicious, "The Deipnosophists" by Atheneus, and "Historia Naturalis" by Pliny the Elder. Dishes described include boiled and roasted pulses and tender immature seeds in desserts. Pliny recommends chickpea as a diuretic, as a lactation stimulant, and as a palliative for skin irritations.

The place of origin of the pigeonpea, so-called because of its appeal to wild pigeons, is not certain. Watt (1908) reports early wild species in China and Indochina; de Candolle (1886) states that wild ancestors grew in Africa from the coast of Guinea to Zanzibar, and in the Nile valley. D.N. De (1974) believes that *Cajanus* species, together with the closely related *Atylosia,* were well established in northern India and on the Deccan plateau at least 3500 years ago.

In common with many other edible legumes, pigeonpea may be eaten raw or cooked as immature green seeds; it may be dried in the field, parched, roasted, or ground into flour or coarse meal. Though measurable quantities are cultivated in the Caribbean, southeast Asia and eastern Africa, close to 90% of total world cultivation is on the Indian subcontinent. The crop is, however, of special significance in eastern Africa where, during seasons of extreme aridity it may be the only crop that survives. As with any other crop cooked and in other ways processed for human consumption, legumes may be examined and evaluated both for their nutritional and functional properties, and the influence upon either or both as a consequence of biochemical and biophysical interactions that result during or subsequent to processing.

It is 14 years since this author contributed to the 1975 workshop on grain legumes at ICRISAT (Hulse 1976). Two comprehensive reviews of literature on chickpea (Chavan et al. 1986) (Williams and Singh 1988) and one on pigeonpea (Salunkhe et al. 1986) do not suggest that any exceptionally new or unexpected knowledge or concepts have come to light during the interim. Research at ICRISAT has revealed a number of potentially useful properties among wild uncultivated species of *Cicer*, *Arachis* and *Atylosia*, some of which could in time be transferred into cultivated wild crosses. ICRISAT's cytogeneticists, employing embryo rescue and other elegant techniques of transgenesis, have embodied resistance to late leaf spot and other infections from wild *Arachis* species into *Arachis hypogeae.* These successes offer hope that cooperation between cytogeneticists and biochemists might discover and transfer from wild species desirable traits in oil content and composition.

Studies at ICRISAT and ICARDA have reconfirmed that cooking times vary widely among genotypes and that seed nitrogen content is significantly influenced by the agroclimatic environment and agronomic conditions of cultivation. In the light of contemporary concepts of human nutritional requirements, and the opportunities and constraints of legume breeders, it is questionable if high priority should be given to a search for genotypes high in sulphur-amino acids. As was suggested in earlier presentations, it could be more rewarding to give greater attention to the inheritable characteristics that make ICRISAT's mandated legumes more or less acceptable to communities which grow, cook and eat them, and to technologies that would arouse greater interest in the food processing industry.

Nutritional Properties

Though in more affluent societies legumes, particularly dried pulses tend to be regarded as protein for the poor, the nutritional complementarity of cereal and legume protein has long been recognized, at least empirically if not biochemically. In Imperial Rome, bean and barley flour were frequently mixed into wheat flour; in medieval England bread for the poorer people was often supplemented with pea and bean flour, a practice that became mandatory during World War II.

Though pulses are generally grown as food for their protein content and amino composition, the oilseed legumes, groundnut and soybean, are most widely grown as commercial crops for their oil content. The oil is extracted either by heat and pressure, and/or by solvent extraction, the residual high protein "oil-cake" being used mainly as animal feed. Where appropriate technological and hygienic control is maintained, the cake can be made suitable for human consumption.

Legume Composition

It is not the purpose of this presentation to address at length methods of analysis. Since, much is published concerning protein and amino acid content in the food we eat, some words of caution may be in order. The crude protein content of plant and other food materials is estimated by multiplying the determined nitrogen content by some accepted conversion factor. One of the earliest and most extensively used is the factor of 5.7 recommended by Osborne and Voorhees in 1893 (Osborne 1924). Following many determinations they concluded that the average nitrogen content of the many wheat protein samples analyzed was 17.54% and that therefore wheat protein content could be estimated by multiplying the analyzed nitrogen content by 5.7.

Though first published in 1883 the method of Johann Kjeldahl remains the standard against which all other methods of protein assay are compared. The Kjeldahl method determines nitrogen content and assumes that nitrogen represents a constant proportion in each natural protein source. The standard Kjeldahl method of determining nitrogen by the oxidative digestion of all amino acid and amide nitrogen to ammonia is, in the best of circumstances, susceptible to some 24 sources of error (Williams 1977). The assumption often made is that N represents 16% by mass of all animal and most plant proteins. Total amino acid analysis shows that the N content of most cereals and legumes is greater than 17.5% and, therefore, that the N-to-protein conversion factor for most cereals, oilseeds, and legumes lies between 5.3 and 5.7 (Tkachuk 1977).

Despite many pleas for greater clarity and standardization of reported data, "protein content" is frequently quoted without reference to the method of determination, the N-to-protein conversion factor employed, or whether on a dry mass or as-is moisture content. Results could be more comprehensible and comparable if presented as total nitrogen and nonprotein nitrogen on a dry mass basis. Similarly, the convention of expressing amino acids as mg AA g N^{-1} and other minor ingredients as mg 100 g^{-1} dry matter would make for simpler comparison of data.

Recognizing the many potential sources of analytical error, the variability among methods and, indeed, among analysts, comparisons of protein and amino acid content among different reports can at best be regarded as approximate.

The subject of the analysis and nutritional evaluation of protein and amino acids is comprehensively discussed in a United Nations University (UNU) publication (Pellett and Young 1980). Based upon data from FAO/WHO, this publication quotes the daily protein requirements of different age groups as varying from 1.85 g kg^{-1} of body mass for infants of 3-6 months, 0.80 g kg^{-1} for children 10-12 years old, and 0.57 g kg^{-1} for adults. From the same source the authors also quote differing amino acid requirement patterns among the described age groups.

The authors emphasize what has long been evident: that opinions about how much protein and of what composition is ideal have varied widely over the past century, even over the past 2 decades. Sometimes overlooked are the increased requirements of people, particularly children under stress of acute and chronic infections that cause depletions of body nitrogen in amounts difficult to determine and likely to vary with the duration, nature and severity of the infection, and the nutritional status of the sufferer at the outset. The UNU authors state : "The total amino acid profile of a food protein is a good indicator of potential nutritional value but may at times be misleading if one or more of the essential amino acids are only partially available. It is therefore critical that the availability of the reactive and most frequently limiting amino acids—lysine, methionine and cystine—be known. This is especially true for proteins present in processed foods and food ingredients."

Hulse (1976), in calculations from various published sources, gives analyses of different samples of chickpea and pigeonpea. In whole chickpea, ether extract ranged from 3.9 to 6.2% (4.6-6.9%), protein 20.8-25.9% (25.3-28.9%), soluble CHO 60-63% (63-65%), crude fiber 8.0-8.7% (1.0-1.5%), the figures in parenthesis being after dehulling. Other analyses showed significant variations between inner and outer segments of the cotyledons: the inner fraction representing 25% of whole grain mass contained 19.4% crude protein; the outer fraction representing 65% of grain mass contained 25.7% crude protein. Both lysine and methionine appeared proportionately higher in the outer than in the inner fractions. Analyses quoted by different authors showed wide variations in amino acid contents (mg g^{-1} protein) among both chickpea and pigeonpea samples. Also other authors referenced by Hulse (1976) report significant variations among samples in biological value: chickpea 52-78, pigeonpea 47-74; and in coefficient of digestibility: chickpea 76-92, pigeonpea 59-90.

Because of the complications inherent in determining the biological values of protein sources by chemical analysis or with human subjects it is customary to use indices based upon rat mass gain or nitrogen retention, the latter determining the balance between intake and loss through excretion. One of the most widely quoted is the protein efficiency ratio (PER) which is a comparative ranking index and not an absolute measurement. A PER estimated at one place and time cannot reliably be rated or ranked against PERs determined with different animals at another place and time. Each PER is location- and time-specific; unlike an atomic weight or the mass or dimensions of a platinum bar it is not an absolute invariable property of any protein.

It would appear that too much reliance may have been placed upon rat growth data in arriving at recommended daily nitrogen intakes for human beings. Expressed as intake per kg of body mass, the daily protein, lysine and S-amino acid intake required to maintain optimum mass increase in rats is significantly greater than the levels required for adult human body maintenance. Young et al. (1984) concluded that nitrogen balance, blood and body composition were satisfactorily maintained in young adults whose sole source of protein was 0.8 g kg^{-1} day^{-1} of isolated soybean protein. Scrimshaw et al. (1983) who determined nitrogen balance in adults reported that isolated soybean protein was indistinguishable from cow's milk at isonitrogenous intake.

Cereal-Legume Complementarity

The nutritional complementarity of cereal and legume protein seems to have been discovered empirically on all continents: rice with soybean in southeast Asia; sorghum or millet plus chickpea or pigeonpea in south Asia; sorghum or millet with cowpea in Sahelien countries; maize with lima beans in Latin America being of long tradition. Chemical analysis has shown that the amino acids deficient in the legumes are generally adequately compensated by the protein of cereals and vice versa. The mutual compensation is closest to ideal when the ratio by mass of cereal to legume is roughly 70:30, in which proportion each provides about equal parts by mass of protein. According to FAO statistics, only in Latin America are the total productions of cereals and legumes in a ratio of 70:30. Across Asia the ratio is closer to 90:10; in recent years legume production appears to be declining possibly because of the greater appeal to farmers of the higher yielding cereals. It is apparent in several areas that legumes are grown on poorer land and given less attention than the more profitable cereal grains. The latter appears to be the case in relation to processes of transformation, the cereals being converted, both domestically and by the processed food industry into a greater variety of edible products than legumes, soybean being the only possible exception.

Antinutritional Factors

The legumes are also disadvantaged in varying degrees by the adverse physiological factors they contain. These include, among others, trypsin inhibitors, haemagglutinins and flatulence inducers, and are the subject of many publications (Milner 1973; Liener 1969). Suffice it here to say that several observers (Jelliffe 1955; Bressani and Elias 1974) suggest that in many developing countries few children are fed legumes during the 1st year of life. Flores et al. (1966), in a study of Guatemalan Amerindian children 1-5 years of age, reported that only bean broth was fed in earlier years, the proportion of cooked beans being gradually increased as the children grew older. Though in adults flatus is possibly more of social than clinical importance, severe flatulence can cause acute discomfort in infants. In a study of infants fed on legume diets, Rao et al. (1973) reported that chickpea induced greatest flatus, followed by black gram pigeonpea and green gram in descending order. The literature available suggests that haemagglutinins are virtually absent from chickpea and pigeonpea and that antitrypsin activity is relatively low when compared with common bean (Hulse 1976).

Legume Consumption

It is well demonstrated that the nutritionally complementary benefit of eating cereals and legumes together in appropriate proportions is greater than if the two are eaten in the same quantitative proportions, but at different meal times.

Despite their demonstrable value as a relatively inexpensive source of protein nutritionally complementary to cereals, except among those who observe strict vegetarianism, the universal trend, as disposable incomes rise, is for legumes to be replaced by animal protein. A growing recognition that excessive consumption of red meat can be detrimental to good health is noticeable in the consumer markets of north America and Europe. The tendency, however, is to replace beef with chicken and fish rather than with vegetable proteins. Though the importance of healthy and wholesome diets is widely publicized and accepted in principle by many better educated north Americans, eating habits are generally persuaded more by what is economical and by what appeals to the eye and palate, than by what is most nutritionally desirable.

Eating is a source of pleasure as well as a physiological necessity. It is therefore not surprising that among the very poor the first significant increments in disposable income are given to increasing the quantity and variety of the diet. The traditional foods of many poor communities reflect the need for economy of fuel and time for preparation. Consequently cereals and legumes are simply ground into meal or flour then cooked in water either into gruels or porridges or as stiffer pastes into flat breads. Foods calling for more time and attention, such as fermented, leavened breads from milled and selectively fractionated flours were first produced by slave labor in the Egyptian and Babylonian courts, and later in imperial Rome by domestic slaves or urban millers and bakers. Women in the poorest communities have access neither to domestic help nor to disposable income wherewith to buy manufactured foods. Consequently simple forms of domestic preparation are most preferred.

Postharvest Conditions

In the case of food legumes, available literature suggests that more effort has been invested in nutritional evaluations than in studies of those physico- and biochemical properties that bear upon technological transformation and postharvest stability. Few components of postharvest systems provide more revealing examples of inappropriate transfers of technology than the storage of food grains. A disturbing assortment of pesticides were found to have been distributed to farmers with instructions they could not understand.

Research in western Africa encountered a diverse array of competing, often conflicting, storage devices imposed by different aid agencies upon the indigenous farming communities:

- Prefabricated metal silos that turned into pressure cookers as the heated exterior drove moisture to the center in sufficient concentration to cook the grain.
- Do-it-yourself kits to construct concrete silos for which all of the materials had to be imported.
- Subterranean hermetically sealed bins which cracked as the subsoil shifted and, though easy to fill, were impossible to empty, the designers seemingly never having heard of Newton's apple.
- Used oil drums, theoretically hermetically sealed but in fact not so, since the top rims were easily bent and sealing gaskets quickly perished.

An imaginative small group at the Centre nationale de recherche agronomique, Bambey, in Senegal, decided that, before importing expensive technologies, it would be wise to examine what local farmers had learned over many centuries of growing and storing sorghum, pearl millet, and cowpeas. With the assistance of women students from a nearby college, storage and utilization practices by 700 farming families were recorded. Few, if any, could afford either the cost of purchase or maintenance of the devices offered by aid agencies. More important, it was demonstrated that, without resort to imported materials or designs, modifications to established storage systems were at least as efficient and more economic than those of foreign origin.

Control and Determination of Loss

The three essential variables to be controlled in stored grain are temperature, moisture, and oxygen content. It was demonstrated how these could be satisfactorily controlled in circular bins made of woven sorghum stalks with a thatch roof of local dried tropical grass. Briefly, to hold 1 t of grain, the height and diameter should be roughly equal; the walls should be lined with mud to improve insulation; the thatch should provide a wide overhang and the silos located under trees to protect the walls from insulation; the grain should be sun-dried and filled into the silo early in the morning when cool; and the interstices in the grain should be filled with clean sand or wood ash to reduce the oxygen content (both sand and ash being abrasive will scour and rupture the waxy chitinous layer that covers an insect's abdomen causing it to die of desiccation). In addition the Senegalese discovered several indigenous plants, including *Hyptis spicigera* and *Cassia nigricans,* that possess natural insecticidal properties (Hulse 1983).

Parpia (1973) gives an interesting account of the causes and consequences of in-storage infestation and mycological infection of grain legumes in India, where 70% or more of the legumes harvested are stored on farms. As in Africa bruchids carried from the field into stores cause direct destruction and faecal contamination. He states that the eight overlapping generations of the pulse beetle, have been known to reduce the mass of stored chickpea by close to 50% in 6 months, and to reduce significantly the nutritional value of both chickpea and pigeonpea by preferential attack upon protein-rich components. Parpia recommends particular fumigant procedures and argues for breeding for greater resistance to insect and fungal attack.

A final point, perhaps more philosophical than technical, is worthy of mention: it has long been the custom to speak about and attempt to quantify "postharvest losses". Quantification can be misleading unless accurately defined both by nature and by cause. Data in terms of proportional loss will be different if expressed by total mass, by volume, or by nutrient loss. Loss or damage may result from a variety of biological, physical, mechanical, or physiological causes. This paper suggests that a more promising approach would be to develop more efficient and effective postproduction systems complementarily integrated with the sustainable production systems that are the declared objectives of most plant breeders and agronomists in the international agricultural research centers. In relation to biological damage this will require integrated pest management both pre- and postharvest. This in turn calls for a more fundamental biochemical approach to entomological and mycological taxonomy, and a more profound understanding of the biological relations between pests and their hosts, between pests and their natural or potential enemies. Postharvest constraints have in large part been considered as a set of discrete entities rather than as components of a complex continuum from the time and place of harvest to the time and place of ingestion.

Functional Properties of Proteins

There are many references in the literature to the functional properties of soybean proteins but relatively little on chickpea and pigeonpea. Briefly, the functional properties of practical importance include the following.

Water-binding Capacity

Sorption isotherms are plotted by incubating the protein of interest at different equilibrium humidities. Generally speaking, at low ERH—low water activity (Aw)—the water binds tightly with high absorption energy. At higher water activity the absorption energy decreases and the water becomes progressively more loosely bound. The absorption energy at different Aw levels characterizes a protein and influences such properties as solubility, swelling and apparent viscosity, gel formation and strength. Based upon NMR determinations of hydration in polypeptides, highest absorption energies occur in those high in ionic and polar amino acids such as aspartic and glutamic acids, tyrosine, and lysine. Lowest absorption energies are apparent where such nonpolar amino acids as alanine, glycine, leucine and methionine predominate.

Solubility

Protein solubility and surface activity, the latter property being conditioned by the balance between polar and nonpolar amino acids, are important in the production of milk analogues and high-protein drinks. Solubility and stable dispersibility influence apparent viscosity. Being non-Newtonian, apparent viscosity is influenced by the method of determination, particularly by rate of shear, a characteristic of particular importance in extrusion and texturization technologies.

Gel Formation

Gel formation can occur at high apparent viscosity or when concentrated solutions are heated. In the latter, the irreversibly denatured protein cools to form a three-dimensional aggregate in which protein dissolved in free liquid is entrapped. In addition to protein concentration, conditions of heating and cooling, gel strength is influenced by pH and electrolyte content. Gels may be formed by heating in the presence of bivalent Ca and/or Mg cations, calcium sulphate being commonly used to produce legume protein gels and curds. Of the various empirical methods of assessing gel strength based upon relative resistance to compression, penetration, shear and other forms of deformation, no method appears to have been objectively standardized or universally adopted.

Lipid Binding

As with water, lipids are absorbed, adsorbed or otherwise bound to polypeptides with varying degrees of affinity, the strongest attachments being at hydrophobic sites where nonpolar amino acids are concentrated. Related to lipid affinity is the surfactant capability of legume proteins to stabilize oil-in-water and mixed emulsions. The balance between hydrophilic and hydrophobic amino acids and the relative solubility of a legume protein influences its ability to orient and form a protective colloid at the oil-water interface.

Foam Formation

Another useful consequence of legume protein surface activity is the property of forming stable foams, a foam being a stable dispersion of air or other gas in water. Foam stability is empirically determined by rate of collapse or syneresis. Since foam stability is largely influenced by protein solubility and concentration, protein isolates tend to form more stable foams than protein concentrates.

Transformation and Utilization

Any comprehensive review of transformation and utilization of chickpea and pigeonpea must take account of both domestic and industrial processing technologies. The history of the technologies that serve basic human needs—food, textiles, pottery, and housing—describe for the most part the transformation of household artisanal crafts into industrial processes by replacing human labor and hand tools by machines. Only recently has chemistry synthesized novel raw materials or permitted greater insight into the essential nature and composition of the naturally occurring raw materials of food, clothing, household utensils, and structures, and the interactions that lead to the end products of processing.

The technologies by which most food materials are processed are little different in principle from the ancient domestic and artisanal techniques from which they were derived. Modern break and reduction flour milling employs exactly similar principles to the rotary quern used by ancient Mediterranean civilizations. The same holds for the extraction of vegetable oils from leguminous oilseeds: the industrial hydraulic press is simply a more elaborate and energetic form of the animal-powered rotary press. What is needed is a deeper understanding of the essential biophysical and biochemical structures of food grains, particularly of grain legumes, if innovative technologies are to yield products of broader application and greater variety than are presently available. This is equally true if the many opportunities for substituting or supplementing animal proteins with legume proteins are to be realized.

Process Technologies for Legumes

But first a brief review of some of the established processes and technologies applied to legumes. According to Parpia (1973) about 80% of the legumes of India are dehusked, split and consumed as *dhal.* Domestic and small-scale milling processes give yields of the order of 75% from chickpea and 68% from pigeonpea, whereas improved milling technologies give yields of about 82% against the theoretical maximum of 89%. (Parpia does not so state, but experience with other milling technologies suggests that these averages significantly vary depending upon the properties of the grain and the efficiency of the processing technologies.) The process to which Parpia refers involves controlled incipient heating of the legume followed by holding in a tempering bin. The adhesive gum which holds the outer husk to the cotyledon breaks down and the husk is then more easily removed by a single corrugated roller. The water-soluble gum is a polysaccharide composed of gluco and galacto-mannans, and some evidence suggests that, the higher the proportion of uronic acids, the stronger is the adhesion. Parpia briefly describes the preparation of cooked *dhal*, of puffed chickpea, of *idli* (a steamed fermented mixture of ground rice and *dhal*), and of *papadam* made from *dhal* pastes.

A personal communication from ICARDA describes the various dishes of which chickpea is a component among west Asian, and north African countries (Hawtin et al. In Press). In Algeria the pulses are soaked before being cooked with mutton, onions, and tomatoes, and served with *couscous.* Egyptians prepare chickpea in a similar mutton stew but also eat the immature seeds raw and green, and the pulse cooked, dried, and salted as a snack. Among the Ethiopian rural poor, cooked chickpea is eaten together with cereal, raw and green in the pod, or during the fasting season as a seasoned cooked paste molded into the shape of a fish and fried. Iranians make an elaborate fruit soup containing meat balls, a variety of vegetables and spices, dried prunes, apricots, walnuts, mint, parsley, and cooked chickpea. In Jordan, Iraq, and Lebanon *hommos* is a traditional favorite. Chickpeas are soaked overnight, cooked, crushed, and mixed with sesame seed oil, garlic, and lemon juice. The creamy paste is eaten as a dip with Arab bread. Clearly these are but a random few of the many ways in which chickpea is eaten in the Mediterranean countries.

For domestic use and industrial processing, the time required to cook legumes to an acceptable texture and consistency is clearly of importance. Hulse et al. (1977) suggest methods of assessing cooking quality; various authors illustrate the significant variability among genotypes in the cooking time required. Bressani and Elias (1974) and others have described how cooking time increases with time in storage.

However, in common with most other assessments of consumer acceptablity, virtually all test methods of cooking quality are empirical, subjective, and, in the hands of the inexperienced, liable to misinterpretation. To determine reliably what constitutes consumer acceptablity requires great skill, experience, and direct contact with a representative population sample, requirements that are not fulfilled by laboratory taste panels. Insensitivity to and the inability reliably to determine what constitutes consumer acceptability is a primary cause of failure in the introduction of both unfamiliar crop types and new food products.

Industrial Processing

In considering industrial processing of legumes, one must differentiate between those high in lipids, such as oilseeds, and legumes low in lipid content. The purpose of oilseed processing is to separate the oil from the protein-rich residual cake, the technology employed, particularly in relation to hygienic control, being the determinant of whether the extracted oil cake may be used as food, animal feed or fertilizer. Whether the oil is to be extracted by pressing, by solvent, or by a combination of the two, the seed is usually first flaked, cooked to rupture the cell walls, reduce oil viscosity, and increase the rate of diffusion. In screwpress extractions, pressures are kept as low as possible to avoid high frictional temperatures with resultant damage both to oil and residual cake. In addition to being of satisfactory hygienic quality, a good press cake will be dry, have a moisture content below 6%, and be relatively free from heat damage.

Normal hexane is the solvent universally employed for vegetable oil extraction. The solvent percolates through the bed of flaked oilseed and the dissolved oil is eventually recovered by evaporating the hexane in several stages by direct and indirect steam heating, the second stage often under vacuum. The critical features of oilseed extraction are: (1) the efficiency of oil recovery, both quantitatively and qualitatively; (2) the efficiency of solvent recovery since hexane is an expensive, toxic and flammable substance; and (3) the quality, particularly the hygienic and nutritional quality of the residual cake. Because of the unhygienic processing conditions that prevail in many small-scale oilseed processing factories, the residual cake is fit only for use either as cheap animal feed or as an ingredient of nitrogenous fertilizer.

PAG Guideline no. 2, published in 1970 by the UN Protein-Calorie Advisory Group, specifies that food-grade groundnut flour should be made from split, deskinned, dehearted, mold-free groundnuts, and that the final product should contain maxima of 8% lipid, 1.0% free fatty acids (FFA), 4.5% ash, 3.8% crude fiber, and a minimum of 48% protein. The prescribed extraction process calls for a maximum temperature of 120°C during cooking and pressing, and between 80°C and 120°C during desolventizing. Other specifications relate to physical, hygienic and nutritional qualities, the latter specifying available lysine and soluble nitrogen expressed as Nitrogen Solubility Index.

Since groundnut is relatively high in extractable oil (ca 50% cf soybean ca 25%) the oil may be separated by pressing or, as is more efficient, by pressing followed by n-hexane extraction. As indicated above, careful control, particularly of the temperature during extraction, produces an edible-grade residual cake. All legumes contain significant amounts of soluble carbohydrate, some in the form of reducing sugars. When heated, alpha-amino groups in proteins react with carbonyl groups of reducing sugars which polymerize to form brown melanoidin pigments. Advantage is taken of carbonyl-amine reactions in the production of peanut butter in which, during roasting, alpha-amino groups react with alpha-dicarbonyl compounds to produce pyrazines from which roasted peanuts derive their characteristic flavor. The effect of cooking upon nutritional value is highly variable; it improves nutritional quality in some instances and depresses it in others.

Processing of Legume Flour

Though legume flour, whether from dehusked low fat cotyledons or from a residual oilseed cake, will have particular characteristics influenced by genetic heritage, conditions of cultivation, and subsequent treatment, there are many technologies by which grain legumes may be processed. The primary processing of leguminous oilseeds consists of extracting the bulk of the lipid content and reducing the residual cake to flour of some predetermined particle size distribution. Unlike cereal flours, oilseed and some legume flours are not easily classified by fine metal or textile screens or sieves and, therefore, air-classification is often a preferable alternative.

The simplest form of processing is to combine legume flour with other finely ground or particulate materials. The literature is replete with reports of many mixtures of cereals, legumes, and other protein supplements intended as infant or weaning foods, most of which never progressed beyond the laboratory. Milner (1981) lists several that achieved some degree of commercial production or communal utilization. Hulse et al. (1981) review reports of composite mixtures of sorghum and millets combined with various legumes and other protein sources.

Difficulties in maintaining uniformity among mechanical mixtures of powdery materials are greatest when the composite ingredients differ significantly in mean particle size. Homogeneity may be achieved in various ways.

Agglomeration

Agglomeration consists of lightly wetting the surface of each constituent particle with an adsorbed film of water sufficient to cause the particles to adhere to one another in agglomerates which, after drying in hot air, form porous granules that mix with water without clumping. The principle is applied in the making of *couscous*, "instant" skim milk powder, and dried coffee.

Extrusion

Probably the simplest and cheapest method of combining composite mixtures of cereal and legume flours is by low-pressure extrusion, the process used to fabricate pasta products. The composites are mixed with water to form a dough sufficiently stiff to be extruded, or sheeted and cut, before low-temperature drying. The dry pasta may be stored as-is or ground and screened to a prescribed particle size range.

More complex and largely empirical in operation and control are the extruder-cookers which may, among a variety of designs, be high-pressure extruders that form pre-gelatinized mixtures into pellets that can be dried, puffed, or toasted; low- or high-shear cooking extruders, the latter used to produce precooked products in which the physical properties are altered to become "texturized" (Hulse 1981). Products of this kind are often referred to as meat analogues since they are largely produced from extruded vegetable (most often soybean) protein and, during processing, may be converted to materials flavored and textured to resemble cooked animal products. Textured vegetable proteins result from what is described as 'protein plasticization', the precise biochemical nature of which is yet to be fully described. It has been suggested that the extrusion process brings about molecular disruption followed by reaggregation and intermolecular peptide bonding into fibrillar configurations.

Extrusion can accommodate predetermined mixtures that may be uniformly blended, and wholly or partially cooked into various forms and textures. The technology is more easily understood and controlled when applied to chemically synthesized plastics. Mixtures of cereal and legume flours are unpredictably biologically reactive, non-Newtonian, with visco-elastic properties that can change rapidly at high pressure, high rates of shear, and rapid temperature rise. Consequently, product and process development and control are essentially empirical. The extruders available commercially vary in complexity, the more elaborate combining more processing variables than can be controlled by simple mathematical computations.

Steam texturization makes use of steam at high pressure; the processed legume flour or protein being charged and fired from a rotating valve into a barrel from which the textured product is discharged.

Recently a little-publicized very high temperature, high-pressure, short-dwell time (about 7 sec) extruder has been developed in Canada that can process dry whole grains into fully cooked uniform granules. At present the inventors and the manufacturing company are not disclosing details but it is expected that machines will soon be commercially available.

Protein Concentration

While efficient dehulling results in a modest proportional increase in protein content, significant protein shifts require more elaborate processes. Wet separation in its simplest form consists of fine-grinding the dehusked legume, the flour being slurried in alkaline water before centrifuging to yield a high protein supernatant and precipitated starch. The protein can be recovered by spray or drum drying.

Legume protein concentrates containing 60-70% protein are produced by removal of most of the soluble carbohydrate. Alternative solvents include:

1) Hot water(70-90°C) at pH 5.5-7.5.
2) Food grade acid at pH 4.5, close to the iso-electric point.
3) Aqueous ethanol (Ethanol:water 70/30 vol/vol).

Legume protein isolates (90% protein) are made by extracting with dilute alkali at about 50°C. Insoluble carbohydrate and other material is centrifuged and the dissolved protein precipitated by food grade acid at the iso-electric pH. The liquid fraction is comparable to the whey produced when casein is precipitated from liquid milk. The dissolved protein may be reprecipitated with alkali and extruded through textile spinnerets into filaments which, after stretching and weaving into a tow, can be textured, flavored, and colored to resemble meat or fish.

Protein Concentration by Air Classification

The structures of legume cotyledons are conducive to protein concentration by fine grinding and air classification. The starch granules in wheat range from 2 to 45 microns, in pearl millet from 8 to 25, in sorghum from 5 to 30, and barley from 2 to 35 microns. In contrast starch granule size in common bean ranges from 30 to 50 microns, and in faba bean from 20 to 40 microns. The starch granules are embedded in a matrix of protein, the latter being shattered into fine fragments by fine grinding. Fine grinding is best achieved by high-speed shearing in a pin mill in which two sets of intermeshing pins counter-rotate at different rotary velocities. Because of their larger size and more uniform shape, starch granules in legumes become detached and are more readily separated from the protein fragments by air classification.

In an air classifier, a centrifugal force is opposed by a centripetal air-drag, the two being so counterbalanced as to cause separation of the particles according to their effective mass. Youngs (1975), Sosulski and Youngs (1979), and Tyler et al. (1981) report the air classification of pin mill ground flours from peas, mung beans, lentils, navy beans, lima beans, and cowpeas. They obtained yields—varying between 20 and 30% of the initial flour—of high protein fractions ranging in protein content from 49 to 75%. The technique is of both commercial and laboratory interest since the separation is made in the dry state and with least likelihood of biochemical change in the starch and protein. It is a technique that, if applied in the laboratory, should enable research scientists better to appreciate the functional properties of these important legume components, an understanding essential if present and future genotypes are to be utilized and processed in the most advantageous manner.

Legume Products

There are many other products derived from legume protein concentration and processing. Though most reported are derived from soybean protein, the technologies are adaptable to other legumes. Hydrolized vegetable protein, manufactured mainly from soybean meal by treatment with HC1 or fungal protease, could be produced from other legumes. Equally, air-classified legume protein could be texturized alone or in composites with other ingredients. What is necessary is to determine the culinary, economic, and biochemical advantages of particular legumes and their constituent components in comparison with other raw materials used in food manufactures, and in what manner legume properties can be most beneficially modified.

Future Research

There are two extreme ends to the spectrum of food product development. The first and most widely employed, begins with a domestic traditional product. Means of producing the product, and variations upon it, on an industrial scale are devised. Variations may include replacing traditional ingredients with biochemically or physico-chemically similar alternatives, or by adding substances that either improve stability or nutritional quality or incorporate some other desirable property. The extreme alternative is to begin with an intensive examination of the fundamental inherent properties of a particular raw material. In the case of a legume this necessitates the microscopic examination of the physical structure, a process facilitated by scanning electron microscopy, followed by the nondestructive fractionation of the principal components in order to assess the potentially useful functional properties of each in comparison with related substances in practical use. The emphasis must be upon desirable functional properties since, in the past, much time and effort has been devoted to chemical analyses and nutritional evaluations that either served little practical purpose or the results of which were predictable. On how many occasions has it been demonstrated that the addition of a legume or synthetic lysine to a cereal diet will cause rats to gain weight more quickly?

With the exception of soybean and groundnut, legumes remain in large part crops for simple household use. There is comparatively little food processing of chickpea and pigeonpea. Only imaginative and coordinated research among biochemists, food scientists, and plant breeders will change this image and imbue food legumes with the importance their properties deserve. The future calls for imaginative investment and coordination in sustainable postproduction systems. However, experience suggests, that sustainable progress will not be realized if research and development is confined to academic institutions and government laboratories. The early involvement of the food processing industry, whether private or parastatal, is essential, particularly in market research and development, and in establishing realistic standards of product quality and process control. For the most part, the food processing sector has remained at arm's length from international agricultural research. If the crop types elaborated by the IARCs are to be fully utilized in improving the quality and variety of human diets, and in generating employment in the food processing sectors, the interest and involvement of industry is essential. How best to stimulate effective cooperation between agricultural research and the food processing industries is a subject deserving more imaginative study than it has received.

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Session II

Production Aspects and Prospects of Chickpea

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Abstract. *Chickpea is a self-pollinating pulse crop that has been cultivated for more than 7000 years. Its crop history and uses are discussed. Specific agronomic and crop protection requirements, together with crop improvement aspects are briefly described. The total area under chickpea and total production have shown little change over the last 20 years. Chickpea is a cool-season sub-tropical legume often grown on residual moisture. This imposes certain restrictions on its agroclimatic adaptation. Production can expand considerably if certain conditions are met.*

Introduction

This paper aims to give a brief summary of the main aspects of chickpea production, and to describe the crop's prospects. It presents general information and not detailed research results. The review is based on the following references: van der Maesen 1972; Russell 1985; Summerfield and Roberts 1985; Saxena and Singh 1987; Summerfield 1988; these are not mentioned again in the text. Three special uses of chickpea are highlighted which would otherwise not receive much attention.

Chickpea is a crop with an ancient history, and has been grown in West Asia and the Indian sub-continent for many millennia. The oldest chickpea finds are from excavations at Hacilar near Burdur in Turkey, and they were estimated by the carbon-dating method to date from about 5450 B.C. The first written record is in Homer's Iliad of around 900 B.C., where the Greek hero Menelaos is being shot at with arrows that bounce off his breast-plate like "chickpeas thrown up by the winnower". It is believed that the Hellenes took the crop westwards from Turkey to the Mediterranean region, and eastwards to West Asia and the Indian subcontinent. There is no mention of chickpea in the Bible, though lentil features in the book of Genesis. The Greeks, Phoenicians, and Romans helped to spread chickpea cultivation through the Mediterranean countries, including northern Africa; more recently, Asian immigrants acquainted several eastern African countries with the crop during the 19th Century. Ethiopia, long a center of trade, has a much longer history of chickpea use. The New World saw the crop introduced by Spaniards and Portuguese merchants, while Asian settlers added new varieties later, for instance in the West Indies. A spectacular expansion of chickpea production took place in Australia, where from 1985 to 1987 the area increased from 8000 to 71000 ha, according to the Food and Agriculture

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Table 1. Chickpea area, production, and productivity in the world from 1961-65 to 1983-87.

Year	Area ('000 ha)	Production ('000 mt)	Yield (kg ha^{-1})
1961-65	11863	7042	594
1969-71	9933	6508	655
1974-76	10144	6245	616
1979-81	9530	5971	624
1983-87	9888	6908	698

Source : FAO Production Yearbook 1961-1987 (FAO 1962-1988).

Organization (FAO) Production Yearbook 1987. The present total world area under chickpea is roughly 10 million ha.

Table 1 shows that area, production and yield of chickpea have not changed much over the past 20 years. It is different for a crop like soybean (Fehr 1987), where commercial interest plays an important role. However, as will be discussed, changes are anticipated in the future.

Uses of Chickpea

There is a wide variety of chickpea usage, including those that are rather unusual. The chickpea plant produces acid exudates, which are occasionally used for medicinal and other purposes. One method of capturing the acid is by spreading cloth over the plants early in the morning, and wringing out the liquid it absorbs. This liquid is used to make a popular and refreshing drink, loved by children. When chickpea seeds are rather soft and still immature, their taste is characteristic, slightly sweetish, and pleasing to many consumers. Such seeds are eaten green, e.g., in India, Ethiopia, and Turkey, where it is not uncommon to see young and old walk or cycle the streets with small bundles of plants, from which the fresh seeds are eaten. In the USA and western Europe chickpea was largely unknown until rather recently, when it was probably introduced through health-food stores, and then became increasingly popular. Chickpeas soaked, boiled, and prepared with a variety of ingredients such as salt, pepper, and lemon, feature prominently in the menus of salad bars.

Types of Chickpea

Chickpea, like groundnut and unlike pigeonpea, is a self-pollinating crop with a negligible percentage of outcrossing (van Rheenen, in press). This is important for its breeding methodology. Most breeders follow the pedigree method, the bulk population breeding method, or a combination of the two, with possible modifications to suit local conditions. The backcross method is also used to transfer desirable characters from a donor parent into a popular cultivar. Although the advantages of population improvement techniques and recurrent selection schemes have been stressed (Gallais 1987; Jensen 1978), they are not widely used for chickpea or soybean (Fehr 1987).

We distinguish two different chickpea types; kabuli and desi. Kabulis have white flowers, no anthocyanin in the aerial plant parts, and relatively large seeds with a thin testa. Desis usually have purple flowers, anthocyanin pigmentation in the stem and leaves, and relatively small, wrinkled seeds with thick seed coats. In growth habit chickpea plants can be upright, semi-upright, and even spreading, like creepers. They may be more than a meter tall, but can also be as short as 10 cm.

Appropriate agronomic practices are important if optimum yields are to be obtained. Recommended agronomic packages vary from place to place, e.g., at ICRISAT Center we sow on broadbeds or ridges, keeping the row distance at 30 cm and spacing the seeds 10 cm apart in the row. But the recommended practice in the state of Maharashtra, India, is to drill seed on the flat at a rate of 65 kg ha^{-1}. No fertilizer needs to be applied on the black Vertisols of ICRISAT Center, but in Maharashtra, 100 kg diammonium phosphate (DAP) ha^{-1} is recommended.

Irrigation can double the yield in peninsular India but at higher latitudes, for instance in the state of Haryana, India, its effect is less favorable.

Stresses that affect Chickpea

The chickpea crop often faces biotic or abiotic stresses which differ from zone to zone (Table 2).

Abiotic Stresses

Chickpea is often referred to as a cool-season subtropical legume, but much of the crop is grown in the tropics, where at times during the growth cycle unfavorably high temperatures are encountered. This can be a major factor in yield reduction (Baldev 1987, personal communication). As the crop is often grown on residual moisture, the high temperatures aggravate the drought stress.

Biotic Stresses

More than 50 pathogens have been reported to affect chickpea, but only a few devastate the crop. The most important are ascochyta blight, fusarium wilt, dry root rot, collar rot, stunt, botrytis gray mold, and black root rot.

These stress factors are very important to breeders as they affect the yield stability of the crop; by breeding for stress resistance, a more reliable crop performance can be expected. Except for collar rot, resistance sources have been identified for all the diseases mentioned. However, for botrytis gray mold and ascochyta blight, the resistance is not strong, and a severe epidemic can cause considerable damage. The inheritance of resistance to fusarium wilt has been studied in detail. Three genes have been identified that can, in any homozygous combination of two, convey resistance to a plant. Genetic studies on the resistance to ascochyta blight have attributed this trait also to a small number of genes.

Table 2. Desirable characters for chickpeas in different zones of the world and their priorities.

	Zones (°latitude)				
	A	B	C	D	
Desirable characters	0-20	20-25	25-30	30-45	
Stable, high yield	+	+	+	+	
Good seed quality	+	+	+	+	
Resistance to stresses					
Biodc					
Fusarium wilt	2-1	2-1	2-1	3	
Ascochyta blight	-	-	6[1]	1	
Botrytis gray mold		5	3	-	
Root rots	3	3	5	4	
Stunt	4	4	4	5	
Helicoverpa	1-2	1-2	1-2	6	
Leaf miner	-	-	-	2	
Nematodes	?	?	7?	7?	
Abiotic				Spring	Winter
Drought	1	1	1	1	-
Salinity	3	3	2	-	-
Excessive moisture		4	5		2
High temp.	2	2	4	2	-
Low temp.	-		3	-	1

1 : in case of epidemics, the crop damage is severe.
+ : required.
- : not required.
?= uncertain.

There is only one report on the inheritance of dry root rot resistance, and the data presented support the hypothesis that it is monogenic (Ananda Rao and Haware 1987). For the other major diseases, genetic data are lacking.

Future Prospects

It is likely that the production of chickpea will considerably expand in future. There are two main factors on which this depends; one is productivity, both in respect of stability and potential yield level, and the other is demand. Yield stability depends on the efforts made to remove or alleviate the effects of stress conditions in which the crop improvement disciplines of agronomy, breeding, entomology, pathology, physiology, and biotechnology are all involved. In this respect we may be optimistic, as we may also be about yield levels, which need continued attention from breeders and physiologists.

On the demand side, we observe that the large Asian market is not easy to saturate. The European and American markets can considerably expand as the consumption of chickpea—already a popular ingredient of salads—is likely to increase. The demand for the

very many snacks that can be made from chickpea will increase if these are popularized. And finally, novel uses of chickpea, be it in the processed food industry or in new recipes, could enhance the prospects of this lovable legume.

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Legume Consumption and its Implication on the Nutritional Status of the Population in India

N. Pralhad Rao and J. Gowrinath Sastry[1]

Abstract. *Food legumes, though secondary to cereals in terms of production and consumption, play an important role in both crop production systems and human nutrition. They form an important component of the diets of people in many developing countries of Asia and Africa. In recent years food consumption trends in India indicate an increase in consumption of cereals, but the overall average daily consumption level of pulses has remained almost static at around 30 g per consumption unit.*

These consumption trends reflect the production pattern of cereals and pulses during the past 20 years in India. Agricultural statistics indicate that pulse production has been either stagnant or declining during the 1970s and early 1980s, while cereal production has registered a dramatic increase.

Notwithstanding the nutritional benefits that pulses confer on an otherwise predominantly cereal-based diet, and also the agronomic advantages that legume crops lend to the production system, neither their output nor consumption levels have improved. Nutrition experts recommend that the ratio of protein derived from cereal to that obtained from pulse in the diet should be around 5:1 if the diet is to be balanced in terms of protein quality. Food consumption data obtained from about 20 000 rural and 8 000 urban households from 10 Indian states indicated that pulse consumption not only shows a clearcut socio-economic gradient, but also exhibits a distorted pattern in relation to cereal consumption. This distortion becomes serious under scarcity conditions, as evidenced during the drought of 1987.

Introduction

Pulses, which belong to the family of grain legumes enjoy the distinction of being protein-rich foods, and form an important constituent of the diets of people living in the developing countries of Africa and Asia. Incidentally, these countries also have the distinction of producing most, if not all, of the food legumes grown in the world. Yet the consumption levels in these countries are below the minimum nutritional requirement recommended by nutrition experts. India is no exception, not withstanding its largely vegetarian population,

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for whom consumption of animal foods is taboo. This paper presents the consumption pattern of pulses in India, as reported by the National Nutrition Monitoring Bureau (NNMB). Quantitative data on food consumption is not so easy to obtain for pulses, which are consumed in a variety of dishes. Hence, it is considered appropriate to describe the background of the NNMB, and the method used to assess food consumption.

National Nutrition Monitoring Bureau (NNMB)

The NNMB was established in 1972/73 by the Indian Council of Medical Research (ICMR), under the aegis of the National Institute of Nutrition (NIN), Hyderabad, to collect and compile data on the diet and nutritional status (clinical and anthropometric) of representative population groups. The Bureau has established 10 regional units, one each in the states of Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh, and West Bengal. Data are collected by a team consisting of a trained medical officer and a nutritionist, with the help of an auxiliary in each state, according to a standard protocol (National Institute of Nutrition 1972).

The Central Reference Laboratory (CRL) at NIN is responsible for data management, processing, interpretation, and reporting, in addition to training investigators.

Every year, the CRL receives diet-survey data from 500 rural households and 250 urban households, from each of the 10 NNMB states. The rural sample in each state is selected from four districts, drawn on the basis of socioeconomic development criteria, while the urban sample of 250 households consists of 50 households selected from each of five distinct socioeconomic groups; the High Income Group (HIG), Middle Income Group (MIG), the Low Income Group (LIG) of white-collar workers, Industrial Labor (IL), and Slum Dwellers (SD).

In 80% of the rural households, food consumption is assessed by the 1-day weighment method of diet survey, where the investigators actually weigh all the raw food cooked and eaten by the family on that day. In the remaining 20% of the households, intra-family distribution of food is assessed using the 24-h recall diet survey method. In the urban surveys, 40% of the households of each socioeconomic group are covered by 3-day weighment diet surveys, and in the remaining 60%, an oral recall method is adopted.

The total raw amount of each food item consumed by the family is converted into nutrients using the Food Composition Tables of Indian Foods (Gopalan et al. 1971a). These intakes of foods and nutrients are expressed on the basis of consumption unit (CU) using calorie-coefficient factors recommended by the Indian Council of Medical Research (ICMR) for the Indian population. It may be noted that calorie-consumption coefficients take into consideration the age, sex, and the physiological and occupational status of all the members of the family who eat the food on the day of the survey. The intakes of foodstuffs are compared with those suggested by the ICMR Expert Committee for Balanced Diets, and the intake of nutrients is compared against Recommended Dietary Allowances (RDAs) (Indian Council of Medical Research 1980).

Dietary Pattern

The average levels of consumption of various food items, including pulses, and the different nutrients derived from them for the rural and urban population groups, are given in Tables 1 and 2. The intake levels of different types of pulses and their relative consumption in different socioeconomic groups are indicated in Figure 1.

Table 1. Average intake of foodstuffs (g cu^{-1} day^{-1}) in different urban and rural groups of India.

Socioeconomic group	Cereals	Pulses	Leafy vegetables	Other vegetables	Roots and tubers	Milk	Fats and oil	Sugar and jaggery
Urban								
High income group	316	57	21	113	82	424	46	34
Middle income group	361	49	21	89	78	250	35	31
Low income group	428	42	16	55	66	95	22	28
Industrial labor	420	41	13	56	67	98	23	29
Slum dwellers	416	33	11	40	70	42	13	20
Rural								
All groups	522	37	13	58	51	90	12	23
Balanced diet[1]	460	40	40	60	50	150	40	80

1. Least cost balanced diet recommended by 1CMR (1981) for adult sedentary male.

Source : National Nutrition Monitoring Bureau Urban Survey Report (1984).

Table 2. Average intake of nutrients (g cu^{-1} day^{-1}) in different urban and rural groups in India.

Socioeconomic group	Protein (g)	Energy (MJ)	Calcium (mg)	Iron (mg)	Vitamin A retinol (µg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Vitamin C (mg)
Urban									
High income group	73	10.89	1121	27	881	1.5	1.5	15	98
Middle income group	63	9.89	821	27	555	1.3	1.1	15	70
Low income group	58	9.33	595	27	332	1.3	0.9	15	50
Industrial labor	59	9.38	548	26	352	1.4	0.9	16	47
Slum dwellers	53	8.40	492	25	248	1.3	0.8	15	40
Rural									
All groups	62	9.90	576	31	270	1.4	0.9	16	40
RDA	55	10.04	400-500	24	750	1.2	1.4	16	40

RDA : Recommended Dietary Allowances (ICMR 1981).

Source : National Nutrition Monitoring Bureau (1984) Urban Survey Report.

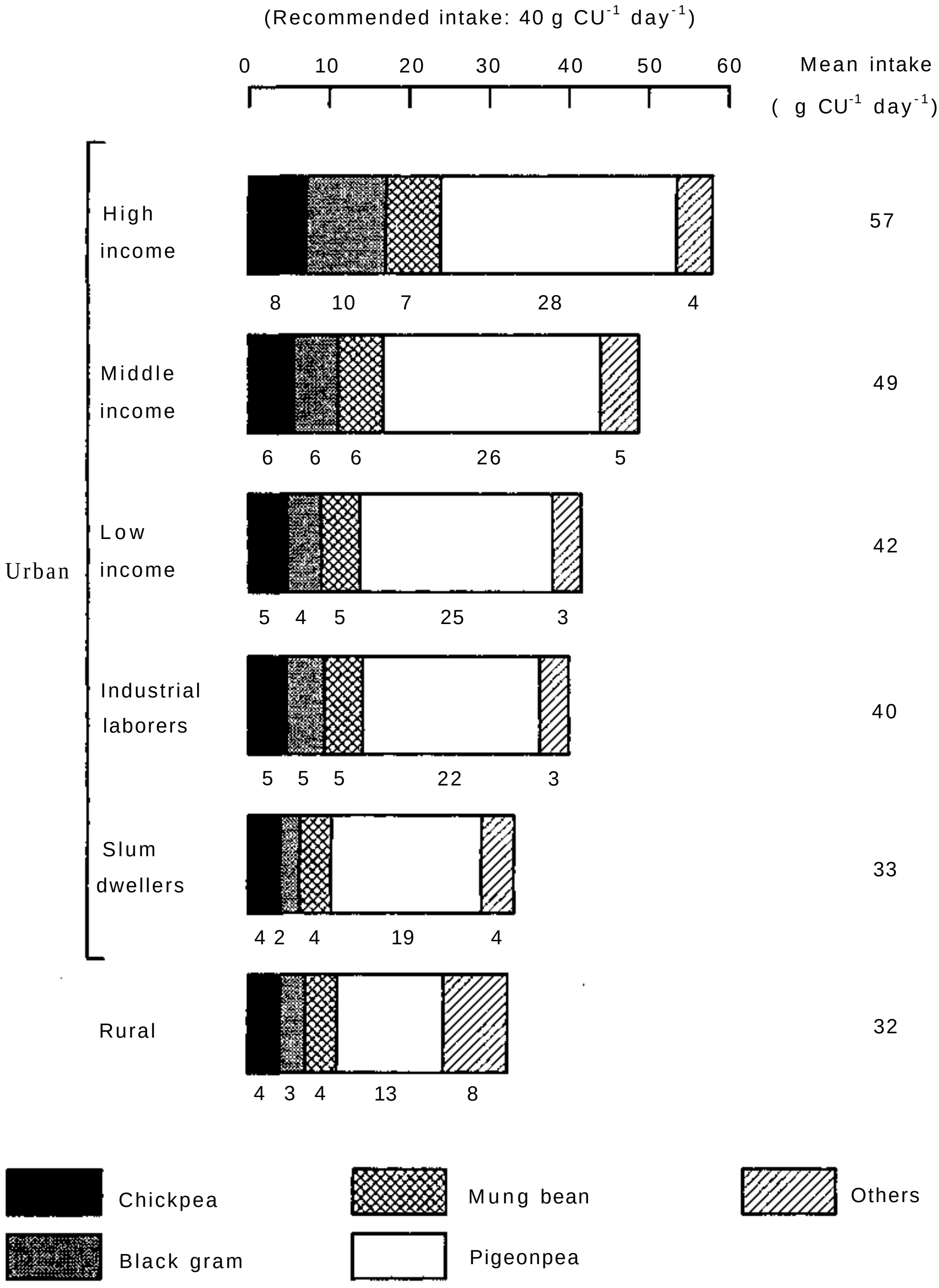

Figure 1. Mean pulse intakes (g CU^{-1} day^{-1}) in different socioeconomic in India.

Food Consumption

1. Cereals i.e., rice, wheat, and millets are staple foods and constitute the bulk of the foods consumed by the population. Their consumption was more in the rural households than the urban population groups.
2. Consumption levels of income-elastic, protein-rich and protective foods such as pulses, milk, vegetables, flesh foods, fats, and oils were much lower in LIG households than in those of HIGs.
3. Among the varieties of pulses consumed, pigeonpea (red gram or *tuar*), chickpea (Bengal gram or *chana dhal),* and black gram *(urd)* were quite common. Of all the types, pigeonpea was the most favored pulse by all the income groups. The share of other less common pulses, such as horse gram (*kulthi*), Lathyrus (*kesari dhal*) and lentil tended to be higher in the rural households.

Nutrient Intakes

Nutrient intakes showed a positive relationship with socioeconomic status. Intakes of all nutrients were higher among the HIG, while the lowest intakes were seen in SD. The LIG and IL groups showed more or less similar levels of intake, and always trailed behind the MIG group, which in turn followed the HIG group. Compared to the levels recommended by the ICMR Expert Committee on RDA (1981), the daily per consumption unit intakes of protein were adequate (above 55 g) in all the urban socioeconomic and rural groups, except SD for whom there was a marginal deficit. The average daily levels of energy intake, however, fell short of RDA (10 megajoules) in all the groups except the HIG. The extent of deficit in the LIG and the IL group was around 10%, and in the slum population it was about 20%. Intake levels of minerals, such as calcium and iron, and vitamins, such as thiamine, niacin, and vitamin C were satisfactory in all the socioeconomic groups. However, intakes of vitamin A and riboflavin were above the RDA levels only in the HIG. They showed increasing levels of deficit in the MIG, IL, LIG, rural and SD groups in that order.

Protein Quality of the Diet

Apart from the quantitative aspects of consumption, the quality of food consumed is of great importance to health and nutrition. Nutrition experts suggest that in order to be wholesome and nutritionally adequate, the diet has to be balanced. It should contain various types of such foods as cereals, pulses, vegetables, roots, and tubers, not only in adequate quantities but also in the right proportions. The ICMR has formulated nutritionally balanced diets for an average Indian, the constituents of which are indicated in Table 1.

According to the Expert Committee the ratio of the protein derived from the cereals to that obtained from pulses should be between 4:1 or 5:1 (Figure 2), so that the protein quality of the diet is not compromised. It may be noted that Indian diets provide, on an average, adequate quantities of protein, as suggested by nutrition experts.

The traditional practice of consuming pulses along with the staple food prevalent in the country is thus scientifically sound. However, the quantities of pulses consumed, particularly in relation to cereals, by the households of lower socioeconomic groups in the rural and urban areas leave much to be desired. Their average intakes are not only below the community averages, but also below the prescribed levels in the ICMR's 'balanced diets' for an average Indian. Figure 2 clearly depicts the malconsumption pattern of pulses: the HIG and the MIG consuming relatively more than the suggested proportion of pulses, the worst off being the rural households and slum dwellers (Rao et al. 1986).

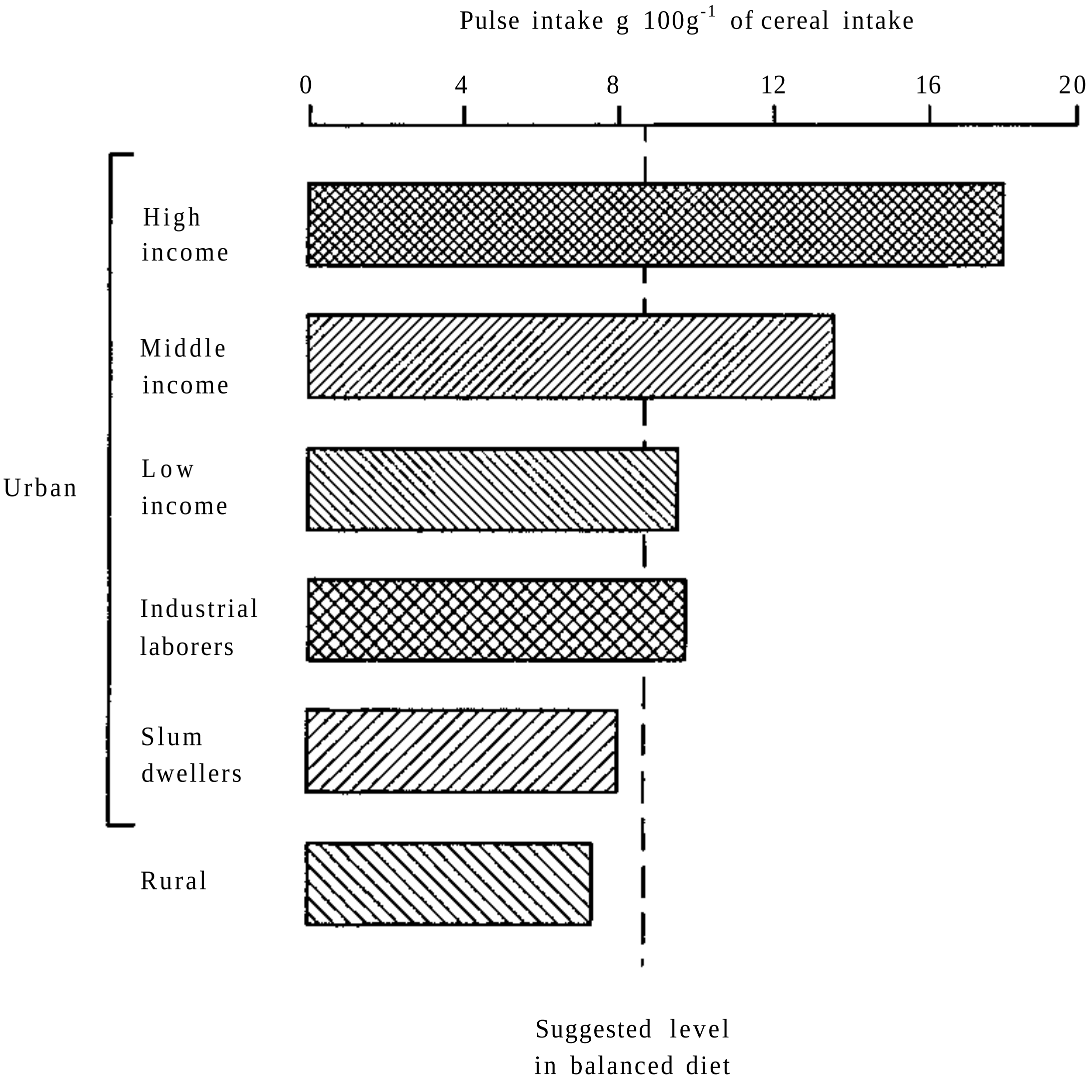

Figure 2. Ratio of pulse to cereal intake in diets of different socioeconomic groups.

Table 3. Rural: Average pulse intakes (g cu^{-1} day^{-1}) according to income in India.

	Income (Rs $caput^{-1}$ day^{-1})						
State	<1	1-2	2-3	3-5	5-10	≥10	Pooled
Andhra Pradesh	19	20	28	33	37	33	24
Gujarat	21	26	30	33	41	50	28
	45	50	51	55	56	53	45
Kerala	6	7	14	21	25	31	12
Madhya Pradesh	28	39	51	52	50	89	43
Maharashtra	28	34	43	50	49	37	34
Orissa	27	34	50	54	57	66	35
Tamil Nadu	18	26	37	41	45	68	33
Uttar Pradesh	31	39	48	58	62	42	39
West Bengal	14	20	27	33	26	DNA[1]	19

1. DNA - Data not available.

Pulse Intake and Income Status

The mean intake levels of pulses according to income status in different states of the country are given in Table 3. The linear relationship between per capita consumption and income is indicated by the regression equation:

$$y = 29.98 + 3.39\ x$$

Where y = pulse intake (g cu^{-1} day^{-1}), and

x = Income (Rs cu^{-1} day^{-1})

Table 3 indicates the positive relationship between consumption and income, and highlights wide inter-state variations in pulse consumption. The lowest daily consumption of 12 g was seen in Kerala, while the highest level of 45 g was seen in Karnataka closely followed by Madhya Pradesh. The data also seem to corroborate the observation that the higher pulse-consuming states are also the larger pulse-producing states, notably Madhya Pradesh and Karnataka, and the adjoining states that have vast tracts of semi-arid and nonirrigated crop lands.

Trends in Consumption

Pulse consumption figures during the past several decades, available from reports of nutrition surveys carried out in the states, suggest a drop in consumption during the 1970s as compared to earlier decades (Gopalan et al. 1971b). It is relevant to note in this context that during the mid and later half of the 1970s the energy content of the diets of rural populations surveyed by the NNMB showed an increase of the order of about 140 $Kcal^{-1}$ $caput^{-1}$ d^{-1}. This increase in energy was mainly due to the increase in the intake levels of cereals, rather than pulses and other foods (Pralhad Rao and Gowrinath Sastry 1986). Hence, the expected result was a higher ratio of cereals to pulses, reflecting diets relatively inferior in protein quality.

Table 4. Average consumption[1] of cereals and pulses (g cu^{-1} day^{-1}) during drought of 1987, in India.

	Cereals		Pulses	
State	During drought	Pre-drought	During drought	Pre-drought
Andhra Pradesh	505	560	12	23
Gujarat	494	430	17	28
Karnataka	550	701	27	54
Madhya Pradesh	448	470	35	50
Orissa	488	566	28	32
Rajasthan	450	494	DNA	DNA
Tamil Nadu	475	511	25	27

1. Intakes during prcdrought period are as per National Nutrition Monitoring Bureau Surveys and data of Rajasthan are collected by Food and Nutrition Board.

DNA : Data not available.

The results of diet surveys conducted in areas severely affected by the 1987 drought of Andhra Pradesh, Karnataka, Orissa, Madhya Pradesh, Gujarat, and Rajasthan (Table 4) showed, as expected, that the intakes of pulses fell not only below the usual (pre-drought) levels, but also far below RDA. This drastic drop (7-50%) in consumption of pulses was accompanied by a marginal (7-14%) reduction in cereals, thanks to the availability of food-stocks and the public distribution network. This was contrary to observations made during the earlier droughts of the 1960s and early 1970s when consumption of both pulses and cereals dropped drastically. The net effect of the current drought in four out of the seven states surveyed was that the average protein intake was less than RDA (55 g), and the ratios of cereals to pulses were higher than usual, indicating a quantitative as well as a qualitative deterioration in the diet in terms of protein content and quality.

Conclusions

Pulses, which belong to the protein-rich group of vegetable foods, are particularly rich in the amino acid, lysine. Hence, their regular inclusion in cereal-based diets, a practice in vogue in India, is nutritionally desirable, as it plays a complementary role in maintaining the protein quality of Indian diets. But the low levels of their consumption by the rural and urban poor, and low income groups whose diets are characterized by excessive cereals, can be expected to result in qualitatively inferior diets, as the ratio of cereal protein to pulse protein is bound to be unfavorable.

Per capita consumption declined, with the production trends of pulses remaining almost static over the past two decades. In contrast, with increased production of cereals as a consequence of the Green Revolution, the availability and consumption of cereals have increased. The net effect of these contrasting trends in production and consumption of these two important foodgrains, is likely to compromise the protein quality of the diets of the poor. Hence, improvement in the production and productivity of pulses through a package of innovative agricultural practices and price support policies seems to hold the key to staving off the impending crisis of pulses, the "Cinderella" of vegetarian diets.

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Utilization of Chickpea in India and Scope for Novel and Alternative Uses

P. Geervani[1]

Abstract. *Among the legumes consumed in India, chickpea is the most versatile, being used for main meals, savory snacks, and sweets. This is chiefly due to its flavor. Chickpea flour is fine and cooks quickly. Technology for developing ready-to-eat foods, biscuits, cookies, fermented foods, and soup-mixes using chickpea flour could provide alternative uses for chickpea.*

Puffing is a well-accepted process for chickpea, but simple and easy-to-operate puffing units need to be developed. Ready-to-use roti *flour mixtures, made by combining different millet flours with chickpea flow of good storage quality, would contribute significantly to balancing diets in areas where millets are staple foods. The effects of different crop species on chickpea protein utilization should be investigated. Less digestible starch formation in different varieties of chickpea during processing is another area for research. The therapeutic value of chickpea, in its hypoglycemic and hypocholesteremic effects, is of nutritional interest. Data on trends in consumption are needed to plan future research. As green chickpea seeds cook in less time, and contain higher amounts of B vitamins than dried or processed chickpea, the characteristics of vegetable chickpeas' nutrient composition should receive attention. Areas related to consumption and utilization need collaborative efforts by research institutes and home science faculties.*

Introduction

Chickpea, commonly called Bengal gram, is India's most important pulse crop, and India is its leading producer. Two best known types of chickpeas are kabuli and desi. The kabuli type is characterized by light-colored seeds with a thin husk while desi seeds are often dark yellow-brown, with thicker husks and a rough surface. Chickpeas are consumed as whole dehulled grain, sprouted grain, immature pods, mature green seed, or as *dhal* and flour. Both the grain and the flour are further processed into several types of products.

Chickpea is popular with all sections of the Indian population because of its taste and flavor. It is used in main meals, in snack foods, and as an ingredient in the preparation of special foods.

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Consumption

There is very little information on per capita chickpea consumption in India, but the consumption of pulses as a whole has shown a declining trend in the past few years. Two important reasons for this decline are the cost and availability of legumes. During the production season vegetable legumes—particularly immature green seeds of chickpea—are consumed in areas where they are cultivated, but information on how much is consumed in different parts of the country is lacking.

Pushpamma and Chittemma Rao (1981) indicated that in Andhra Pradesh the frequency of chickpea consumption is mainly in the form of flour and *dhal.* Several low-cost snack foods now sold both in urban and rural markets are prepared with chickpea flour. Hence, if data on frequency of consumption of ready-to-eat products of chickpea flour are collected, a more realistic estimate of overall consumption can be made.

Nutrient Composition

Chickpea is a good source of carbohydrates and proteins, which together constitute about 80% of the total dry seed mass. The starch contents of chickpea cultivars have been reported to vary from 41% to 50%. The kabuli type contains more soluble sugars (Jambunathan and Singh 1980). The unavailable carbohydrate content is higher in chickpea than in other legumes (Kamath and Belavady 1980), and chickpea carbohydrate has a lower digestibility than that of other pulses (Rao 1969; Shurpalekar et al. 1979).

The crude protein content of chickpea varies from 12.4 to 31.5%. Chickpeas contain about 6% fat that is important in the vegetarian diets of resource-poor consumers. The fiber components of kabuli and desi varieties differ quantitatively and qualitatively (Singh 1985).

Chickpea contains nutritionally important minerals, notably calcium and iron, and the availability of iron is reported to be good (Murthy et al. 1985). Immature green chickpea seeds are reported to contain 2.2 mg thiamine $(100\ g)^{-1}$ and 1 mg riboflavin $(100\ g)^{-1}$, while physiologically mature seeds contain 2.7 mg thiamine $(100\ g)^{-1}$ and 0.7 mg riboflavin $(100\ g)^{-1}$ (Geervani and Umadevi 1989).

Fermentation improves the protein quality of chickpea in such products as *dhokla,* by increasing the levels of limiting amino acids (Zamora and Fields 1979a), and thiamine and riboflavin, the two important B-vitamins which are usually not consumed in adequate amounts to meet daily requirements in India (Aliya and Geervani 1981).

Processing

Primary processing refers to dehusking of the grain, splitting it into *dhal,* and grinding it into flour, secondary processing refers to treatments which convert the *dhal* and flour into acceptable, edible products. The primary processes do not greatly influence the nutrient composition or acceptability of the product. Secondary processing varies widely according to different user groups, e.g., soaking legume seeds in an alkaline solution was reported by some users to increase the water uptake of *dhal* during cooking and decrease cooking time, while increasing dispersion of solids (Chavan et al. 1983).

Processing time, temperature, and moisture level are three important factors that influence the nutritional quality of chickpea products. Moist heat methods are better than dry heat methods (Geervani and Theophilus 1980). Processing for longer than 10 min above 120°C is reported to cause considerable damage to proteins (Rama Rao 1974).

The secondary processing of *dhal* may involve dry or moist heating, i.e., roasting, boiling, steaming, and frying. Secondary processing of chickpea flour involves its conversion into batter, which is fried, or fermenting batter, which is steamed. By controlling the proportion of water to flour in a batter, fried products of varied texture can be prepared.

Puffing chickpeas, a secondary process, is a cottage industry in India. The following procedures have been suggested to maximize puffing (Pratape and Kurien 1986):

- Use seed with an initial moisture content of around 7-8%;
- roast the grain with sand at 170°C for 75 sec;
- temper the grain for about 90 min until it reaches a moisture content of 4.9%;
- dip the grain in water for 5 sec to absorb about 0.5% additional moisture;
- puff the grain by heating in sand at 230°C for 30 sec; and
- pass the grain between a roller and a hot plate to dehusk and split it

The bulk volume of the grain increases two-fold by puffing. Simple, easily manageable puffing equipment needs to be developed, as puffing is an acceptable process, and puffed grain is of good nutritional quality. Roasting reduces the lysine availability by 12.3% and puffing further reduces it by 13.8%. Puffing is better than roasting in terms of in vitro digestibility of protein, storage stability of lipids, and in improving the texture of the product (Murthy and Urs 1980).

Sprouting legumes is a traditional practice, but needs standardization for large-scale production, and to obtain a desirable level of germination. Deep frying and boiling are also common methods of processing chickpea for direct consumption.

There is very little information on the nutritional implication of cooking chickpea flour products. Further research is needed in this area. Converting chickpea into *dhal* and flour saves cooking time, particularly in the preparation of soups and gravies. Sometimes even puffed chickpeas are ground into flour and cooked. Rancidity changes are common and more severe in flour than in whole seeds and *dhal.* Studies on preventing rancidity in flour for improved shelf-life need to be undertaken because flour has the potential for several alternative uses.

Alternative Uses of Chickpea

Roti/Flour Mixes

In population groups where cereals are the staple foods, a desirable level of legumes need to be consumed to maintain a good balance of essential amino acids in the diet. A proportion of 5:1 in cereal-pulse combinations is considered desirable (Khalil and Chughtai 1984). This is one area that offers good scope for alternative uses of chickpea. If appropriate flour blends are developed, they can be used to produce nutritionally well-balanced food, cookies, biscuits, snacks, and flat breads. Flour products take less time to cook and are convenient to use. Cultivars of chickpea that are not acceptable as whole grain because of their physical characteristics can be used in such blends. Several protein foods based on blends of cereal, chickpea, soyabean, and sesame in different proportions have been developed and tested (Guttikar et al. 1965). Low-cost weaning foods containing chickpea flour, have been developed and found effective in promoting growth in preschool children (Desai et al. 1970). When a 4:1 mixture of precooked chickpea and defatted powdered milk (80+20) supplemented with methionine was used to feed infants, they grew normally without any gastrointestinal disturbance (Barja et al. 1974). The complementary value of chickpea to cereals has been investigated at different levels. An addition of 20% chickpea flour to wheat flour raised the protein efficiency ratio (PER) significantly and had little effect on bread quality (Shehata and Fryer 1970). But supplementation with chickpea flour above 30% level in the preparation of bread impaired the quality of bread, while at lower levels it was acceptable (Hallab et al. 1974). Cookies prepared with wheat and chickpea flours in a ratio of 3:2 produced significantly higher PER values than commercial cookies prepared without chickpea flour (Hernandez and Sotelo 1984). A combination of chickpea and maize variety Opaque-2 induced excellent growth in rats (Chandrasekhar et al. 1972). Whole wheat and maize flour when supplemented with 20% groundnut- chickpea flour improved the protein quality significantly (Khalil and Chughtai 1984).

Ready to use flour mixtures, prepared with appropriate combinations of millet and chickpea flour may find good markets in urban areas, and offer scope for fortification with minerals such as iron and iodine. *Missi roti,* a preparation of wheat and chickpea flour, is quite popular in rural areas. Studies on consumer preferences, need to be conducted to popularize roti flour mixtures. Urban populations are interested in ready-to-cook products, while migrants from rural to urban areas may continue to eat *roti* provided they can get millet flour easily.

Convenience Foods

There is much scope for developing ready-to-eat snack foods, using chickpea flour either alone or in combination with cereal flours. One such product that is prepared from cereal legume flour is sorghum-chickpea *muruku,* an extruded deep-fried product. This contains sorghum flour (80 g), chickpea flour (20 g), chili powder (1.25 g), salt, cumin (1.25 g) and caraway seeds (1.25 g), and oil for deep frying. It is prepared by roasting chickpea flour slightly to remove the beany flavor, mixing it with sorghum flour, adding chili powder, salt, cumin and caraway seeds, and making the mixture into a dough with water. The dough is then divided into balls, that are formed in a *muruku* mould and extruded using a special device into heated oil where they are deep fried until golden-brown. A variety of spices are used in cooking legumes, notably as extruded snack products. Information on the effects of these spices on nutritive value will be of practical use.

Table 1. Comparative costs (Rs[1]) of producing 100 g sorghum-chickpea biscuits[2] and processed wheat flour (*maida*) biscuits.

Sorghum-chickpea biscuits			Maida biscuits		
Ingredients	Quantity (g)	Cost (Rs)	Ingredients	Quantity (g)	Cost (Rs)
Sorghum flour	800	2.20	Wheat flour (processed)	1000	4.25
Chickpea flour	200	1.70	Fat	400	11.20
Palmolein oil	400	7.40	Sugar	400	2.20
Sugar	400	2.20	Baking powder	25	0.25
Baking powder	25	0.25	Labor and electricity charges		3.00
Labor and electricity charges		3.00			
Total cost of 1.6 kg product		16.85	Total		20.90
Cost of 100 g biscuits		1.05	Cost of 100 g biscuits		1.35

1. US $ = Rs 17 (approximately).
2. Method of preparation : Mill sorghum and chickpea into fine flour separately. Roast the chickpea flour slightly to remove the beany flavor. Mix sorghum and chickpea flours and sieve through 80 mesh sieve with baking powder. Rub in the fat. Add sugar and make into dough. Divide the dough into balls and roll each to 3 mm thickness.Cut into desired shape using a biscuit cutter. Bake at 177°C for 12 min.

In the preparation of infant foods, cookies and biscuits, part of the cereal flour can be substituted with chickpea flour to improve its nutritional quality. Table 1 gives the comparative costs of making biscuits using a combination sorghum-chickpea flour, or wheat flour. The use of chickpea-flour starch as a thickening agent in the preparation of soup mixes has not been fully explored in India. Such flour could be combined with vegetable concentrates or dehydrated vegetable shreds to manufacture soup mixes.

The relative nutritive value of soups and chips prepared from fermented samples of chickpea were significantly higher ($P < 0.05$) than those prepared from non-fermented chickpea. Chips made from fermented chickpea flour contained significantly higher amounts of limiting amino acids than products prepared from non-fermented samples (Table 2).

Table 2. Nutrient contents of non-fermented and fermented chickpea flour and chips.

Factors analyzed	Flour		Chips	
	Raw	Fermented	Non-fermented	Fermented
Relative nutritive value (%)	83.27[1]	91.65[2]	83.70[1]	91.74[2]
Methionine (mg N g^{-1})	1.61[1]	10.41[2]	0.03[1]	8.422
Isoleucine (mg N g^{-1})	2.22[1]	18.83[2]	2.32[1]	16.22[2]
Tryptophan (mg N g^{-1})	13.13[1]	16.07	10.66	13.29[1]

Factors having the same superscripts under different treatments do not differ significantly ($P < 0.05$).

Source : Zamora and Fields 1979b.

There are reports in the literature of resistant starch formation in the processing of wheat (Bjorok et al. 1987) and sorghum products (Bach Knudsen et al. 1987). This resistant starch has adverse effects on the digestible energy and protein quality of the products. Chickpea flour products, particularly baked and deep fried foods, should be tested for resistant starch in view of its nutritional implications.

Therapeutic Uses of Chickpea

Among common legumes chickpea is the most hypocholesteremic agent, followed by black gram and green gram (Soni et al. 1982). Germinated chickpea was effective in reducing cholesterol levels in rats (Jaya et al. 1979), and roasted chickpea diets had a beneficial effect both on triglyceride and cholesterol levels in rats (Chandrasekhar et al. 1983). Green immature chickpeas and kabuli chickpeas were found to have considerably higher hypocholesteremic and hypolipidemic effects than desi chickpea (Birender et al. 1987). Contrary to these findings on rats, studies on rabbits fed on chickpea (75%) showed

that it did not lower blood lipid, and had no effect on atheroma formation (Nityanand and Kapoor 1973). There are reports about the beneficial hypoglycemic effect of chickpea *dhal* compared with wheat and rice (Dilawari et al. 1981). Studies on therapeutic effects of chickpea are not conclusive so far and need further investigation, particularly using human experimental subjects.

Suggested Areas for Future Research

- Systematic studies on consumption, varieties, frequencies, and forms of utilization.
- Selection of varieties suitable for consumption as a vegetable.
- Designing simple, easily manageable puffing units to promote use of puffed chickpea and flour. Testing suitability of varieties for puffing characteristics.
- Development of *roti* flour mixes combining millet and chickpea flours, and exploring the acceptability and marketability of *roti* flour mixes.
- Development of technology for ready-to-eat foods such as biscuits, cookies, fermented foods, and soup mixes.
- Study of the influence of spices on the utilization of processed chickpea.
- Investigation on resistant starch formation in the processing of millet and chickpea combination products.

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Factors Affecting Quality in Chickpea

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Abstract. *Uses of chickpea are summarized together with the main physical and chemical factors associated with chickpea utilization in primary and secondary processing. The influence of variability of these parameters on end-product utilization is discussed with particular reference to seed characteristics, protein content, and cooking time. The most important factors causing variability are location and season of production, cultivation practices, moisture status, and temperature during the maturation period. These are analyzed in relation to heritability.*

Introduction

Kabuli chickpea is the chickpea of choice in the West Asia/North African (WANA) region, where about ! million tonnes are grown annually. In addition, about 5-10% of the 5-6 million tonnes grown on the Indian subcontinent are also of the kabuli type. Most of the chickpea consumed in western Europe and North America, and in countries (Turkey and Mexico) chiefly concerned with export of chickpea, is of the kabuli type. The chief grain quality parameters of the kabuli chickpea are listed in Table 1. Of these the first four are the most important for export purposes. The most important use of kabuli chickpea in North America and Europe is as a salad vegetable. The seeds are soaked overnight, boiled until tender and eaten cold. Seeds which are of ram-head shape and of uniform large to medium size are preferred. They should be bright beige in color. On the Indian subcontinent relatively smaller-seeded kabuli chickpea is more widely used. Its method of preparation includes soaking, boiling until tender, and serving as a hot vegetable cooked with herbs and spices.

Composition and Quality Parameters

Food legume grains are important as protein supplements to cereals, mainly because of their high protein content. On an as-eaten basis it is necessary to consume 100g of bread at

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Table 1. Quality factors in kabuli chickpea.

Factor	Requirement
Seed size (mass)	Medium to large seeds
Seed uniformity	Uniformity in size important
Seed shape	Ram-head shape best
Seed color	"Bright" beige best
Protein (%)	High as possible
Lysine (%)	High as possible
Methionine (%)	High as possible
Cooking time	Short is best
Cooking quality	
Taste	Off-flavors, e.g., bitterness unacceptable
Texture	Lumpiness and fibrousness in pastes and soups unacceptable
Oligosaccharides (%)	Low as possible
Husk (%)	Low as possible

45% moisture in order to obtain as much protein as from 70g of ready-to-eat kabuli chickpea at 66% moisture. Of all the popular food legume grains chickpea is one of the lowest in protein content (Aykroyd and Doughty 1964). Kabuli chickpea protein content has a broad sense heritability of 0.55, and selection for increased protein content in kabuli lines should be possible (Singh et al. 1989).

As chickpea has the lowest lysine content among the common pulses, further research could be devoted to improving its lysine content (Williams and Singh 1988). The methionine content of chickpea is about equal to the average methionine content of the common pulses, but the levels of tryptophan and threonine are lower (Williams and Singh 1988).

Cooking time is an important quality parameter in food legumes. A highly significant positive relationship exists between seed size and cooking time (Williams et al. 1983; Singh et al. 1989). On a dry seed basis, an increase of 1 g 100 seed"[1] corresponds to an increase of about 3.5 min in cooking time. But kabuli chickpea is always soaked before cooking. This causes changes, not only in cooking time but also in other parameters. There are important interactions between seed size and cooking time brought about by soaking the seeds, but in general soaking the seeds overnight reduces cooking time in kabuli chickpea by over 60% (Singh et al. 1988).

Cooking quality includes appearance, taste, and biting texture of the food. Food smell is also important for consumer preference and acceptability, but this is often strongly influenced by spices and herbs. The appearance of foods, such as *homos bitiheneh* or *tisqieh* is affected by the original color of the seeds, and bright clean seeds make better cooked products. This also applies to dry snacks prepared by roasting the seeds. A high tannin content can cause bitterness, but kabuli chickpeas are not normally high in tannins. The biting texture of purged foods, such as *homos bitiheneh,* is affected by the fiber content and the initial hardness of the seeds. The hardness effect can be largely overcome by increasing soaking and cooking times, but fibrous material may persist through cooking into the final food. A certain amount of fiber is desirable, and the texture of *homos bitiheneh* prepared from whole seeds is preferred to that prepared from dehulled seeds (Singh et al. 1988).

Chickpea is higher in the oligosaccharides, stachyose, raffinose, and verbascose than most pulses (Rao and Belavady, 1978), although little information is available concerning the kabuli type. Other antinutritional substances—including trypsin inhibitors, hemagglutinins, and tannins—have been reported to exist in chickpea. There appears to be a general consensus that trypsin inhibitors and hemagglutinins are reduced to harmless levels by boiling and other heat treatments, while high tannin content is not usually associated with light-colored seeds, such as the beige kabuli type.

Factors Affecting Quality Parameters

Factors affecting quality parameters in kabuli chickpea are summarized in Table 2. The seed samples came from non-replicated plots of single 4-m rows, spaced 0.45 m, between rows and 0.1 m within rows. For all other trials discussed in this paper, plots were 4 rows each 4 metres long, 0.45 m apart. Either, 3 or 4 replicates were planted. Protein content was determined by near-infrared reflectance (Williams et al. 1978) with verification by a Kjeldahl procedure (ICARDA 1986). Moisture content was determined by an air oven method (AACC 1983). Seed size (100-seed mass (g)) was determined manually/gravimetrically, and cooking time by visual evaluation (Williams et al. 1983).

The influence of genotype on seed size, protein content, and cooking time is summarized in Table 3. Protein content was normally distributed about a mean of 19.8% (dry mass basis). The range of protein content was from 14.3 to 27%, but generally the variance in protein content of the nursery (n = 3003) was low (cv = 9.1%). Seed size showed a bimodal distribution with "peaks" at 15-21 g (100 seeds)$^{-1}$, and at 39-42 g (100 seeds)$^{-1}$. (Range was from 8 to 67 g (100 seeds)$^{-1}$, and coefficient of variability was 42% about a mean of 26 g (100 seeds)$^{-1}$. Cooking time of dry seed also showed bimodal distribution with a large peak at 90-100 min and a smaller peak at 120-140 min.

Table 2. Factors affecting quality parameters in kabuli chickpea.

Factor	Quality parameter affected
Genotype	Seed size, shape, color, protein (%)
Growing conditions	
Rainfall	Protein (%), seed size
Temperature	Protein (%), seed size, seed texture
Soil	not tested
Cultivation practice	
Sowing time	Protein (%), seed size, color
Irrigation	Protein (%), seed size
Fertilizers	not tested
Processing	
Dehulling	Fiber content
Roasting	Texture (biting)
Soaking and drying	Texture (biting), protein (%)

Table 3. Analysis of kabuli chickpea germplasm[1].

	100-seed mass (g)	Protein (%)	Cooking time (min)
Mean	26.4	19.8	118
SD[2]	11.1	1.8	35
C V %	4.2	9.1	29.7
Highest	67.0	27.0	296
Lowest	8.1	14.3	50
Standard error/test	0.84	0.50	4.7
CV % test	3.0	2.5	2.8

1. Number of germplasm accessions analyzed=3003.
2. SD = Standard deviation.

The relationship between seed size and cooking time noted earlier (Williams et al. 1983) was verified, but in the medium seed-size range, the coefficients of correlation between seed size and cooking time was much lower than those between small seeds (r = 0.87) or large seeds (r = 0.91) and cooking time. Between 25-42 g (100 seed)$^{-1}$, the coefficient of correlation was only 0.4. This means that in growing situations where the seed size is in that range, the relationship may not be apparent.

The influence of the environment on the three quality factors was tested by growing 65 genotypes in 4 replicates and at 3 locations, two in Syria (Tel Hadya and Jindiress) and one in Lebanon (Terbol). Seed size showed a range in location means of 3.4 g, with protein content of 2.7% and cooking time of 12 min (Table 4). Significant genotype x location interaction occurred for all three parameters. Another noteworthy feature was that the mean cooking time at Jindiress was higher than at the other two locations. Protein content was significantly higher at Tel Hadya than at Jindiress and Terbol, which is consistent with the higher rainfall at these two locations. Neither seed size nor cooking time appeared to be related to rainfall on the basis of the single-season data.

To study the effect of growing season on quality parameters, an experiment was conducted at Tel Hadya using 62 lines in 1983/84 and 65 lines in 1985/86. Mean seed size increased by 8% in 1985/86 while mean cooking time was reduced by 16%, which is

Table 4. Influence of growing location on quality parameters in kabuli chickpea.

	Seed size[1]		Protein %		Cooking time (min)		
Location	Mean	SD[2]	Mean	SD	Mean	*SD*	**N[3]**
Tel Hadya	30.2	12.2	21.9	1.5	107	24	80
Jindiress	27.0	10.8	19.2	1.4	119	33	19
Terbol	30.4	12.8	19.3	1.3	107	24	29

1. 100-seed mass (g).
2. SD = tandard deviation.
3. N = mber of genotypes tested.

Table 5. Influence of growing season on quality parameters in kabuli chickpea.

	Seed size[1]		Protein %		Cooking time (min)		
Year	Mean	SD[2]	Mean	SD	Mean	SD	N[3]
1983/84	27.9	12.9	19.9	2.0	127	48	62
1985/86	30.2	12.2	19.6	1.5	107	24	65

1. 100-seed mass (g).
2. SD = Standard deviation.
3. N = Number of genotypes tested.

another indication of season x genotype interaction with regard to cooking time (Table 5). Mean protein content was slightly lower in 1985/86, and the variance was reduced for all three parameters in 1985/86. The influence of the growing season on protein content was studied by using 4 genotypes as controls in 3 growing seasons, and at 3 locations; Tel Hadya, Jindiress, and Terbol. Mean results for the three locations snowed little difference between 1982/83 and 1983/84, but mean protein content rose by 11% (relative) in 1984/85, while variance was also increased by a factor of 2.

Hawtin and Singh (1984) showed that in Syria sowing kabuli chickpea in winter instead of in March as is the tradition resulted in very significant increases in yield. The influence of winter sowing on quality parameters was studied on 206 genotypes during 1985/86 at Tel Hadya and Terbol. Winter sowing gave seeds with slightly (but not significantly) higher protein contents and 100-seed masses than spring-sown seeds, but there was no significant difference in the variance of protein content (Table 6). There was no significant difference in the mean cooking time of winter- and spring-sown kabuli chickpea lines, but winter-sown lines showed more variability.

Another factor likely to influence the quality of kabuli chickpea is irrigation practice. Irrigation used in conjunction with careful fertilizer management can realize large increases in yield. Its effect on quality parameters in kabuli chickpea was examined by growing 96 genotypes under full irrigation, partial irrigation and rainfed conditions at Tel Hadya, Syria during 1984. Plot size was 4 m x four rows, and the trial was replicated three times. Irrigation was scheduled according to water deficit, calculated using daily water balance of rainfall and pan evaporation, and validated by soil moisture measurements

Table 6. Influence of sowing time on quality parameters in kabuli chickpea.

	Seed size[1]		Protein %		Cooking time (man)		
Sowing season	Mean	SD[2]	Mean	*SD*	Mean	SD	N[3]
Spring	35.5	9.4	20.7	1.2	129	17	98
Winter	36.2	7.9	21.6	1.2	129	22	30

1. 100-seed mass (g).
2. SD = Standard deviation.
3. N = Number of genotypes tested.

Table 7. Influence of irrigation on quality parameters in kabuli chickpea[1].

Extent of irrigation	Seed size[2]		Protein %		Cooking time (min)	
	Mean	SD[3]	Mean	SD	Mean	SD
No irrigation (Rainfed)	34.4	7.1	21.9	1.0	129	22
Part irrigation	32.7	7.5	19.3	1.0	146	25
Full irrigation	32.1	7.7	18.1	1.2	142	27

1. Number of genotypes tested = 96.
2. 100-seed mass (g).
3. SD = Standard deviation.

(neutron probe). In full irrigation, total water deficit during the reproductive period was replenished, whereas in partial irrigation only 75% of the water balance was replenished.

Seed size, cooking time, and protein content were studied. The results are summarized in Table 7. While the highest increase in yield occurred under partial irrigation, protein content was progressively reduced under conditions of increasing water availability, while variability in protein content was increased although not significantly. Partial irrigation increased cooking time by 13%, and full irrigation produced no further change. Seed size was surprisingly reduced by 6% with partial irrigation, and by a further 2% on full irrigation. Variability in seed size was also increased as a result of irrigation, and analysis of variance verified that interaction between genotype and irrigation practice was involved.

Conclusion

The influences of genotype, growing locations and season, sowing time and irrigation practice on three quality parameters of kabuli chickpea have been examined on field-grown plots in Syria and Lebanon. Seed size (100-seed mass), protein content, and cooking time were the quality parameters studied. Protein content ranged from 14 to 27%, 100-seed mass from 8 to 67 g, and cooking time from 50 to nearly 300 min (air-dry seeds) in the world kabuli germplasm collection. Variance in these three parameters was highest in 100-seed mass (CV=42%) and lowest in protein content (CV=9%).

While both growing location and season affected all three quality characteristics, growing location had the biggest influence on seed size (100-seed mass) and protein content, while growing season had the slightly greater influence on cooking time. Planting in winter as opposed to spring had no influence on cooking time. Winter planting effected slight, but not significant increases in both protein content and seed size. Partial irrigation caused reductions in both seed size and protein content, while cooking time was increased by irrigation.

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Utilization of Chickpea in West Asia and North Africa

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Abstract. *Most of the chickpea grown and consumed in the Mediterranean region of West Asia is of the kabuli type. Foods are prepared mainly from whole seeds. Their preparation involves soaking, boiling, mashing, frying, roasting, and some dehulling. A small proportion is consumed as green seeds, or ground into flour and used in making a wide range of snack foods and sweets. The methods of preparation of the main foods are summarized. Quality factors important in food preparation from kabuli chickpea include seed size and protein content. Large seeds are preferred for most purposes. Protein and moisture contents of foods vary widely depending on the form in which they are eaten.*

Introduction

In the Mediterranean region of West Asia and North Africa, the chickpea grown is predominantly of the kabuli type. Of these, only a small proportion of the 1 million tonnes produced annually is exported, and the remainder is used in a wide variety of foods. Unlike the variable-colored desi-type chickpea, which is predominantly grown on the Indian subcontinent, and mainly used after dehulling, kabuli chickpea is light beige in color, and is not dehulled before cooking. Primary processing of kabuli chickpea consists of removing foreign material from the produce, and may include sizing with sieves. Secondary processing techniques involved in food preparation include soaking, boiling, frying, and roasting. A certain proportion of the total produce is also consumed raw, in the form of green seed. This paper summarizes the results of some of the studies made on the utilization of kabuli chickpea in the Mediterranean region of West Asia and North Africa. A more comprehensive survey would probably reveal many other foods produced on a small scale, but the present data is believed to account for over 95% of the commercially produced and marketed kabuli chickpea.

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Food Usage of Kabuli Chickpea

Table 1 summarizes the main food types in which kabuli chickpea are used in the region, and includes basic procedures used in food preparation.

About 75-80% of all the kabuli chickpea in the region is consumed in the form of purees, such as *homos biteheneh, tisqieh,* and *falafel. Homos-biteheneh* involves soaking chickpeas, boiling, cooling, and then blending with *tiheneh* (mashed sesame seed), garlic, lemon juice, and olive oil. The resultant puree may be garnished with black pepper, paprika, and olives, and served cold. It is eaten as a *mezze* (starter) dish, or used as a sauce with other dishes. *Tisqieh* that is very popular in Syria is prepared from soaked whole chickpea, which is boiled, and then mixed with soaked Arabic flat bread, yoghurt, and olive oil, and served hot. *Falafel* is prepared by soaking and boiling the seed. The seed is then mashed with hot peppers and herbs, formed into small cakes and deep fried. In the larger cities of Syria, Jordan, Lebanon, Egypt, and Turkey, these three foods are produced on a fairly large scale by retailers who use up to a 0.25 t chickpea day^{-1}.

The preparation of kabuli-based snack foods can be quite complicated. For the making of *qadami stamboulieh,* the seed is wetted with an amount of water, depending on the type

Table 1. Kabuli chickpea-based foods of West Asia and North Africa.

	Primary processing	Secondary processing
High moisture foods		
Homos akhdar	Green seeds	Boiled or eaten raw
Homos maslou	Soaked	Boiled and served as is
Homos biteheneh[1] *(Mousabaha)*	Soaked	Boiled, mashed, mixed with pulverized sesame (*tiheneh*), olive oil, lemon and herbs, and eaten cold
Tisqieh[1]	Soaked	Boiled, mixed with soaked bread, olive oil, yoghurt, and served hot
Burghul bihomos	Soaked	Boiled, and served with steamed *burghul*
Riz bihomos	Soaked	Boiled, and served with rice
Balila	Soaked	Boiled, mixed with salt and cumin seed
Falafel[1]	Soaked	Mashed with peppers and herbs, and deep fried
Low moisture foods (mainly snack foods)		
Qadami stamboulieh	Soaked, dried	Roasted
Qadami stamboulieh bimeleh	Soaked, dried	Roasted, and salted
Qadami safra	Soaked, dried, moistened again and dried x 2	Roasted, dehulled (40-day process)
Qadami bisukar	Soaked, dried, moistened again and dried x 2	Roasted, dehulled, and coated with sugar
Da' a	*Ground safra*	Mixed with lemon juice and salt
Sharab sakhin	Roasted, ground	Hot drink, sometimes mixed with coffee

1. Constitute about 75% of all kabuli chickpea consumed in the region.

and origin of the chickpea, blended well, and allowed to stand for 24 h. It is then heated for 5-7 min in a rotating kiln, followed by cooling for 2 h, and reheating for 3-5 min in the kiln. The seed is cooled, and graded into two sizes for marketing. At the same time, broken seed is separated out. *Qadami stamboulieh bimeleh* is prepared in the same way, but during the second heating a saline solution is added. During heating and rotation, the seed becomes coated with a thin layer of salt.

Qadami safra (yellow roasted chickpea) is prepared by a more complicated method. The seed is sieved to remove broken seed, and separated into two sizes. It is then roasted in a rotating kiln for about 6 min at an intensive heat (200°C), placed in wooden boxes and stored for 1 week, followed by a further week of standing in the open in a shaded area. These steps, i.e., roasting and storage in a box and letting the material stay in a shaded area, are repeated three more times. After the fourth cycle the seed is sprinkled with water, allowed to stand in closed containers for 24 h, then stored in the open for 4 days. Finally the seed is roasted again for 2 min at intensive heat (200°C), and dehulled using a device consisting of a rotating bowl or mortar with a wooden pestle. The final traces of husk are removed by manually rubbing over a sieve with a cloth.

Softer seed is used for *qadami safra* than for *qadami stamboulieh,* and the removal of the seed coat reveals the yellow cotyledons. The large *qadami safra* seed may be coated with sugar of various colors, and marketed as *qadami bisukar. Safra* seed may also be ground to a flour and mixed with lemon juice and salt, to make *da' a.*

Another form in which kabuli chickpea may be consumed is as a hot drink. The seed is roasted brown, ground to flour and used to make the drink, sometimes after mixing with coffee.

Other forms in which kabuli chickpea are consumed include *burghul bihomos* (soaked, boiled chickpea served with steamed *burghul*), and *riz bihomos,* in which the *burghul* (broken parboiled durum wheat) is replaced with steamed rice. In *balila,* kabuli chickpea is boiled and mixed with salt and cumin seed. A wide range of snack foods, sweets, and savory dishes are also prepared, marketed, and consumed on a small scale. The most popular home recipes have been assembled into a chickpea cookbook (Hawtin 1981).

Quality Considerations

Quality demands on kabuli chickpea for export mainly concern seed size, color, and uniformity. For consumption in the region, quality requirements vary only slightly from one food type to another, and in general large ram-headed seed (about 30-40 g 100 seeds^{-1}) is favored for foods, in which the seed is consumed whole, whereas for foods which use chickpea in pureed or mashed form, seed size requirements are rather less important.

The quality of a food (as distinct from the seed) can be subdivided into three main areas; appearance, taste (including after-taste), and texture. Kabuli chickpea is extremely hard, and all foods prepared from it involve a soaking stage. The texture of the final foods is affected by fiber content and by inherent seed hardness; fiber content is in turn negatively related to seed size. Our data showed that as seed mass increased from 11 to 48 g 100 seeds^{-1}, the husk percentage decreased from 7.7% to 4.2%, while neutral detergent fiber of husk increased from 60% to 70%.

Table 2. Protein content[1] of kabuli chickpea on a dry basis and as eaten.

	Protein (%)			
	Dry basis		As eaten	
Form	Mean	SD	Mean	SD
Green	23.6	±1.7	5.5	±0.5
Mature	22.3	±1.4	-	-
Soaked	22.1	±1.6	9.1	±0.7
Dry cooked	22.7	±1.7	7.6	±0.9
Soaked/cooked	22.2	±1.8	7.3	±0.6
Roasted	21.6	±1.7	20.6	±1.6

1. Based on 24 genotypes.

Table 2 summarizes the protein and moisture content of kabuli chickpea in its various forms before and after secondary processing. The data were drawn from an experiment in which 24 genotypes were selected on the basis of high, medium, and low protein content. These were then grown at Tel Hadya, Syria during 1987/88. Seed was harvested at the immature stage (green), and at maturity. The mature seed was treated by soaking and boiling to complete cooking as indicated by visual evaluation of split pea cotyledons (Williams et al. 1983), both before or after overnight soaking, and roasting. Moisture content was determined in fully hydrated, treated seed, and in green seed by a two-stage oven method (AACC 1983). Nitrogen concentration was determined by the Kjeldahl procedure (ICARDA 1986), and the results were converted to crude protein using a factor of 6.25 and reported both on moisture-free, and as-is basis.

The most important results given in Table 2 are the very significant differences which occur in the protein content of the as-eaten seed. On a dry-matter basis, green seed had the highest protein content. Seed that is mature, dry, soaked, and cooked directly, did not differ significantly in protein content from cooked and soaked seed. On an as-eaten moisture basis, green seed, having the highest moisture content, also had the lowest protein content. Soaked seed had the highest as-eaten protein content, with some genotypes being twice as high in protein in the soaked mature seed, than in the green seed. On an average, soaked seed was about 67% higher in protein content than green seed. Cooking directly without soaking reduced protein content by about 1.5%, while cooking after soaking effected a further reduction in protein content. The changes in protein content brought about by various soaking and cooking procedures were caused mainly by differences in moisture content.

The differences in protein content between cooked and soaked kabuli chickpea can be largely accounted for by losses in the cooking liquor. Protein content of the liquor was determined in 50 mL of the 200 mL liquor used to soak and/or cook 20 g of seed. On an original seed basis, liquor contained about 0.06% protein after soaking, and about 2% after cooking, whether cooked directly from the dry state or after soaking.

Roasting chickpea seed involves a preliminary soaking stage, without which the seed would be too hard to eat. Kabuli chickpea contains a high proportion of starch and about

Table 3. Relationship among protein contents of green, mature dry, and processed kabull chickpea seed.

	Dry	Soaked	Cooked	Soaked/cooked
Green seed	0.77[1]	0.70	0.52	0.59
Mature dry seed	-	0.78	0.82	0.78
Soaked		-	0.55	0.68
Cooked[2]			-	0.74

1. Coefficient of correlation; all are significant at $P > 0.01$.
2. Cooked directly without soaking.

20% protein. The combination of soaking, drying, and roasting changes the texture and bulk density of the seed, which becomes very hygroscopic after roasting. Roasted kabuli chickpea contains about 5% moisture and is slightly lower in protein content than dry seed.

Examination of the protein data (Table 2) of green seed, and soaked and cooked seeds revealed that the variance of protein content of green seed was higher than that of mature seed. There appeared to be significant interaction between genotypes and treatment in terms of changes in protein content. All of the genotypes absorbed more water during cooking than soaking, but the degree to which this took place varied among the genotypes: some absorbed more water during direct cooking from the dry state than during cooking from the soaked state whereas others did not, and were consequently higher in protein content.

The protein content of green seed (dry basis) was highly correlated with that of mature dry seed (Table 3), but the magnitude of relationship between green seed protein and that of mature seed after soaking, cooking, and roasting was reduced. The correlation between green seed protein (dry basis) and 'as-is' protein content of mature seed after soaking and cooking was not high. In contrast, the protein content of mature seed (dry basis) was highly correlated to the protein content of soaked, cooked, or roasted seed on a dry-matter or as-eaten moisture basis. These findings illustrate the influence of secondary processing on the protein and moisture content of kabuli chickpea.

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Chickpea Utilization in Turkey

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Abstract. *In Turkey, chickpea is sown on 665 000 ha (3.8% of the total cultivated area) with an annual production of 725 000 t (37.2% of the total edible legumes production). In recent years, chickpea has been grown in rotation as a dryland crop on fallow areas. Chickpea is also sometimes used as a green manure.*

In Turkey, mainly light-colored grain chickpea is cultivated. The protein-rich grain is used in soups, in appetizers, either roasted, or as green grain, as homos, *in baby food, in desserts, and as a flour fermented with yeast.*

In addition, chickpea starch is used in making plywood, while acids from its leaves are used in medicine. Ground seed coats and green or dry stems, and leaves are used as animal feed. If economically grown, whole plants could be used as fodder.

Introduction

Chickpea is an important leguminous vegetable crop in Turkey. It is grown in rotation with cereals because of its high protein content, and drought tolerance. The area sown to chickpea, and chickpea production have increased rapidly in recent years. The crop is grown on 665 000 ha with an annual production of 725 000 t, and an average yield of 1.09 t ha^{-1} (Table 1). Chickpea is second to lentil in production among the leguminous crops and accounts for more than 3.8% of the total area sown, and 37.2% of the total production of pulses (Table 1) (Anonymous 1988).

While Turkey has good potential for increasing chickpea production, limiting factors include inadequate weed control, mechanization of harvesting, marketing, and control of such diseases as anthracnose. However, a newly released variety, Eser 87, is tolerant to this disease.

To reduce the area of fallow land, chickpea is rotated with winter cereals; it has been noted that the yield and quality of the cereals improve after rotation with chickpea.

Turkey annually exports about 350 000-450 000 t of chickpea, more than half the total world exports (Table 2). Turkey also annually exports 5 000-10 000 t of roasted chickpea and 500-1000 t of seed.

In Turkey, 300 000 t of chickpea are annually consumed as human food and animal feed. The daily per capita consumption of dry legumes is 36 g during the winter months,

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Table 1. Sown area, production, and yield of chickpea in Turkey, 1970-88.

Year	Sown area ('000 ha)	Production ('000 t)	Yield ($t\ ha^{-1}$)
1970	100	109	1.09
1980	240	275	1.15
1985	399	400	1.00
1986	534	630	1.18
1987	665	725	1.09
1988[1]	779	778	1.00

1. Estimate.

Source: The summary of the State Agricultural Statictics.

Table 2. Turkish chickpea exports, 1980-88.

Year	Volume ('000 t)	Value ('000 US $)
1980	88.535	35.721
1982	156.322	65.196
1984	159.230	63.337
1985	189.085	84.218
1986	248.408	98.311
1987	369.357	98.851
1988[1]	487.554	141.469

1. From January to November 1988.

and it varies marginally during other seasons. Annual chickpea consumption, accounting for a third of all legumes consumed, is about 250 000 t. Another 25 000 t of chickpea are consumed after they are roasted, and as appetizers. About 20 000-25 000 t of chickpea are used by the food-processing industry and as animal feed.

Utilization in Human Nutrition

Dry chickpea seed is generally used in human foods. The seed contains 21.2-26.2% protein, 38-59% carbohydrate, 3% fiber, 4.8-5.5% oil, 3% ash, 0.2% calcium, and 0.3% phosphorus. The digestibility of its protein varies from 76% to 78%, and of carbohydrate from 57% to 60% (Eser et al. 1987; Gurbuz 1988).

Like other food legumes chickpea is consumed in several different ways. A complete meal can be made out of chickpea, or it can be used to give flavor to a meal, or as dessert. In Turkey, it is used in making soups and appetizers, as *homos* (chickpea paste), as an ingredient in baby foods and canned foods, as a flavoring in fermented foods, as roasted nuts, and as flour. About 75-80% of the domestic consumption of chickpea is in the following forms.

Table 3. The names and ingredients of some popular dishes.

Name	Main ingredients
Etli nohut (meal)	Chickpea, meat, butter or margarine, tomato paste.
Sade nohut (meal)	Chickpea, butter or margarine, tomato paste.
Pastirmali nohut (meal)	Chickpea, pastrami, butter or margarine, tomato paste.
Iskembeli nohut (soup)	Chickpea, tripe, butter or margarine, tomato paste.

Chickpea Soups and Main Dishes

There are many kinds of soup and spiced dishes that are prepared in the south and southeast regions of Turkey. These are delicious and nutritious even when consumed without meat (Table 3).

Chickpea Flavoring

Chickpea is added to improve the taste of many dishes, e.g., *nohutlu pilav* (pulao), *nohutlu kabak* (sweet squash dish), *asure* (desert), and *eksili corba* (soup).

Chickpea Appetizers

Kabuli chickpeas, after cleaning and washing, are boiled in water for 1 h, and consumed as an appetizer mixed with raisins, hemp seeds and boiled beans. Chickpea is also boiled with 1-2% wheat grain, and eaten.

Chickpea seeds are soaked in cold water until they become soft, then roasted on a hot iron pan. This easy preparation is favored by farmers who produce chickpea and consume it in this form during the winter. Seeds can also be roasted without soaking, but are harder than those roasted after soaking.

Roasted Chickpea

Roasted white and yellow chickpeas can be eaten plain, or as salted or sugared nuts. White chickpea seeds are cleaned and boiled in water containing 10% sodium chloride, 2% carbonate, and 1% oxalic acid. Then the seeds are drained and kept for 4-10 h in a dish. The seeds are then roasted, cooled for a short time, and roasted again in coarse salt. This process is completed by the cracking of chickpea.

To roast yellow chickpeas, the seeds are cleaned, separated according to size, roasted for 8-10 min, and kept for 24 h in a sack at room temperature. They are then spread out flat in a 10-15-cm thick layer, and left for 10-20 days and stirred twice a day. The seeds are collected when cracking is over, and the above procedure is repeated. The seeds are kept for 20-24 h, and roasted over a hot fire. Seeds can be roasted again following the same procedure, and salt, sugar, black pepper, and red pepper added. Roasted white and yellow chickpea constitute 10-15% of the total human chickpea consumption. Approximately 4000-5000 t of roasted chickpea are annually exported from Turkey.

Green Chickpea

Developing green grains can be consumed when the seeds are at the milky stage. They are tasty at this stage, and their protein content is high. Sometimes the green plant is roasted over an open fire.

Chickpea Flour

The flour of raw or roasted chickpeas is consumed in different ways. It may be mixed in low proportions with wheat flour for making macaroni, pastry, and biscuits. Gluten can be added to improve the quality of the mix. Roasted chickpeas are ground, mixed with sugar and consumed as *kavut. Hadji halvah, halvah,* and pastry made with roasted chickpea flour are popular dishes in Turkey. The seeds of chickpea roasted to a dark color are ground to a powder and used to make a refreshing hot drink either by themselves, or in combination with coffee beans. This form of consumption accounts for 2-3% of the total human consumption of chickpea in Turkey.

Homos

Chickpea seeds are boiled in water, and mashed after soaking for a while, or without soaking, to make *homos,* which is consumed plain, or with red peppers and other spices, or with meat. *Homos* can be canned to prolong its storage life.

Baby Food

Chickpea is a good source of many amino acids, and is rich in oil. Chickpea has also the highest biological value among legumes and is close to mother's milk in nutritive value. The protein score of chickpea is 62 against an accepted score of 100 for eggs, while for other legumes, the scores range between 37 and 44. Chickpea has more histidine and some other amino acids than mother's milk, and is therefore used as a nutritious baby food.

Canned Chickpea

A small proportion of canned chickpea (1% of total consumption) is consumed in Turkey, but most of the tinned product is exported to West Asian countries. In order to can it, chickpea is first soaked for 8-12 h and then cooked in boiling water for 5 min at 99°C, cooled, heated again to 60°C, and then sterilized for 40 min at 118°C.

Fermentation

Chickpea flour has been used in the past to make dough yeast. At present, this process is not much used, because it causes rancidity or color problems, whether used alone or when mixed with other ingredients. Chickpea flour is mixed in water, kept for 6 h at 25-35°C then mixed into dough which is allowed to rest for about 3 h before being made into bread and buns.

Animal Feeds

As seed, 5-10% of Turkish chickpea production is used in animal feeds. Since chickpea is mainly produced for human consumption, the price of chickpea is higher than that of other legumes used as fodder. Chickpea with dark seed coat is grown as animal feed in some countries but it has some disadvantages. Immature seeds are better as animal feed, as mature seeds are used as human food.

Chickpea may be used for feeding all domestic animals, if the seeds are in good condition. Chickpea is reported to cause flatulence if it is consumed or grazed too much when it is in the seedling stage. Chickpea straw is not suitable for animal feed, since its stem and branches are tough to chew. The straw can be used for animal feed if it is chopped and mixed with cereal straw. The industrial processing of chickpea results in some by-products, mainly seed coats (15-20%) obtained during grinding and these are used in animal feeds. The residues which are collected during cleaning are also very suitable as fodder. Chickpea straw contains 137.4 kg protein t^{-1}, while cereal straw contains 70.5 kg protein t^{-1}. When biological values are taken into consideration, 11 legume straw is equal to 8 t cereal straw.

Utilization in Industry

Less than 1% of chickpea production in Turkey is used in industry. Chickpea starch is used in the textile industry to give brightness to wool and silk in the finishing stages. The starch is also used in the manufacture of plywood. A indigo-like dye is obtained from chickpea leaves. The stems and leaves have high concentrations of malic, malonic, citric, and oxalic acids which are used in medicine.

Possibilities for Increasing the Utilization of Chickpea

It is necessary to increase the use of chickpea to meet the protein needs of the population, and increase the consumption of chickpea grain. The quality of flour mixes containing chickpea need to be improved. The possibilities of using chickpea in the biscuit industry should also be investigated. Chickpea may be used as a green manure in regions where it is easily grown.

A study was carried out (Eser et al. 1987) on 160 local chickpea varieties collected from chickpea-growing provinces, and conserved in the Tosun Gene Bank, Ankara, Turkey. The results obtained showed wide variation in several characters, e.g., their protein contents ranged from 21.2 to 26.2%. According to the study, the numbers of seeds per plant, fertile pods per plant, and primary and secondary branches can be used as primary selection criteria to select plants for high seed yield.

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Uses and Possibilities of Chickpea in Spain

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Abstract. *Chickpea in Spain is used both as human food and animal feed. Cultivars with white seed coats are used for human consumption. During the last 20 years, the use of chickpea as fodder has decreased to a negligible quantity. Chickpea is nowadays not merely a source of protein for the poor, but also a basic component of several popular dishes. Therefore, the best chickpea types can command a very high market price.*

The introduction of winter-sown chickpea technology is again making it possible to use chickpea for animal feed. High-yielding cultivars not suitable for human consumption may be used for this purpose.

Resistance to ascochyta, winter conditions, fusarium and other root parasites, and drought are urgent areas that need to be researched. Chickpea seed has a high biological value, but studies on protein quality and technological characteristics are also required to ensure its adequate utilization as animal feed. These are also the most appropriate areas for collaborative research.

Introduction

Chickpea was used in Spain till the late 1950s both as human food and as animal feed. Kabuli types, usually characterized by large, ramhead-shaped, white or beige seeds, were mostly consumed in human diets. Both desi and kabuli types that exhibited poor cookability were used as animal feed. The seed size of desi should not be too small and the minimum acceptable size is about 25-30 g $(100\ \text{seeds})^{-1}$. The size of most popular kabuli varieties used for human consumption is around 70 g $(100\ \text{seeds})^{-1}$.

Chickpea for Human Consumption

Chickpea is an important ingredient in various dishes, and contributes significantly to the basic daily nutritional requirements of a large segment of society. In this sense, it is similar to lentil, and common bean, pea, and faba bean. The traditional, but not the only procedure

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of cooking *cocido* (boiled chickpea) is to soak seeds overnight, and drain off excess water. Additional ingredients, such as pork, beef, and potato, are boiled for 30 min, and added to the previously soaked seeds. Boiling is continued until the seeds become tender, usually in about 2 h. The cooking time depends on the cultivar, the soil in which they are grown, and some other factors. Sodium bicarbonate is usually added to hasten the cooking process. Seeds of good quality should cook in a short time without losing their seed coat during culinary operations. *Cocido* is a traditional and widely popular dish, but the basic recipe is often modified according to regional preferences. The relative proportions of the other ingredients may also vary. One of the most popular dishes only uses vegetables. It is worth emphasizing that the most appreciated ingredient in any *cocido* recipe is chickpea.

Cocido is no longer the staple dish it was in earlier days. Improved transportation of animal products to cities and consequent increased meat consumption in Spain has resulted in decreased per capita consumption of chickpea. This is only one of the causes of the reduction in the chickpea-cultivated area in Spain during the last 50 years. This reduction has been accompanied by an increase in the price for high-quality seed, and has resulted in an increase in the import of chickpea (Table 1). Imported chickpea forms a significant portion of Spanish chickpea consumption (Cubero 1976).

At present, chickpea is sold in 0.5- or 1-kg packets in supermarkets. Bulk quantities of chickpea are not available. The price of chickpea can vary from US \$ 2-3 kg^{-1} in a medium-sized town such as Cordoba, to even double that amount in large cities like Madrid or Barcelona. This high market price is advantageous to the farmer, as he can get up to US \$ 2 kg^{-1}, depending on the quality of the grain. A limitation to consumption exists because chickpea is no longer a basic food, but only appreciated as an occasional dish. Finding new uses for chickpea as an ingredient in locally acceptable dishes and in the processed food industry would increase consumption of chickpea, and pave the way for an increase in cultivated area. Among such new uses, roasted chickpea as a snack, and boiled

Table 1. Chickpea production and trade in Spain, 1976-86[1].

	Irrigated		Rainfed				
	Area (ha)	Yield ($t\ ha^{-1}$)	Area (ha)	Yield ($t\ ha^{-1}$)	Total production (t)	Import (t)	Export (t)
1976	1844	1.07	101 103	0.52	54 963	31 928	249
1977	1760	0.95	99 197	0.55	57 936	28 538	473
1978	2149	0.99	109 544	0.63	70 995	55 874	2622
1979	2090	1.18	101 728	0.61	64 737	46 986	5304
1980	1700	1.27	88 430	0.66	60 670	27 388	2667
1981	1615	1.15	81 917	0.38	33 218	43 204	388
1982	1424	1.14	77 459	0.59	47 073	43 366	719
1983	1372	1.07	89 418	0.54	49 430	32 935	1377
1984	1513	1.42	90 182	0.66	61 942	26 669	225
1985	2005	1.21	88 280	0.62	57 275	25 964	911
1986	1959	1.26	88 454	0.63	57 777	37 026	540

1. Spring sowing, large kabuli, for human consumption.

and seasoned chickpea in salads may be preferred by consumers as they are somewhat familiar with these products. Other ways of preparation, such as *homos,* are completely unknown and the introduction of such products to Spain would require an extensive promotional effort.

All factors considered, the potential for increased human consumption of chickpea is small. An increase in chickpea production for human consumption may only be possible by restricting imports. However, canning chickpea could offer new opportunities, and some commercial brands are already available. Further research is required in order to mass produce a product comparable in taste to home-made preparations.

Chickpea for Animal Feed

In contrast to its restricted prospects for human consumption, chickpea for use as animal feed offers excellent opportunities for increased production. However, some constraints need to be overcome.

The competition for using chickpea as animal feed will mainly come from the demand for human consumption. If the grain does not have good cookability characteristics, the farmer will not be tempted to sow the crop for human consumption. Since the price of chickpea for human consumption is much higher than that for animal feed, the yields of cultivars grown for animal feed need to be very much higher than those of cultivars selected for human consumption. At present, yields of some winter chickpea cultivars are about 4 t ha^{-1}, but with improved breeding and agronomy practices the yields of cultivars both for human consumption and as fodder are likely to increase to 4.5 or even to 5 t ha^{-1}. Resistance to ascochyta blight is a must to achieve this objective, and even though winter chickpea can escape fusarium wilt, root diseases pose a permanent potential threat to the crop (Jimenez-Diaz et al. 1989).

The scope for sowing chickpea cultivars for animal feed on marginal lands is good, as neither the cooking quality nor the yields will be of great concern to the farmer. There are at least two kinds of marginal lands for chickpea cultivation; those on which temperature is the limiting factor, and those on which poor rainfall is the problem. To meet these requirements, winter chickpea cultivars that can tolerate -10°C at least for 3-4 days in a row are needed; so are high-yielding cultivars that can be sown in February, or even sooner, with the potential to germinate at low temperatures. In the case of dry areas, winter chickpea is the only solution. The existing cultivars could provide a first generation of chickpea varieties for these zones. A breeding program could eventually be set up to select for higher drought resistance, while noting that it is unlikely that areas receiving less than 300 mm rainfall will ever be cultivated for seed crops in Spain.

A third marginal type of light acidic soils could be of potential interest to chickpea breeders. Cultivars adapted to these soils should also have resistance to low temperatures.

The biochemical value of raw chickpea is high, being similar to that of soybean, but its protein content (around 20%) is one of the lowest among food legumes. As the use of chickpea as a component in animal feed will mainly involve its inclusion in industrial formulations, it would be desirable to raise its protein content to about 25%, without decreasing the lysine content or the yield.

Areas Requiring Further Research

Research efforts should be directed to increasing: the yield and yield stability (both in spring and winter types); the level of tolerance to low temperatures; resistance to ascochyta blight and root diseases; and to improving the agronomy of chickpea, especially by application of herbicides and pesticides.

Further, research efforts should help identify types adapted to moderately low pH, while studies on canning or freezing chickpeas, their use by the processed food industry and as animal feed, will boost demand for the legume.

Research in the following areas should also be considered:

1. In the case of chickpea for human consumption, cooking quality characteristics must be maintained.
2. In the case of chickpea for animal feed, the protein content has to be increased without loss of lysine content, biological value, and yield.

There is a need to develop reliable methodologies to screen for resistance to low temperatures and to diseases; for better evaluation to select for good culinary characteristics; and for rapid methods to screen for both protein and lysine content. The near infra red (NIR) technique is very useful, at least when screening for protein, but it has to be properly calibrated to avoid any bias that may arise while measuring black or white chickpea.

More efforts are required in the application of genetic engineering techniques to standardize the technique for regeneration of plants from vegetative parts of chickpea.

Areas for Collaborative Research and Training Needs

There is now active collaboration between the plant breeding and plant pathology laboratories located in ICRISAT and ICARDA. This collaboration should expand in future, and should also involve institutions from other countries. Areas requiring further collaboration are tissue culture and methods for protein and lysine analysis. The strengthening of collaboration in these areas would be part of our training needs as well.

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Utilization of Chickpea and Groundnut in Egypt; Some Popular Dishes

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Abstract. *Dishes consumed by large sections of the population from various socioeconomic backgrounds are not all nutritionally adequate. Some Egyptian dishes were analyzed for their contents of carbohydrates, amino acids, fat, protein, fiber, ash, calcium, phosphorus, and iron. Chickpea and groundnut were added to raise the protein efficiency ratio, net protein utilization, digestibility, and chemical score of three of these dishes.*

Introduction

Popular chickpea dishes are prepared and consumed by large sections of the Egyptian population at varying socioeconomic levels, but some of these dishes do not satisfy human requirements for calories and essential nutrients.

Special Egyptian cereal dishes, include *beleila dhurah* (maize *beleila*), *lokmet el-kadi,* and *fattir* with dry dates are prepared early in the morning and have been chemically analyzed by the authors to determine their biological value.

Materials and Methods of Preparation

The ingredients and their ratios for each dish are given in Table 1. The dishes were prepared in the laboratory, according to traditional methods, and analyzed. Groundnut, chickpea, and sesame seeds were supplemented to the dishes to investigate their effect on net protein utilization, and the analyses were repeated.

Beleila Dhurah. Maize kernels were washed and cooked in boiling water until they became soft. Sugar, dry raisins, and milk powder were added, together with a flavoring substance, such as vanillin. The ingredients were stirred and poured into special serving dishes.

Lokmet El-kadi This popular breakfast dish eaten with milk was prepared by mixing

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Table 1. Ingredients used to prepare traditional and supplemented Egyptian foods.

Local name	Traditional ingredients	Quantity (g)	Supplemented ingredients	Quantity (g)
Beleila Dhurah	Maize	16.5	Maize	15.0
	Sugar	26.6	Water	40.0
	Dry raisin	1.2	Sugar	22.0
	Milk powder	8.2	Dry raisin	1.0
	Water	47.5	Milk powder	8.0
			Groundnut	14.0
Lokmet El-kadi	Wheat flour	17.2	Wheat flour (72% extraction)	14.0
	Dry yeast	1.0	Water	27.0
	Sugar	34.9	Dry yeast	1.0
	Cotton seed oil	13.8	Sugar	32.0
	Lemon juice	0.8	Cotton seed oil	11.2
	Water	32.3	Lemon juice	0.8
			Chickpea	14.0
Fattir with dry dates	Wheat flour	43.0	Wheat flour (72% extraction)	35.0
	Hydrogenated oil	15.5	Nabatine (hydrogenated oil)	12.0
	Dry yeast	0.5	Water	15.0
	Semi-dry dates	22.0	Dry date	22.0
	Fennel	0.3	Fennel	0.2
	Anise seeds	0.3	Anise seeds	0.3
	Water	17.1	Dry yeast	0.5
	Sesame	1.3	Sesame seeds	15.0

wheat flour with water and baker's yeast to form a soft dough and fermented for 2 h. The fermented dough was divided into small pieces, then fried in an open pot in very hot oil. The fried product is usually mixed with sugar before consumption.

***Fattir* with date.** Prepared from wheat flour mixed with water, fennel seeds, anise seeds, hydrogenated oil, and baker's yeast made into a dough. The dough is fermented for 2 h, divided into small pieces, and a piece of semi-dry date added to each piece. The dough is then baked in a preheated oven (250°C) for about 20 min.

Methods of Analysis

All food samples were dried in a vacuum oven at 70°C for 48 h, finely ground to powder, and stored in plastic containers at 4°C before analysis. The foods were analyzed for iron, calcium, moisture, ash, fat, fiber, and protein contents according to the AOAC method (1980). The carbohydrate content was calculated by difference. Phosphorus was determined according to Stuffins (1967). Amino acids were identified according to Moore et al. (1958). Cystine and methionine were determined after performic acid oxidation (Moore et al. 1958). Tryptophan was estimated after alkaline hydrolysis (McFarren and Mills 1952) using a colorimetric method (Opeinska-Blauth et al. 1963).

The protein quality of the different dishes was evaluated using the method of Miller and Bender (1955), and casein was used as the control diet. Results of traditional and supplemented dishes analyses are shown in Table 1.

Results and Discussion

Chemical Composition. The chemical composition and the concentrations of some of the minerals in the analyzed dishes are given in Table 2. *Fattir* with dates had the lowest (9.7%) moisture content. *Lokmet el-kadi* had the lowest protein content (6.14%). The phosphorus content of *beleila dhurah* (220 mg 100 g^{-1}) was high.

Biological Evaluation. The essential amino acid composition of regular and supplemented diets are given in Table 3 and compared to the FAO/WHO (1973) pattern. It is clear that there was a marked improvement in the quality of protein after supplementing with chickpea, groundnut, and sesame seeds. These findings are in agreement with those of Jansen (1974), Rosenberg et al. (1960), and Bressani et al. (1972), who reported that lysine is limiting in all cereals, and tryptophan is limiting in maize.

The results of net protein utilization (NPU), true digestibility (TD), and biological value (BV) before and after supplementation of the diets are shown in Table 4. The NPU values of the analyzed unsupplemented dishes were very low, their values ranging from 20.3% to

Table 2. Chemical composition and selected mineral contents of tested Egyptian foods.

Local name	Moisture (%)	Protein	Fat	Carbo-hydrate[1]	Ash	Fiber	Calcium	Iron	Phos-phorus
		g(100g)$^{-1}$ dry matter					mg (100 g)$^{-1}$ dry matter		
Beleila Dhurah	54.50	7.73	6.90	79.90	1.30	2.30	158.00	0.63	220.00
Lokmet El-kadi	18.80	6.14	16.80	75.95	0.29	0.48	22.50	0.52	57.00
Fattir with dry dates	9.70	8.69	13.50	74.01	0.44	2.20	83.00	0.80	78.70

1. Estimated by difference.

Table 3. Essential amino acid composition (mg g^{-1} N^{-1}) of traditional and supplemented Egyptian foods as compared with the FAO pattern[1].

Amino acids	Before supplementation BD	LK	FD	FAO pattern 1973	After supplementation BD	LK	FD
Theronine	228	232	251	250	267	234	261
Valine	219	177	149	310	265	256	183
Isoleucine	193	88	155	250	263	163	248
Leucine	367	187	220	440	489	280	346
Phenylalanine + tyrosine	361	233	321	380	578	379	391
Lysine	72	116	138	340	127	164	208
Methionine + cystine	123	70	85	220	225	157	217
Tryptophan	27	35	31	60	36	39	41

1. See FAO/WHO 1973 for details.
BD = *Beleila Dhurah,* LK = *Lokmet El-kadi,* FD = *Fattir* with dates.

Table 4. Net protein utilization (NPU), digestibility (D), and biological values (BV)[1] of traditional and supplemented Egyptian foods.

	Traditional food			Supplemented food		
Foods	NPU	TD	BV	NPU	TD	BV
Beleila Dhurah	31.3	74.0	42.3	73.0	84.0	86.6
Lokmet El-kadi	20.3	84.5	26.0	61.0	83.9	72.7
Fattir with dry dates	23.6	78.9	29.9	65.0	82.0	79.3
Casein (8%)	82.5	88.0	93.8	-	-	-

I. Expressed as percentages.

31.3%. BV was lowest for *lokmet el-kadi* (26%), while TD of the three dishes was high, ranging from 74% to 84.5%. The NPU value of *fattir* with dry dates improved from 23.6% to 65% by supplementation with sesame seeds. The NPU value of *beleila dhurah* was 31.3% and became 73% when supplemented with groundnut. Its BV changed from 42.3% to 86.6%. A similar trend was noticed for the NPU and BV of *lokmet el-kadi* when fortified with chickpea.

The results showed that the three dishes could be supplemented with protein sources in order to improve their nutritional value, and that groundnut, chickpea, and sesame seeds could be used for this purpose. Supplementation of *beleila dhurah* with groundnut improved its protein concentration from 7.73% to 11.52%, and its fat content from 7.73% to 11.52%. Similarly, supplementing *lokmet el-kadi* with chickpea improved its protein concentration from 6.14% to 10.20%, but its fat content changed slightly from 16.80% to 15.02%. In case of *fattir* with dry dates, using sesame seeds lead to similar changes in both protein and fat contents of the sample.

The results of this study showed that some traditional Egyptian dishes are nutritionally unsatisfactory, but supplementing these dishes with sesame, chickpea, or groundnut can improve their nutritional quality. This indicates possible future uses of these legumes in Egypt.

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Uses of Chickpea, Lentil, and Faba Bean in Ethiopia

Senayit Yetneberk[1]

Abstract. *The most widely cultivated food legumes in the Ethiopian farming systems are chickpea, lentil, faba bean, and field pea. These food legumes serve as important protein supplements in the cereal-based diets of Ethiopians. The consumption rate increases during fasting days (approximately 140 days per year) when orthodox Christians abstain from meat and eggs. There are numerous dishes prepared from these pulses. Several procedures such as boiling, roasting, fermenting, sprouting, dehulling, and milling are used in traditional food preparations. Consumer preference of seed quality for ease of processing is also indicated.*

Introduction

The most widely cultivated food legumes in Ethiopa are faba bean, chickpea, field pea, and lentil. They are the second most important food after cereals (Westphal 1974). The total production of legumes in Ethiopia during 1985/86 was 407000 t (CSAE 1986).

Food legumes are mainly eaten in stews together with *injera* (a leavened bread made from cereals), and are an important source of protein, especially during the numerous fasting days (about 140 per annum). Different kinds of boiled, sprouted, and roasted foods made from pulses are consumed as snacks. In the absence of pea, chickpea is substituted as one of the ingredients of *fafa,* a commercial weaning food.

A survey of faba bean utilization in the central zone of Ethiopia showed eight types of traditional foods distinguished by their vernacular names (Senayit Yetneberk 1987), demonstrating the versatility of faba bean and the long history of its use. This paper discusses the consumption pattern, grain processing, and preparation methods of chickpea, lentils, and faba beans in Ethiopia; it also describes the practical implications of processing.

Traditional Foods from Legumes

The consumption of food legumes in Ethiopia shows wide variation. Legumes are eaten in the form of sauce to supplement the cereals-based staple diet. When fermented or made into paste, legumes are served as a side dish. They are served as a snack, when made into bread, boiled like rice, or roasted.

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Wot. Different versions of *wot* can be prepared from legumes. The basic seasoning ingredients are onion, garlic, oil, red pepper, spices, and salt. These are made into a sauce. Whole lentil seed, or split lentil or faba bean seed is cooked in a separate pan, and then mixed with the sauce and allowed to simmer till the mix becomes homogeneous. The *wot* from split seed is called *kik wot,* and that from whole lentil is called *difin misir wot.* With the same basic sauce, flour from roasted, dehulled, and spiced chickpea or faba bean is used as a thickener, and the mixture is allowed to simmer. This is called *shiro wot. Wot* is always served with *injera,* a leavened bread made from cereals. A popular and unique dish for fasting days is prepared from chickpea as follows: using dehulled chickpea flour, unleavened small breads of different shapes are baked on a clay griddle. The same basic sauce mentioned above is prepared and the bread is dropped into the boiling sauce and allowed to simmer. It is called *shimhra asa wot. Azifa* is also a popular dish for fasting days made from lentils. Whole lentil seed is soft boiled and mashed; it is seasoned with chopped raw onion, garlic, green pepper, lemon, oil, and salt, and served.

Nifro. Made from chickpea, lentil, or faba bean, the grain is either cooked and served by itself, or boiled and mixed with cereals, commonly wheat. The cooked product is salted and served hot as a meal or a snack.

Kollo. Prepared from roasted chickpea, lentil, and faba bean. Before roasting, cooking or soaking is involved. In case of chickpea and lentil, the grain is commonly mixed with roasted barley or wheat. Three different roasted products are made from faba bean. *Ashuk* is roasted and boiled beans; *endushdush* is soaked and roasted beans; and *gunkul* is sprouted beans which are boiled or roasted. All these products are served as a snack with coffee or tea.

Dabo. Yeast culture is added to wheat flour and a dough is made using warm water, and it is left to ferment overnight. The following day, split chickpea flour, salt, and coriander are added to the fermented dough and kneaded well, adding lukewarm water as necessary. The mix is allowed to stand for 1 - 2 h, then baked into bread.

Kitta. Split pea flour is mixed with wheat flour in a 1:3 proportion and made into dough, using warm water. Salt and oil are added and the dough kneaded well. It is baked on a hot griddle, turning the bread occasionally to obtain an even golden-brown color.

Elbet. Salt, fenugreek, and water are added to a mix of equal proportions of roasted and dehulled lentil flour and faba bean flour. A batter of good consistency is made, which is poured into boiling water and cooked until it becomes thick. The paste is allowed to cool, and then beaten with a spoon till it becomes fluffy. It is served as a side dish with *injera* together with other sauces.

Siljo. Split faba bean flour is made into a paste with an extract of cooked and pounded sunflower seeds. The paste is mixed with mustard, fresh garlic, and rue, and allowed to ferment for 3 - 6 days. It is served as a side dish with *injera,* especially during the fasting period.

Every food legume cannot be used to make all the types of food discussed above. Chickpea makes *nifro, kollo, shiro, dabo,* and *shimbra asa wot.* Lentil makes *nifro, kolla kik, azifa,* and *elbet.* Faba bean makes *nifro, kik, shiro, endushdush, gunkul, gulban,* and *siljo* (Senayit Yetneberk 1987). This is by no means an exhaustive list of legume foods in Ethiopia, since a detailed survey of legume preparations has not been carried out for the whole country.

Legume varieties vary widely in seed size, and in suitability for processing. Responses to a survey on faba bean utilization indicated that large-seeded beans were not easy to dehull, cook, and sprout, while small-seeded beans were easy to dehull, but not to cook. Medium-seeded beans were easy to dehull, sprout, and cook (Yetneberk 1987). The influence of lentil seed size on husk percentage showed that losses due to husk abrasion are proportionally higher in small seeds (Williams et al. 1984). They have also reported that lentil and chickpea were relatively free of antinutritional factors although chickpea is fairly high on flatulence-causing factors.

Cooking is an indispensible process for legume food preparation. It softens the grains and facilitates palatability and protein digestibility. However, Aykroyd and Doughty (1964) concluded that boiling, as ordinarily practiced, probably leads to 25% losses of water-soluble nutrients. This implies that as boiling is prolonged, serious nutrient losses occur.

Cooking time variation among varieties and their different growing environments was recorded. A laboratory study on cooking time of the faba bean variety CS20DK grown in different soil types of the central zone of Ethiopia showed a range in cooking times of 13-25 min, after soaking for 16 h. The variation is attributed to the levels of K and P in the soil (Yetneberk unpublished). Estimated times taken to cook local varieties of faba bean without prior soaking in farmers' households ranged from 1-4 h with an average cooking time of about 2 h. This leads to very high firewood consumption, and aggravates the existing fuel problem in the country.

For processing and consumption of legumes, the breeder's attention should be directed not only to obtaining high yields and disease resistance, but also to improving grain quality for processing and human consumption.

Areas for Further Research

The following are important areas of research for the future.

- Screening of varieties with short cooking time to minimize losses of nutrients and reduce fuel costs.
- Development of varieties with good splitting or detailing characteristics to minimize grain loss due to abrasion, and to obtain clean split seeds free of husks.
- Selection for low levels of anti-nutritional factors in faba bean.
- Breeding for high-protein content of food legumes to improve the protein intake of consumers who depend on legumes for protein in their daily diet.

Areas for Collaborative Research

Collaborative research in breeding and agronomy of food legumes does exist between national programs and the international centers, the International Center for Agricultural Research in the Dry Areas (ICARDA), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), for germplasm exchanges, field visits, and training. There is a need to establish collaborative research work in the field of grain quality evaluation through joint research, manpower and facility development.

Training Needs

Essential training needs include:

- Intensive training in laboratory techniques for legume evaluation; and
- degree-level training in food science.

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Utilization of Some Important Food Legumes in the Sudan

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Abstract. *Groundnut, broad bean, common bean, lentil, and chickpea are the most important food legumes consumed daily in the Sudan in one way or another by a large part of the population. The most popular dishes are stews, curry,* flafal, *and soups. Since local production of these legumes cannot meet demand, the country annually imports large quantities of legumes. Prices are unstable and vary over time. Groundnut is the only legume processed on an industrial scale; it is roasted, salted, made into a paste or cake for use in confectionery or to fortify other foods, and for oil extraction. As most methods used in the preparation of food-legume dishes are time-consuming and expensive, especially with regard to fuel consumption, research is required in the fields of production and utilization. The present trend to produce cheap protein-rich foods will stimulate further investigation into food formulation and recipes containing grain legumes, especially for breads, biscuits, weaning food, and confectionery. The food legume industry should be fully supported as a means of promoting such crops. Research should also concentrate on controlling various undesirable aspects, such as antinutritional factors, or those causing flatulence, and poor cooking quality.*

Introduction

The northern region of the Sudan is the homeland of most of the food legumes grown in the country. Legumes are consumed daily in the Sudan as a rich and inexpensive source of vegetable protein. Although production has increased significantly during the last few years, the country has to import large quantities of legumes annually to meet local demand, especially for broad bean, lentil, and chickpea. The production of groundnut and dry bean or haricot bean is in excess of local demand, and appreciable quantities are therefore exported. With the exception of groundnut, the food legume industry is not yet well established in the Sudan, mainly because of shortage of raw materials.

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Groundnut

Groundnut is the only legume not produced in the northern region of the Sudan. It is cultivated under both irrigated and rainfed conditions. Most of the area (1985/86 - 0.7 millions ha) of groundnut production is under traditional rainfed conditions which is characterized by a low yield as compared to the yield (1985/86 - 1876 kg ha^{-1}) from irrigated areas (1985/86 - 137 000 ha). Table 1 shows the production and utilization of groundnut in the Sudan during the 1983/84 season.

Groundnut is used as a direct and an indirect food. The oil extraction industry is well established in the country, and a factory has recently been established to produce peanut butter.

Common groundnut products include oil, roasted seed, salted seed, peanut butter (locally called *fufu)*, and soup. Oil and peanut butter are produced on an industrial scale. Most of the roasted and salted nuts are produced by traditional methods, using a simple procedure consisting of shelling, and roasting the nuts in hot sand or ashes. The typical roasted groundnut flavor is developed during this process. The Food Research Centre (FRC) has developed a recipe for making groundnut *(Jul Sudani)* soup, which is a popular dish served in restaurants.

Although groundnut is used widely in other countries for production of milk, butter, and protein, such products have not yet been produced in the Sudan. Therefore, there is a need to broaden the utilization of the crop in the country. Research work should be directed to develop locally acceptable products from processed groundnuts. Another key area of research is to breed cultivars or develop the technology to obtain aflatoxin-free groundnut.

Table 1. Groundnut production and utilization in the Sudan, 1983/84.

	(Unit x 10^{-3})
Production	
Area (ha)	770
Production (t)	413
Exports in shell (t)	7
Domestic supply in shell (t)	406
Domestic utilization	
Direct food (t)	26
Seed (t)	64
Processed (t)	129
Oil production (t)	58
Oil export (t)	2
Oil used for food (t)	56

Source : CAS Current agricultural statistics (1988).

Broad Bean

Broad bean, or faba bean, commonly called *ful masri,* is grown almost exclusively in the northern region of the Sudan. It is the most important pulse crop in the Sudan, both in terms of area sown and production. It is the staple food for millions of people, and perhaps the main source of protein for middle-, and low-income groups. Since production of the bean has not kept pace with consumption, efforts have been made not only to increase its yield in areas where it is produced, but also to extend its cultivation to new areas such as Gezira, Rahad, and New Haifa to the south of Khartoum. Ageeb (1988) reported that broad bean can be successfully produced, in terms of yield and economics in the Gezira area, but that the quality of the seeds was inferior to that produced in traditionally cropped areas (Elmubarak Ali and Galiel 1988). Although there has been a significant increase in both the area and the quantity produced in the country in the past few years, the Sudan imported broad bean during 1985 (1035 t), and 1986 (259 t) to meet increasing demand. The per capita consumption of broad bean has been estimated at 1.54 kg month^{-1} during harvesting time (March-April) and 1.16 kg month^{1} prior to harvesting during the winter (Elmubarak Ali et al. 1983a). This decrease in consumption was mainly due to the high prices for which the legume is sold during winter.

The consumption levels mentioned in the surveys of 1982/83 are well within the range of broad bean consumption in Egypt (Hussein 1983). A common pattern in both the farming and the urban communities is that broad bean dishes are consumed mainly in the morning (breakfast) and in the evening (supper), but rarely at midday. Broad bean is usually prepared in one of two ways: as a stewed dish *(Jul),* or as *tamia (flafal). Tamia* is made by soaking decorticated dried seeds. The seeds are ground to a paste, spices and onion added, and deep fried. Since raw broad beans are not eaten in the Sudan, favism is not commonly encountered.

Rural households often consume broad beans alone, while urban households more often report combining them with other foods, such as cheese, eggs, and salads (Elmubarak Ali et al. 1983b). The high demand for broad beans may be attributed to many factors such as the high prices of meat and meat products, the relatively low price of the bean, and the ease with which it can be cooked at home.

Haricot Bean

Haricot bean is mainly grown in the northern region of the Sudan, mostly in the Shendi and Berber areas. The *baladi* type, which is a medium, white, flat-seeded variety, is widely grown (Mohamed 1983). Some trials were carried out by Hassan (1969-76) to grow haricot bean in the Central region (Wed Medani and Sennar). Although results were encouraging, production has yet to start. About 60% of the crop produced (2000 t in 1985/86) is exported annually (Salih and Salih 1985).

This bean is mostly consumed dry, although a small amount is canned. Whole dried beans are soaked overnight and cooked with meat and/or tomato sauce to form a stew, which is usually eaten with bread or rice. The straw is mainly used as forage. Research on the quality of this crop is limited in the Sudan, with the exception of the work done by Hassan and Ali (1979).

Lentils

Although the northern region is the most suitable area for the production of lentil, the amount produced locally is insufficient to meet local demand. Since the consumption of lentil is high, the country imports it annually (0.66 t in 1986). Government policy should therefore encourage lentil production in the northern region at least to satisfy domestic requirements.

Lentils are used to make soup, stew, *tamia* (*flafal*), and stuffing. A consumption survey in the urban areas around Khartoum in 1982/83 indicated that lentil is the main substitute for broad bean in the Sudanese diet (Ali et al. 1984). The per capita consumption was estimated to be 0.41 kg month^{-1}. Lentil is usually eaten at all meals.

As lentil is a processed crop, research in decortication should be carried out, and methods for improving traditional flour milling should be investigated. The study should also cover socioeconomic and marketing factors.

Chickpea

Chickpea is grown as a rainfed, and an irrigated crop on cracking clays and sandy soils (Salih 1980). The area under chickpea cultivation represents 10% of the total area under leguminous crops. The northern region is the main chickpea producing area. Since local production is less than the demand, the country imports a certain amount (3 t in 1986).

Chickpea is usually prepared in two forms; *balilah,* and *tamia (flafal). Balilah,* an important chickpea dish is prepared by boiling chickpea in water with salt and sesame oil. It is a very popular, energy-giving food, eaten especially during the fasting period of Ramadan. ChicJcpea is also widely used for the preparation of *tamia (flafal),* which is eaten at breakfast and supper.

Until now concerted efforts have not been made to increase chickpea production as it has not been considered a cash crop. Since demand is limited, the country could easily become self-sufficient.

There is an urgent need to promote the production and utilization of these important legumes. With the present trend towards production of cheap, protein-rich foods, attention will no doubt be focussed on these crops, and lead to the formulation of recipes containing legumes, which are a cheaper source of protein. As most legumes characteristically have some objectionable factors, e.g., they produce flatulence and have poor cooking qualities, further studies need to be made to eliminate or reduce these factors. These factors have been studied in detail in some countries, so exchange of information will be helpful to those countries where such studies have not been made.

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Utilization of Chickpea and Groundnut in Pakistan

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Abstract. *Food legumes are important and economical sources of protein and other nutrients in diets in Pakistan. The total annual production of chick-pea is 372,000 t and that of groundnut is 52,000 t in Pakistan, and the annual per capita availability is 3.04 kg of chickpea, and 0.45 kg of groundnut. Chickpea is processed and used in many forms, as fresh green seed, dried whole seed,* dhal, *and flour, whereas groundnut is mainly consumed as whole kernels. The nutritive value of chickpea-based products, prepared from desi and kabuli types, and of groundnut are discussed.*

Introduction

Food legumes, being economical sources of protein, calories, and certain vitamins and minerals, are an essential component in the diet of 700 million people (Khan 1987). However, consumption of legumes is restricted due to the scarcity caused by their present low yields and consequent higher cost, and due to certain defects in their nutritional and food use qualities (Elias and Bressani 1974; Khan and Ghafoor 1978).

Food legumes improve soil fertility, and the rotation of grain legumes with cereals increases the yield of cereals and reduces weed, disease, and insect problems (Borlaug 1973). Chickpea is reported to have medicinal properties, its seeds being astringent and antibilious (Khan et al. 1989). When roasted, the grain is considered to be an aphrodisiac and the fried seeds are diuretic. Hypocholestrolaemic effects and diabetic management have also been associated with chickpea (Chopra et al. 1956).

In Pakistan cereals constitute the bulk of the average diet. They are known to be limited in lysine content (Khan and Eggum 1978a; Khan 1981). In contrast, legumes are a rich source of lysine, but are limited in sulfur amino acids (Khan et al. 1979; Khan 1980; Khan et al. 1987). Combinations of cereals and legume have been reported to meet the protein requirement of various age groups in the population (Khan et al. 1976; Khan et al. 1977; Khan and Eggum 1978b; Khan et al. 1979; Khan and Eggum 1979; Khan et al. 1979).

Legume production in Pakistan has not only remained stagnant but has actually suffered a set-back in terms of per capita availability. Recently, however, more attention has been paid to developing high-yielding, disease- and insect-resistant legume cultivars, and to improving the economy of their cultivation.

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Table 1. Area and production of chickpea and groundnut in Pakistan, 1978/79 to 1987/88.

Year	Chickpea Area ('000 ha)	Chickpea Production ('000 t)	Groundnut Area ('000 ha)	Groundnut Production ('000 t)
1978/79	1224.4	537.8	36.5	45.5
1979/80	1128.5	313.4	40.8	50.3
1980/81	842.9	336.9	46.5	57.4
1981/82	901.6	293.7	59.7	72.2
1982/83	892.9	491.0	69.3	84.1
1983/84	919.6	521.9	72.6	88.0
1984/85	1013.7	523.7	59.1	69.1
1985/86	1033.3	586.2	54.9	63.1
1986/87	1082.1	583.3	62.8	75.0
1987/88	820.6	371.5	66.5	52.1

Source : Government of Pakistan. Ministry of Food and Agriculture, Food and Agriculture Division, (Planning Unit) All Pakistan Final Estimates for Chickpea and Groundnut, 1987/88.

The present paper deals with the utilization of chickpea and groundnut in Pakistan, and with the identification of areas for further research and development.

Area and Production Trends

The area sown under chickpea and chickpea production have remained static in recent years, except from 1979/80 to 1982/83 and during 1987/88 (Table 1). Ascochyta blight and weather conditions were the major causes of these fluctuations; during these periods the area sown declined by 33%, and production by 31%. Groundnut is mainly grown as a cash crop and most of the produce is consumed as roasted nuts. About 92% of the total area under groundnut lies in the Punjab, 7% in the North West Frontier Province, and 1% in Sind (Khan and Quayyum 1986). There has been a 45% increase in sown area, and a 15% increase in production, from 1978/79 to 1987/88 (Table 1). The present yield is still lower than the potential yield obtained on research stations.

Availability

The per capita consumption of pulses in Pakistan is 15.7 kg annum^{-1} (National Nutrition Survey 1988). Legumes contribute 8% protein, 8% calories, and 7% iron to the average diet in Pakistan. During 1987/88, the per capita availability of chickpea was 3.04 kg annum^{-1}, and the per capita availability of groundnut was 0.45 kg annum^{-1}.

Processing of Chickpea

Before being consumed, chickpea is subjected to primary processes i.e., dehulling, splitting, grinding, puffing, parching, and roasting. The main effect of this processing is to improve appearance, texture, culinary properties, and palatability; to decrease dry-matter content, and alter the bioavailability of nutrients (Kurien 1987).

Dehulling

Dehulling chickpea seed to prepare *dhal* involves pretreatment to loosen the seed coat from cotyledons, splitting, and dehusking.

Inefficient traditional household milling techniques yield 63% *dhal,* and commercial milling techniques yield only 70% *dhal* (Malik 1980). Household processing of chickpea into *dhal* reduces the levels of protein, calcium, iron, phosphorus, thiamine, riboflavin, and niacin it contains (Pushpamma et al. 1983). There is an urgent need to develop loose-husked chickpea varieties and to improve milling technology.

Puffing

Puffing chickpea improves its flavor, modifies its texture, and helps in dry or wet grinding (Kurien et al. 1972). For puffing, the seeds are soaked in water and then roasted on heated sand at 200-500°C for 1-2 min. The roasted chickpea is gently rubbed against a coarse surface to break the husk, which is then removed by winnowing. Processors prefer chickpea cultivars grown in specified agroclimatic tracts, which are known to give superior products with good aroma (Kurien 1984). Grains with 12-14% husk content are good for puffing (Kurien 1987). There is a need to study the factors affecting puffing and develop methods to increase puffing expansion.

Grinding

Whole chickpea, or *dhal,* is ground dry to a flour, known as *besan.* The eating quality of many chickpea flour-based products depends on flour composition, the degree of fineness of grinding, mesh grades, and cooking conditions (Kurien et al. 1972). Traditional processing methods need to be refined to improve the nutritional quality of chickpea and increase the consumer appeal of products made from it.

Traditional Uses of Chickpea

Chickpea is used in many forms, from fresh green seed to dried whole seed, *dhal,* and flour. Methods of processing used to make traditional chickpea-based products include boiling, roasting, frying, and puffing (largely a commercial process) (Table 2).

Green immature chickpea is used as vegetable. It is mixed with meat or vegetables to make curries, with rice to make *pilau,* and after shelling the roasted pods the seeds are used as a snack.

The most common method of processing whole chickpea is by boiling it, either in an open pan, or in a pressure cooker. The seed is usually soaked overnight in water sometimes with baking soda before cooking, to reduce cooking time. Seed size is important since it affects such processing operations as cleaning, decortication, and sugar coating. In general,

Table 2. Utilization of chickpea in Pakistan.

Form	Types of product	Processing conditions
Fresh green seed	Curry	Mix with meat or vegetables, boil (30-40 min) and serve with bread or boiled rice.
	Pilau	Mix with rice and boil or steam (30 min).
	Holan	Roast pods, and consume as a snack.
Whole dry seed	Curry	Soak, boil alone or mixed with meat or vegetable (10-30 min), and serve with bread or boiled rice.
	Chaat	Soak, boil (10-30 min) mix with potato or fruits, and serve as a snack.
	Pilau	Soak, boil with rice (30 min) steam (5 min), and consume as a main meal.
	Roasted chickpea	Soak and puff (240-250℃, 2-3 min), dehusk, and consume as a snack.
	Sweet *chanay*	Puff, coat with sugar, and consume as a snack.
Dhal	Curry	Soak, boil alone or mixed with meat or vegetable (10-30 min), and serve with bread or boiled rice.
	Kichri	Soak, boil with rice (20-30 min), steam (S min), and use as a main meal.
	Shami kabab	Soak, boil with minced meat (10-30 min), make into cutlets, fry in oil, and serve as a snack.
	Haleem	Soak, boil with ground wheat, rice, maize, millet, and lentil, mash, and meat, (boil 30-60 min), and serve alone or with bread or boiled rice.
	Namkeen dhal	Soak, fry (20 min), and serve as a snack.
	Halwa	Soak, boil in water or milk, mash, add sugar, fry and serve as a sweet.
Flour *(besan)*	*Missi roti*	Mix with wheat flour, make into *roti* bake (2-3 min), and consume as a main meal.
	Pakora	Make thin batter, mix with vegetables and fry (2-3 min), and consume with bread or serve as a snack.
	Dhal sawayan	Make dough, extrude as noodles, fry (3-5 min), and serve as a snack.
	Halwa	Roast with ghee (clarified butter), add sugar syrup, make into thick paste, and serve as a sweet

larger seed is considered to be of better quality and this is also preferred by consumers. Kabulis are preferred to desis. The mean cooking time of dry desi is 125 min and of kabuli is 114 min. These times are reduced to 38 min for desi and 33 min for kabuli when soaked overnight in water, and further reduced to 29 min for desi and 23 min for kabuli when soaked in a 0.5% sodium bicarbonate solution (Khan 1988). In a pressure cooker kabulis soaked overnight cook in 10 min.

Dhal is cooked until tender and soft depending on the desired texture of the finished product. *Dhal*-based products are widely used in the home and on a commercial scale, to make curry, *kichri,* and *shami kabab.*

In Pakistan, chickpea flour is a major ingredient in snacks, such as *pakoras,* and in sweets. It is also used in ground meatball preparations, and in coating fried fish and chicken pieces. Chickpea flour is also blended with wheat flour to bake *missi roti,* a bread commonly consumed by diabetic patients.

Many of the procedures adopted in product development have certain beneficial side effects. Soaking reduces the trypsin inhibitor, hemagglutinating activity, and flatulence sugars, since some of the inhibitors leach out during soaking (Kakade and Evans 1966). Boiling softens the husk, due to the reaction of phytate with insoluble calcium (Ca) and magnesium (Mg) pectates in the ceil wails to produce soluble pectate. The influence of the seed coat cell wall is a factor governing cooking time and quality. During the roasting of *dhal,* a brown color develops due to the Maillard reaction, and the aroma of the seed improves, imparting a highly acceptable quality to the roasted product. In puffing, the seed becomes light due to shrinkage of the endosperm and loss of water, and the seed starch is dextrinized (Pushpamma and Geervani 1987).

Nutritive Value of Chickpea-based Products

In practical dietetics, nutritive value and the availability of dietary constituents are more important in cooked food than in raw foods. The ingredients of dishes that go to make desi and kabuli chickpea products, and the nutrient content of cooked chickpea products are presented in Tables 3 and 4. About 50-75% of the daily calcium requirements of adult males and females can be provided by 100 g of dry chickpea. On a dry-weight basis, 100 g of roasted chickpea and *missi roti* can meet 50-100% of the daily iron (Fe) requirements of an adult male. As Fe-deficiency anemia is a public health problem in Pakistan, the use of chickpea could help to ameliorate iron deficiency in the local population.

Nutritive Value of Chickpea-based Meals

The nutritive value of composite dishes is of great importance, and the nutritional significance of these dishes lies in the frequency with which they are consumed. The composition of some chickpea-based meals commonly used in Pakistan, and their nutrient content

Table 3. Ingredients of some Pakistani chickpea products.

Products	Chickpea Variety	Chickpea Form	Chickpea Mass (g)	Wheat flour (g)	Potato (g)	Fat (g)	Onion (g)	Chilies (g)	Salt (g)	Spices (g)	Sugar (g)
Curry	Kabuli (Cholla)	Whole seed	200	-	-	30	38	3	8	2	-
	Desi (CM 72)	Dhal	140	-	-	16	28	3	8	2	-
Missi roti	Desi (CM 72)	Flour	100	200	-	-	15	10	2	-	-
Pakora	Desi (CM 72)	Flour	200	-	50	250	30	1	9	-	-
Chaat	Kabuli (Cholla)	Whole seed	200	-	50	-	30	1	8	-	-
Halwa	Desi (CM 72)	Flour	200	-	-	110	-	-	-	-	150
Roasted chickpea	Desi (CM 72)	Whole seed	200	-	-	-	-	-	-	-	-

Source : Khan and Jaffery 1989.

Table 4. Nutrient content (dry basis) of some Pakistani chickpea products.

Products	Protein (N x 6.25)	Fat	Carbohydrate	Crude fiber	Ash	Energy [KJ (100 g)$^{-1}$]	Ca	P	Fe	Zn	Mn	Cu
		(g 100 g^{-1})					(mg 100 g^{-1})					
Whole kabuli curry	17.7	12.6	60.9	4.4	4.4	1684	360	315	5.3	3.9	2.6	1.1
Dhal desi	20.3	12.8	60.9	1.6	4.4	1647	226	273	3.9	3.3	2.6	0.7
Missi roti	14.6	3.1	75.9	4.1	2.3	1395	239	284	6.9	4.6	5.4	0.9
Pakoda	17.2	12.4	53.4	11.1	5.9	1898	239	243	7.2	2.5	2.9	0.8
Cham	19.3	5.3	68.2	3.9	3.3	1555	328	279	5.8	3.6	1.6	0.9
Halwa	8.9	21.8	63.7	4.4	1.2	2573	247	126	3.8	1.8	1.5	0.6
Roasted chickpea	21.1	5.0	60.3	10.6	3.0	1513	268	264	8.2	5.4	2.6	1.1

Source : Khan and Jaffery 1989.

Table 5. Composition (g) of some Pakistani chickpea-based meals.

Ingredients	Meals[1] 1	2	3
Wheat flour	120.0	-	-
Rice	-	30.0	-
Chickpea *dhal*	18.0	15.0	-
Chickpea flour *(besan)*	-	-	10.0
Semolina *(suji)*	-	-	20.0
Onion	12.0	-	-
Sugar	-	-	30.0
Vegetable oil	10.0	8.0	12.0

1. Meal 1 = Wheat bread + chickpea *dhal*, 2 = *Kichri*, 3 = *Halwa (suji + besan)*.
Source : Khan and Eggum, 1978, 1979.

are given in Tables 5 and 6. In a well-balanced diet, 10-15% of the total energy requirement is usually derived from protein, 55-70% from carbohydrate, and 20-30% from fat (Passmore and Eastwood 1986). A meal containing wheat bread and chickpea *dhal* can provide 12% of the total calories from protein, 55% from carbohydrate, and 18% from fat (Table 6); while for *kichri,* 10% is derived from protein, 48% from carbohydrate, and 32% from fat. *Halwa* provides 6% of the total calories from protein, 57% from carbohydrate, and 32% from fat. It is evident that the first two meals compare favorably with the characteristics of a well-balanced diet.

True protein digestibility (TD), biological value (BV), net protein utilization (NPU), and net dietary protein calorie % (NDpCal%) of chickpea-based meals are presented in Table 7. The NDpCal% of meals varied between 4.3 and 7.3 (Khan and Eggum 1978b; 1979). According to FAO (1965) the protein allowances in terms of NDpCal% for different age groups are 8.0 for infants, 7.8 for toddlers, 5.9 for children (4-9 years), 8.4 for adolescents, 4.6 for adults, and 9.5 for lactating mothers. When judged in terms of NDp-Cal%, the protein values of a wheat bread and chickpea *dhal* meal, and of *kichri* are only

Table 6. Chemical composition (dry basis) of some chickpea-based Pakistani meals.

Meals	Protein (N x 6.25)	Fat (g 100 g^{-1})	Carbohydrate	Crude fiber	Ash	Energy [KJ (100 g)$^{-1}$]	Ca (mg 100 g^{-1})	P	Fe
Wheat bread + chickpea *dhal*	14.3	9.3	65.0	1.2	2.3	1978	392.0	196.0	7.6
Kichri	11.4	18.6	60.7	1.5	1.7	2137	51.3	184.7	3.5
Halwa suji + Besan	7.0	18.2	71.7	0.9	0.7	2124	32.9	82.1	2.1

Source : Khan and Eggum 1978; 1979.

Table 7. Protein quality (%) of Pakistani chickpea-based meals.

Meals	True digestibility	Biological value	Net protein utilization	Net dietary protein calories
Wheat bread + chickpea *dhal*	92.0	66.0	60.0	7.3
Kichri	92.0	71.0	65.0	6.1
Halwa suji + *Besan*	99.0	75.0	74.0	4.3

Source : Khan and Eggum 1978; 1979.

adequate to meet the protein requirements of children (4-9 years) and adults. Similar results have been reported by Ali and Miller (1963) and Hussain et al. (1981). The NDpCal% of *halwa* is 4.3 and is inadequate to meet protein requirements, but it can be used as a source of energy (Khan and Eggum 1979). Similar results have been reported by Rana et al. (1966). Cereals and legumes will continue to be the major sources of protein and calories in Pakistan and protein needs can be met provided legumes are made available at the required level.

Traditional Uses of Groundnut

Groundnut is widely used in Pakistan in the roasted form as a snack food by all age groups, but more by preschool and school-going children. It is also used in confectionery and baked products.

Over 300 uses of groundnut have been developed, including as food, feed, and in the manufacture of industrial products. These products however have not been popularized because groundnut production in Pakistan is low. Since the entire produce is consumed as roasted nuts, it becomes imperative to determine their nutritional quality.

Nutritive Value of Roasted Groundnuts

The chemical composition, calorific values, and protein quality of some varieties of groundnut grown in Pakistan are given in Table 8. The protein content was highest (30.3%)

Table 8. Nutritive value of roasted groundnuts consumed in Pakistan.

Varieties	Protein	Fat	Fiber	Ash	Energy [KJ (100 g)$^{-1}$]	Ca	P	Fe	Zn	NDpCal
	(g 100 g^{-1})					(mg 100 g^{-1})				
Banki	27.9	46.7	5.0	3.9	2623	55.2	288.2	1.3	4.7	8.5
Hsuji	26.8	48.2	4.9	3.8	2661	64.0	310.9	1.5	4.4	8.6
Kurram	30.3	46.0	4.3	3.3	2657	62.8	348.2	1.4	6.0	8.4

Source : Khalil and Chughtai 1983.
NDpCal % = Net dietary protein calorie percent.

in *kurram.* With respect to the Recommended Dietary Allowances, 100 g of roasted kernels can furnish 7% of calcium, 39% of phosphorus (P), 14% of iron, and 33% of zinc (Rana and Khan 1986). Lysine was the first limiting amino acid in all varieties. The protein value, which is an index of nutritional quality, is a product of both the quantity and the quality of proteins, and is expressed in terms of NDpCal% for roasted groundnut. The NDpCal% values vary between 8.4 and 8.6, and are adequate for all age groups. Groundnut and its derivatives could enter into commercial competition with other oilseeds if production were able to meet the demand.

Future Research Areas

Chickpea

Higher and more stable yields should be the primary objective of chickpea improvement programs. The increase in yield should not be at the expense of acceptability in the marketing system, or of protein or lysine content. The most important factors to breed for are: sulfur amino acids, tryptophan, lysine, protein, large seed size, regular seed shape, low decortication loss, low gasogen (flatus producing substances) content, and resistance to pest infestation during storage.

Economic studies should be carried out on cultural practices, including use of fertilizers, pesticides, and other direct inputs, relative to returns obtained from different legume genotypes grown in different environments and locations. Reassessments will need to be made for new varieties as these are developed. The effect of improved agronomic practices should be more carefully studied, particularly on the vitamin and mineral contents of chickpea seed. Studies concerning the interaction between cultivars and such factors, and their effect on nutritional composition would be desirable.

It is particularly pertinent to study the functional properties and biochemical changes in proteins and carbohydrates induced by cooking, because the digestibility of protein, and the availability of amino acids are low even after cooking. The losses and bioavailability of minerals and vitamins should also be studied. The presence of hemagglutinins, cyanogenic glucosides, estrogenic factors, metal-binding constituents, and toxic amino acids in chickpea also needs to be investigated. The effect of chemical treatments to control insect infestation and microbial growth on nutritional quality should be examined.

Research is needed on storage stability, postharvest technology including processing, food-product development, cooking quality, and consumer acceptance. The processing technologies that are largely traditional, and partially mechanized versions of age-old home-scale techniques, need to be further improved after proper understanding of the principles involved.

Groundnut

More area should be brought under improved technology for groundnut cultivation. Farmers should be encouraged to sow high oil yielding varieties. Breeding efforts should focus on improving the quantity and the quality of oil and meal, and reducing the various anti-nutritional factors. Groundnut can only be crushed for oil in Pakistan if there is a market, and a fair price to the farmers for their crop. Machinery for shelling seed, expelling oil, and processing oilcake should be made easily available. Groundnut seed may be partially defatted to produce kernels high in protein and low in oil content. Such nuts have longer shelf-life and can be processed into a variety of final products by using various additives. The level of aflatoxins in fresh and processed groundnut products should be continuously monitored and methods for detoxification of the contaminated products should be improved.

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Uses of Grain Legumes in Bangladesh

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Abstract. *Among the pulses that are grown in Bangladesh, chickpea is the third important pulse crop after grass pea and lentil. Pulses still provide the only high-protein component in the cereal-based diets of the vast majority of people in Bangladesh. About 10-15% of chickpea whole seed is used in the preparation of* boot birani *while chickpea dhal flour (besan) is used in the preparation of* pianjoo, beguni, chanachur, roti, bundia, *and* halua. *Pigeonpea is a minor legume crop and about 2500 t are produced annually. The crop is entirely consumed in the form of dhal. The young leaves and shoots are used as fodder. The husk and pod walls are used as cattle feed. The stems are used as fuel and many farmers grow pigeonpea primarily for this purpose. Groundnut is the second important oil seed crop. About 90% of groundnut is consumed in the form of nuts and very little used for the extraction of oil. Roasted nut is the major product followed by confectionery items, peanut butter, and other snacks. Puffed and sprouted chickpea, and chickpea based weaning food for children are some of the avenues for potential alternative uses. Groundnut oil, boiled groundnut, groundnut milk, peanut butter are items that could find ready acceptance. There is a need to improve the production of these legumes for increased utilization.*

Introduction

Food legumes, particularly pulses, are important foods in Bangladesh. Pulses have been considered as the cheapest source of protein for human beings since the dawn of civilization (Kay 1979). In fact, they still provide the only high-protein component in the cereal-based diets of the vast majority of people in Bangladesh.

Many pulses are grown and consumed in Bangladesh. These include : grass pea, lentil, chickpea, black gram, mung bean, pea, and pigeonpea. Pulses cover an area of about 0.3 million ha (less than 3% of the total cultivated area) and produce about 0.2 million t of grain (less than *2%* of the total grain production) in the country (Table 1) (Ahmed 1984). There is an acute shortage of pulses; the present per capita availability about 7 g caput^{-1} day^{-1}, is far below the recommended consumption of 60 g caput^{-1} day^{-1}. As a result, the majority of the people suffer from protein malnutrition (BARI 1987).

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Table 1. Area and production of chickpea, groundnut, and pigeonpea in Bangladesh (5 years' average from 1982/83 to 1986/87).

Crop/season	Area ('000 ha)	Production ('000 t)	Yield (t ha^{-1})
Chickpea			
postrainy	55	37	0.67
Groundnut			
postrainy	18	22	1.22
rainy			
Pigeonpea			
rainy	4	2.5	0.63

Source : Bangladesh Bureau of Statistics 1987.

Traditional Uses of Chickpea

Chickpea commonly called *chola,* is the third most important pulse crop, after grass pea and lentil in Bangladesh.

Most of the produce (60-65%) is consumed as *dhal* which is cooked with hot spices and consumed with rice. It is also cooked with meat, eggs, and vegetables, and consumed as curry with rice, *chapati,* or *parota.* Sometimes, *dhal* is mixed with rice and cooked to make *khichuri,* which is consumed as a main dish with egg, or meat curry.

Whole seeds are rinsed with salt water and roasted with small quantities of turmeric paste, on hot sand, and eaten as a snack. Whole seeds are also soaked in water overnight, boiled, and fried with oil, using salt, onions and chilies. About 10-15% of chickpea grain is used for this preparation, called *boot birani.*

Dhal is ground to make flour, called *besan,* and used in the preparation of several hot snacks, such as *pianjoo, beguni, chanachur,* and a sweet snack, called *bundia. Pianjoo* is prepared by mixing *besan* paste with sliced onion, salt, and other spices, and deep frying in oil. *Beguni* is prepared by applying *besan* paste to sliced eggplant, and frying it in oil. To prepare *chanachur, besan* paste is fried in oil as flakes, and mixed with roasted groundnut, mung bean, and lentil seed. To prepare *bundia, besan* is mixed with wheat flour, formed into small balls fried in oil, and then soaked in a thick sugar solution.

Another sweet snack called *halva,* is prepared from dehulled seeds, which are soaked overnight, boiled, and then made into paste. The paste is cooked with sugar, butter or oil, and aromatic spices. About 10-15% of the total produce is used to make *halva.*

In some parts of Bangladesh, chickpea flour is mixed with wheat flour to make *chapati* a common food of Bangladesh. Chickpea flour made from sand-roasted grain, called *chhatu* is also consumed after mixing with molasses. About 1-2% of chickpea seed is used for this purpose. In some places, tender leaves are used as a vegetable. About (10-12%) of total production is used for seed.

Dried and broken stems and pod hulls left after threshing, and the seed coat that remains after *dhal* milling, are used as cattle feed. Whole grains are soaked overnight and fed to horses.

Traditional Uses of Pigeonpea

Pigeonpea, commonly called *arhar,* is a minor grain legume crop in Bangladesh. It is grown on about 4 000 h, and produces about 2 500 t of grain annually. As a field crop it is grown only in small areas, and around homesteads, on field bunds, or as hedges. Pigeonpea is a very long-duration crop, taking around 300 days to mature, and its yield potential is low. The uses of pigeonpea in Bangladesh can be summarised as follows.

- The entire produce of pigeonpea seed—except the amount required for seed—is consumed as cooked *dhal.*
- The young leaves and shoots are used as fodder. The husk and pod walls are used as cattle feed.
- The stems are widely used as fuel by the majority of the rural people. Many farmers cultivate pigeonpea primarily for use as fuel.

Traditional Uses of Groundnut

Groundnut, commonly known as *China badam,* ranks third in area (18 000 ha), second in production (22 000 t), and first in yield (1.22 t ha^{-1}) among the oilseed crops of Bangladesh. It is cultivated in both the rainy and postrainy seasons. Although groundnut is considered an oilseed crop, 90% of output in Bangladesh is consumed as nuts, and no oil is extracted from it.

Groundnut is very popular in Bangladesh for its many uses. About 60% of the total produce is directly consumed as roasted nuts, 20% is used to make different confectionery items, 10% is used to prepare peanut butter, home-made sweets, and snacks; and the remaining 10% of the produce is used as seed.

Alternative Uses of Chickpea and Groundnut

There are many potential alternative uses of chickpea and groundnut in Bangladesh. The mechanization of processing chickpea- and groundnut-based food products will go a long way to improve their nutritional quality and taste, and will popularize different food products (Saxena and Singh 1987). The cereal-based low-protein diets of the people of Bangladesh could be supplemented with low-cost chickpea protein used in combination with cereals. For example, weaning food for children, aged about 5-6 months, could be prepared using chickpea flour in combination with wheat, soybean, groundnut flour, or skim milk powder. Puffed chickpea seeds mixed with salt and chili powder is a popular snack food in Bangladesh, made at present with imported kabuli type chickpea. Sprouted chickpea seed is becoming popular in Bangladesh.

Groundnut oil, milk, and butter, boiled fresh groundnut, and groundnut-enriched bread could find ready acceptance in Bangladesh, if they were be made available at an affordable price (Kaul and Das 1986).

Legumes play a vital role in the economy of Bangladesh by supplying vegetable protein to human diets, and nutritious feed to livestock. They improve the productivity of the soil through fixing atmospheric nitrogen. However, before the potential alternative uses of chickpea, pigeonpea, and groundnut in Bangladesh can be explored or exploited, more emphasis should be placed on increasing the production levels of these crops.

Further research efforts are required to determine and improve the nutritional quality of the traditional food items that incorporate grain legumes, and to find suitable alternative uses for them as substitutes for animal protein, to provide cheaper balanced diets in Bangladesh.

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Discussions

- The area under chickpea cultivation has increased substantially in Australia, Turkey, and Spain. The influence of salt-laden winds on the physiology of chickpea grown in the coastal areas of Myanmar (Burma) needs to be explored.
- It is essential to have reliable, rapid, simple, and nondestructive techniques to assess the heritability of quality traits.
- Chickpea protein is important in the diets of people in many countries. The protein is highly variable as it is influenced by several factors such as soil type, environment, irrigation, fertilizer application, etc., though it was reported to be less affected by these factors in Lebanon and Syria. To produce chickpea of stable protein content, the above conditions may sometimes have to be controlled. There is no correlation between improvement in protein content and the loss in the quality of protein, such as that incurred by a decrease in lysine.
- Cooking time is important but is highly variable, and has economic implications.
- The reasons for uncookable seed (stony) characteristics are not well understood, but are of minor consequence in chickpea. Hydration (water absorption) is related to cooking time. Seed size is also related to cooking time and considered an important and practical selection criterion in breeding programs.
- The processing quality of chickpea is important, and is related to pericarp thickness and cotyledon hardness that are influenced by the environment. The heritability of these two characteristics has yet to be established. A compromise has to be reached on yield versus grain quality when a desired quality characteristic is incorporated. The heritability of grain quality factors should be better understood. Farmer and consumer preferences should be considered.
- The amount of chickpea used in puffing (parching) and the quality characteristics of desi and kabuli types that are related to puffing need to be studied.
- In chickpea food processing, it is essential to determine the role of such different functional properties as water absorption, oil retention, and shelf-life. Efforts should be concentrated on identifying regional usage and the associated functional properties. These functional properties should then be translated into different grain quality traits and the feasibility of breeding for such traits should be explored.
- It was noted that producers in Syria take great care to maintain the quality of chickpea products such as *qadami safra.*
- A small portion of chickpea produced in Turkey is used to prepare a glue-like substance used in the plywood industry and as a soup-thickener.
- Supplementing traditional foods with chickpea in the form of whole seed, *dhal,* or flour greatly improves their nutritive and biological value, which should be evaluated with all new formulations using chickpea.
- The keeping quality of chickpea flour influences its consumption, and is determined by its fat content, and the environment in which it is stored.
- Attempts should be made to understand and improve the traditional systems that are used to make food products; where commercial methods could simplify the process, these should be encouraged. While evolving new processing methods and food products

for various regions, the role of cultural practices and traditions of the region must be well integrated if products are to be accepted by consumers.

- Subjective evaluations have more influence on quality of processes and products than objective evaluations, and often determine their acceptance. Therefore, efforts should be made to translate subjective evaluations into objective traits.
- Major contributions to improving quality aspects may be achieved by genetic engineering even though this is still in its infancy.
- There is a strong need to find alternative uses for chickpea. Increasing production of chickpea itself is very important; since chickpea can only be considered as an animal feed when the production exceeds its demand for human consumption.

Recommendations

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- review existing knowledge on uses of (in this case) chickpea,
- identify areas for further study,
- research ideas to provide new end uses,
- identify areas for collaborative research, and
- identify training needs

Review Existing Knowledge on Uses of Chickpea

This was considered from two aspects; the composition approach, and the survey approach.

Composition approach. This was discussed in the light of documented data concerning the constitution of the chickpea, and of the influences of primary and secondary processing practices on the composition.

The deliberations are summarized in Table 1. Check marks indicate areas where it was felt that knowledge was adequate to predict the influences of the various parameters on composition. It was apparent that our knowledge on the influences of procedures such as fermentation and frying, and the interrelationships between parameters such as fiber content and viscosity is inconclusive or completely absent. Practically no knowledge is documented on the influences of parameters such as fiber content or starch gelatinization pattern on the taste or texture of popular foods. The difficulties of the breeder in enhancing nutritional quality of chickpea-based food that is acceptable to consumers were discussed.

Needs for improvement in the level of knowledge of the above factors were identified as follows:

- Develop reliable test methods.
- Determine range and standard deviation of a representatively large population of genotypes grown in the same location.
- Determine heritability, using a statistically sufficient number of genotypes.
- Determine environmental effects (location and season).
- Develop network of testing laboratories which agree with each other within reasonable limits.

Table 1. Summary of current knowledge on chickpea consumption.

Constituent/ parameter	Primary processing[1]	Secondary processing[2]	Physical/ physicochemical[3]
Protein	* * *	* * *	*
Starch	* * *		
Fiber			
Oil			
Sugars	* * *		
Oligosaccharides	* * *		
Polyphenols	* * *		
Hemagglutinins			
Trypsin inhibitors			
Amylase inhibitors		**	
Phytate	* * *		
Metals			
Chemical residues			
Lysine			
Methionine			
Tryptophan			

1. Dehull, mill, grind, sprout, ferment, puff.
2. Soak, boil, roast, fry, bake.
3. Seed size, color, seed coat, viscosity, hydration capacity.

Survey approach. Since the primary objectives of the meeting concerned future uses of three food legumes, it was felt that it would be very helpful to first find out more about what consumers like or dislike about present foods and the raw materials used in their preparation. A consumer can be described as someone who acquires a commodity or product and disposes of it as a finished product. Primary consumers acquire raw materials as grain, and process them into secondary raw materials, such as *dhal* or *besan.* Secondary consumers acquire partially processed raw materials from primary processors, and dispose of them as foods. Tertiary or "final" consumers acquire foods from primary or secondary consumers and eat them. At all three levels, consumers have individual preferences; however, a survey of a sufficiently representative number of consumers should lead to a consensus on some aspects. It is likely that the aspects upon which most consumers would agree would be the most important aspects. Steps necessary to conduct the survey were identified.

- Develop questionnaires (three; representing primary, secondary and final consumers).
- Identify scrutineers (people to carry out the survey).
- Organize format and methods.
- Organize reporting.
- Organize financing: (transport, daily expenses, supplies, printing, sample bags, etc.).

The following factors should be covered in the questionnaires.
- Quantities acquired, physical form, price etc.
- Primary and secondary processing methods, recipes, etc.

- Attractive features, appearance, taste, texture, industrial processing potential (part of the survey of consumers could involve showing the industrial primary consumer samples of chickpea of different sizes, shapes, uniformity, color, etc. and asking for their preferences, with reasons), etc.
- Raw materials and ingredients, including spices.
- Other foods that are consumed along with chickpea-based foods.

On the subject of new foods it was felt that it was not the mandate of an international center to develop new types of food, and that new foods were more likely to happen as a result of industrial involvement. The consumer survey may reveal several home-made foods with a high degree of acceptability, which are not commercially available. It would then be possible for an institution such as a university or research institution with a food technology facility to develop the recipes and processes for their commercial exploitation. Industry-scale development, and introduction through advertising and provision of samples could then lead to the development of new foods. Surveys of rural dwellers, for example, may reveal food that city dwellers have not encountered, but which may receive great acclaim. Any new food would require both compositional and nutritional evaluation.

Identify Areas for Further Study

1. Alternative industrial uses of chickpea, including individual constituents:

- starch (possible use in paper industry, etc),
- cell wall fiber (this constituent of field pea is in high demand in western-style baking industries),
- gums,
- seed coat (abrasive, stuffing material, etc), and
- protein (production of textured vegetable protein products, etc).

2. Development of alternative types of foods:

- baby and weaning foods,
- domestic animal food concentrates,
- chickpea milk,
- therapeutic uses,
- soups and thickeners,
- pet foods, and
- others.

3. Standardization of methods for testing composition, nutritional and functional properties of chickpea. It is essential to have agreement among scientists and centers as to the properties of chickpea genotypes and foods made from them.

4. Effects on storage on compositional, nutritional, physical and functional properties of chickpea. This includes length of storage, storage conditions (temperature, humidity, baro-

metric pressure, atmospheric composition, etc), and containers (plastic or fiber bags, metal or plastic containers, etc.)

5. Economics of production and use of new products. The development of a new food product or the use of a legume by the food-processing industry has to be studied from all aspects to ensure improvement of the economic status of all involved in chickpea production and utilization.

6. Legislation of new product development. A new product has to conform to government regulations on composition, length of time between production and utilization, packaging, advertising, etc.

7. Development of cultivars with better dehulling properties. The group felt that research should be directed toward improving the dehulling properties of chickpea. This would involve study of:

- Seed coat composition and thickness
- seed morphology and histology, and
- dehulling equipment in *dhal* mills, with possible extension to development or adaptation of laboratory-scale dehulling equipment. This could eventually lead to improvements in the efficiency of dehulling/splitting of chickpea for use by agro-industries.

8. Further research on cooking properties needs to concentrate on:

- *besan* and other flours,
- hydration and fat absorption capacities,
- amylose:amylopectin ratio, and
- other parameters

Identify Areas for Collaborative Research

Four areas for possible collaborative research were identified:

1. Food utilization and acceptability survey (described above). This survey should be as comprehensive as possible, and could involve international centers, universities, government institutions, and the larger food processing corporations. It should be coordinated from ICRISAT, since chickpea finds extensive use in the Indian subcontinent.

2. Standardization of methods. A manual should be prepared and circulated for comment to research centers in countries where chickpea is used. It can then be finalized and used as a reference manual for all institutions involved in analysis and evaluation of chickpea.

3. Collaborative evaluation of varieties and environmental effects.

4. Establishment of reference sample system. This would include provision of samples, and circulated reports on results, to evaluate inter-laboratory agreement.

It was felt that the development of a network of laboratories working together in these four areas would be very beneficial to all aspects of chickpea utilization.

Identify Training Needs

The group considered that scientists, research associates, research assistants and technicians could benefit from training in the following areas:

- laboratory methods for determination of composition, and evaluation methods,
- acceptability parameters,
- short-term (early generation) and long-term (advanced material) evaluation of chickpea genotypes,
- use of laboratory equipment; this would involve funding of laboratory equipment for training purposes in many institutions in developing countries,
- use of computers in data processing and report development, and
- pilot chickpea processing and food preparation plant.

The training itself would involve:

- training sessions at institutions with well-established laboratory facilities,
- preparation of comprehensive manuals,
- intensive hands-on workshops for small groups of trainees, and
- follow-up training by exchange of samples and data.

Session III

Production Aspects of Pigeonpea and Future Prospects

Laxman Singh[1]

Abstract. *The current production of pigeonpea in the semi-arid tropics is principally confined to the Indian subcontinent (particularly India and Myanmar), eastern and southern Africa, and the Caribbean. Except in Australia where extensive commercial production has recently been catalyzed, the cultivation of pigeonpea is practiced by small farmers to meet domestic needs for food (as dry grain, split* dhal, *and green vegetable), and for animal feed and fuel wood; to produce a marketable surplus for cash income, and to form an important component of intercropping in cereal-based production systems for sustainability, and risk aversion.*

The production is constrained by the current cultivation practices; less productive land-resource allocation, excess water or drought stress peculiar to rainfed agriculture, and losses caused by diseases and pests, and long-duration cultivars of 160-250 days. Other problems are; inadequate support for technology generation and its transfer, the lack of stress-resistant, high-yielding genotypes, agronomic management, new production systems, and lack of utilization research and promotion, both of processed and raw material, for human and animal consumption.

The future prospects for enhanced and sustained production are bright, in that new short-duration cultivars (90-130 days) make pigeonpea amenable to field-scale cultivation as a sole crop in several production systems involving multiple cropping, both under rainfed and irrigated farming systems. New genotypes in the long-duration group with stable resistances to major diseases (fusarium wilt and sterility mosaic disease) are available. They will contribute to the improvement of the traditional intercropping or mixed cropping production system of annual crops, and short-lived perennial to alley and agroforestry systems. However, instability of production under rainfed conditions caused by excess or reduced rainfall, and diseases and pests, still remain major issues for research in the short-duration group of cultivars.

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The potential exists to new niches of production systems using short-duration cultivars, provided simultaneous research and development are carried out for appropriate utilization. A quantum jump in productivity could be achieved by using hybrid pigeonpea, new dwarf plant types, biotechnology techniques for introgressing incompatible wild species for germplasm development, and new sources of tolerances to abiotic stresses (drought and salinity), and biotic stresses (insect pests and diseases).

Introduction

The pigeonpea is a member of the subtribe *Cajaninae,* tribe *Phaseoleae,* and family *Leguminosae.* Although it is often stated to be a monotypic genus, van der Maesen (1986) proposed merging of the related species of genus *Atylosia,* whereby *Cajanus* now numbers 32 species. According to him, the Indian subcontinent contains 17 species, Australia 13 species, and New Guinea and West Africa one species each.

Van der Maesen (1980) concluded that evidence points to an Indian origin of the pigeonpea, from where it was most probably distributed to Africa, by two millenia BC at the latest. He also suggested that Africa is a secondary center of origin.

Pigeonpea is inherently a perennial, erect, bushy plant. However, it is also cultivated as an annual crop, with a range of maturity duration from 90 to 250 days. It can grow over 3 m tall, has woody stems, and a long tap root. Plant type and growth habit exhibit wide variation. The angle of primary branches determine the spread of the plant, varying from compact types with acute branch angle, to open types with obtuse branches. The leaves are trifoliate, having lanceolate to elliptic leaflets that are acute at both the ends. The inflorescence is an axillary raceme, varying in length from 4 to 12 cm. The dry seeds vary greatly with respect to their size (100-seed mass 2-24 g), shape (round, oval, or flattened), and color (white, brown, red, purple, or black). The seed coat is smooth, and the cotyledons are light yellow. In general, there is no seed dormancy, and germination is hypogeal.

Pigeonpea is a quantitative short-day plant. Because of its sensitivity to photoperiod and temperature interactions, sowing time and location influence both plant growth and phenology. Short-duration pigeonpea cultivars are less sensitive to changes in daylength than medium- and long-duration ones.

Production and Uses

Pigeonpea grows well in subtropical and tropical environments, extending between latitudes 30°S to 30°N, at elevations from sea level to 2000 m. India accounts for more than 90% of the world's pigeonpea production and area (Table 1). Other major producing countries are Kenya, Uganda, Malawi, Myanmar, Tanzania, Puerto Rico, the Dominican Republic, Venezuela, and the Caribbean islands. Area and production figures are often underestimated because a considerable amount of the crop is grown on homesteads, borders, and hedges, and consumed in rural households as dry grain and green peas. Although little of the crop enters world trade, pigeonpea is the fifth most important pulse crop in the world after bean, pea, chickpea, and broad bean.

Table 1. World area (ha), production ('000 t), and yield (kg ha^{-1}) of pigeonpea[1].

Countries	1980 Area (ha)	1980 Production ('000 t)	1980 Yield (kg ha^{-1})	1987 Area (ha)	1987 Production ('000 t)	1987 Yield (kg ha^{-1})
Bahamas	420 F[2]	520 F	1 238	510F	660 F	1 294
Bangladesh	3 737	2 780	744	2 500	2000	800
Dominican Republic	14915	10 331	693	11 769	10 966	932
Grenada	500 F	901	1 802	420 F	630 F	1500
Haiti	8 500F	4000F	471	8600F	4400F	512
India	2 731 000	1 757 000	643	3 235 700	2 316 300	716
Jamaica	2 462	2 351	955	1 971	1 813	920
Malawi	125 000 F	84 000 F	672	134 000F	90 000F	672
Myanmar	31 277	20 520	656	53 612	36 014	672
Nepal	16 400 F	9000F	549	22 800 F	12 400F	544
Pakistan	2 800 F	1 500 F	536	2 200F	1000F	455
Panama	2100F	2004	954	2900F	2 500F	862
Puerto Rico	6 485	5 216	804	5 100F	3400F	667
Tanzania	36 000F	22 000 F	611	63 000F	40 000F	635
Trinidad and Tobago	1 750 F	3 532	2018	950 F	1 300 F	1368
Uganda	50 000	26 000	520	54 520	24 950	458
Venezuela	6 624	3 447	520	8 900	5 200	584
World total	3 039 970	1 955 102	643	3 609 452	2 553 533	707

1. Estimates for Kenya not available.
2. F = FAO estimates.
Source: Personal communication by Dr E.A. Kueneman, FAO, Rome.

The crop is most commonly grown for its dry, split seeds *(dhal)*, but seeds are also eaten as a green vegetable. In the Caribbean islands (particularly the Dominican Republic and Puerto Rico) the crop is grown primarily for export, and canned green seeds are exported to North America.

Dry seeds and the by-products of *dhal* manufacture, together with leaf and pod residues after harvest, can provide suitable feed for ruminants, which may also browse the standing crop (Whiteman and Norton 1981). Grain, whole pods, and milling trash, suitably processed and mixed with additives, have been proposed as substitutes for soybean and maize in poultry and pig feed (Wallis et al. 1986).

Dry stems of pigeonpea are an important source of fuel in rural India. Average stick yields of 7-10 dry t ha^{-1} are routinely reported, and yields of 20 t ha^{-1} from irrigated, short-duration varieties have been reported (ICRISAT 1986). Dry-stem material of pigeonpea is also used for fencing, the construction of thatch roofs, and basket making. In some semi-arid regions of northern India (Haryana), farmers pay half the wages in the form of dried threshed stems for harvesting, threshing, and bagging pigeonpea seed.

The pigeonpea plant is also used as a host plant to rear lac insects. If pruned to prevent flowering, the plants can be maintained as lac hosts for several years.

Cropping Systems

Intercropping

The prevalent production systems for pigeonpea are based on medium- to long-duration (160-250 days) types, and virtual shortlived perennial types. In rainfed agriculture, these cultivars are adapted as components of mixed-cropping or intercropping systems with such crops as sorghum, millets, maize, cotton, upland rice, groundnut, soybean, and root crops. These are proven systems used to maximize stability of agricultural production in central and peninsular India (Rao and Willey 1980). Dryland agriculture is characterized by high variability in the incidence of rainfall; for subsistance farmers at least, stability of production over seasons is a more important consideration than simply pursuing high yields. The characteristics, advantages, and disadvantages of this system are discussed by Willey (1985). Rao and Willey (1980) found a 1:1 or 2:1 proportion of sorghum:pigeonpea in an intercrop quite an efficient system in India, and Kannaiyan et al. (1986) reported maize/ pigeonpea intercropping to be a productive system in Zambia. The range of cropping systems involving pigeonpea in India has been summarized by Singh (1980).

The productivity of medium- and long-duration pigeonpeas in the cropping systems mentioned above is not only constrained by high variability of moisture availability in rainfed agriculture (waterlogging, intermittent, and terminal drought), but also by other biotic and abiotic stresses. The biotic stresses of diseases, primarily fusarium wilt and sterility mosaic, localized diseases (witches'-broom, alternaria blight, phytophthora blight, dry root rot, and collar rot) and of pests (primarily the pod borer and the podfly and localized sporadic infestations by blister beetles, and pod-sucking bugs) also pose severe constraints to yield.

Short-duration pigeonpeas, just as medium- and long-duration ones can also be intercropped with short-statured grain legumes such as mung bean, urd bean, cowpea, soybean, and groundnut.

The Postrainy-season Crop

In areas where total annual rainfall is > 1000 mm, with wider seasonal distribution of rainfall (e.g., with bimodal distribution), moderate to warm winter temperatures 25-35°C, and deep, moisture-retentive soils, it is possible to sow pigeonpea well after the longest day. This even further widens the flexibility of pigeonpea in being able to fit into various cropping systems. In northeastern India (Bihar and West Bengal) Roy Sharma et al. (1981) and Sengupta (1982) reported 2-3 t ha^{-1} yields of pigeonpea from Sep-Oct sowings. There is a large potential for growing pigeonpea in rice fallows, considering the area of such land in India, Bangladesh, Myanmar, Sri Lanka, the Philippines, and Thailand.

The Multipurpose Perennial

The multiplicity of uses and perenniality of pigeonpea makes it a good choice for agroforestry systems, as an alley crop, as an intercrop in tree plantations of coconut, rubber, oil palm, or forest trees, and in resting shifting-cultivation lands. Pigeonpea is widely used as a backyard or garden crop, particularly in Africa and the Caribbean, and also in parts of India and Southeast Asia. Such plants are simultaneously used for their dry grain, and green seeds, and as fodder, construction material, and fuelwood. It is difficult to quantify production in such systems in comparison to field-scale commercial cropping.

Combined resistance to fusarium wilt and sterility mosaic diseases have now been identified in medium- and long-duration pigeonpea with excellent agronomic traits. These cultivars can be grown as perennials for 3-4 years. However, in some regions, diseases, e.g., rhizoctonia root rot, and attack by white ants also constrain perennial pigeonpea production.

Future Prospects

Intensive research efforts on pigeonpea improvement, begun in the early 1970s, have resulted in the development of short-duration genotypes, rendering pigeonpea amenable to field-scale cultivation as a monocrop. Short-duration genotypes permit the use of pigeonpea in double- or multiple-cropping systems, as distinct from their traditional use as a long-season crop. Such cultivars (ICPL 151, Manak, AL 15, UPAS 120) have been adopted in pigeonpea-wheat rotations in wheat-growing regions of India; the pigeonpea is grown during the monsoon period and harvested by November, in time to sow the winter cereal crop.

Being less sensitive to photoperiod and temperature interactions, extra-short-duration genotypes (maturing in 90 days at ICRISAT Center) have the potential to extend the area of adoption of pigeonpea from the equator to 45° latitudes N and S, and higher altitudes. In Sri Lanka in South Asia, and in Trinidad in the Caribbean (both at latitude 8°N), short-duration pigeonpea, when grown at any time of the year, can be harvested for mature pods in 100-120 days, and can also be used for multiple pickings of green vegetable pods or ratooned for multiple dry-grain harvests. The use of short-duration pigeonpea thus ensures that in several regions, vegetable pigeonpea is available all through the year.

In environments with warm winters (minimum temperatures >15°C) in peninsular India, the perennial characteristics of short-duration pigeonpea were exploited by ratooning. Chauhan et al. (1987) reported that this system gives much higher yields than the traditional medium-duration genotypes grown in this environment over a similar time period. A short-duration cultivar, ICPL 87, with good ratoonability was released in India in 1986, and is becoming increasingly popular with farmers.

Short-duration and short-statured (1.0 to 1.5 m) pigeonpea are amenable to mechanization, which had been a goal of pigeonpea research in Australia (Wallis et al. 1981). The potential to mechanize is also an important consideration in the improvement of traditional agricultural systems in Africa and the Caribbean. In India, farmers in addition to using animal power for cultivating short-duration pigeonpea have increased usage of threshers, hitherto not used for traditional long-season types.

With the availability of shorter-duration genotypes (< 100 days at latitude 17°N, ICRISAT Center) there is scope for extending pigeonpea to drier environments in the subtropics, to temperate climates up to 45° latitudes N and S, and higher altitudes, where they reach maturity before the onset of severe drought stress and killing frosts. Breeding and selection at ICRISAT Center of short-duration genotypes with large, white seeds, and large pods have also provided options for their use as vegetable types (Jain et al. 1981), provided problems inherent in such a system e.g., those posed by insect pests could be overcome. This could facilitate development of facilities to process and can vegetable pigeonpea, as a viable option in more tropical environments where garden pea does not grow well. A determinate plant type with synchrony of bearing has advantages for a mechanized production system, while either determinate or indeterminate types with good ratoonability would be suitable for multiple harvesting in small-farm fresh vegetable production systems.

Identification of genetic male sterility, and ICRISAT's studies on the utilization of hybrid vigor have led to the development of short-duration pigeonpea hybrids, which exhibit considerable heterosis in seed yield over their parents and other control cultivars. A private seed organization is marketing a medium-duration pigeonpea hybrid in India, and several private seed companies are now using genetic male sterile sources developed by ICRISAT for hybrid pigeonpea production. Its future seems promising.

To provide stability of production in both long- and short-duration pigeonpea, genetic resistances to major diseases (single and multiple resistances) have been incorporated in improved cultivars. This development is particularly important in enhancing and sustaining the productivity of traditional and new production systems. Recommended for cultivation are such lines as ICP 9145, a wilt-resistant long-duration type in Malawi; and ICP 8863, a medium-duration wilt-resistant type in Karnataka, India. ICPL 366, a long-duration sterility mosaic disease resistant line is being tested in farmers' fields in Nepal.

Tolerance, or reduced susceptibility to pod borer have been sought by entomologists and breeders at ICRISAT; we now have medium-duration pigeonpeas-ICPL 87088 and ICPL 84060, with considerable field tolerance to this pest. This is a significant development for stability and productivity of long-duration pigeonpea that is usually not protected by insecticidal sprays. Entomologists have also developed procedures and schedules for the judicious use of insecticides to protect short-duration pigeonpea. Research is being conducted on integrated pest management, which is vital for the future prospects of pigeonpea.

The transfer of available technology (on utilization and crop improvement aspects) will be faster if efforts for enhanced production are closely linked with the promotion of multiple uses, linking production with market demand and the requirements of agroprocessing industries. Such integrated research and developmental efforts will catalyze global commercial production of pigeonpea for use as vegetable, grain, fodder, and fuelwood.

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The Role of Pigeonpea in Human Nutrition

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Abstract. *Pigeonpea is used in various human foods in several developing countries, particularly in India as a source of dietary protein,. Like other food crops, the nutritional potential of pigeonpea as a human food is primarily determined by its chemical composition, bioavailability of nutrients, and the levels of various antinutritional factors. Proteins and carbohydrates are the principal constituents of pigeonpea seeds, and a variety of factors influence the nutritive value of these constituents. At ICRISAT, high protein lines of pigeonpea are available, and these lines are nutritionally better than the commonly grown cultivars. Pigeonpea seed contains noticeable amounts of antinutritional factors, such as protease inhibitors, oligosaccharides, and polyphenols, hut these constituents can be wholly or partially removed by suitable processing methods. Globulins that are deficient in sulphur amino acids, methionine and cystine, constitute nearly 65% of the total seed proteins of pigeonpea, and hence play an important role in determining its protein quality.*

India accounts for about 80% of the total world pigeonpea production. For human consumption a large proportion of this produce is dehulled to convert whole seed into dhal. *Quantitative and qualitative nutritional losses occur during dehulling. Cooking of* dhal *and whole seed affects the palatability and bioavailability of nutrients. Various physico-chemical characteristics and environmental factors affect cooking quality. Traditional processing practices used to convert pigeonpea into consumable forms include soaking, fermentation, boiling, roasting, frying, and steaming, and all these practices influence nutritive value.*

Developing green seeds are consumed as a vegetable. Their nutritional composition is better than that of mature seed, as their protein and starch are more digestible, and they contain lower amounts of protease inhibitors, polyphenols, and the flatulence-causing sugars; raffinose, stachyose, and verbascose.

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Introduction

Grain legumes are traditionally consumed as human foods, along with cereals in various forms. Among food crops, legumes contain the highest amount of protein, generally twice the level found in cereal grains. Grain legume proteins are rich sources of lysine, but are usually deficient in sulfur-containing amino acids, methionine, and cystine. Cereal-grain proteins are low in lysine, but have adequate amounts of sulfur amino acids. Therefore, the supplementation of cereals with legumes has been advocated as a way of combating protein-calorie malnutrition problems in developing countries.

Pigeonpea is an important grain legume commonly grown and consumed in tropical and subtropical regions of the world. India accounts for over 80% of the world's supply of pigeonpea (ICRISAT 1986). Other countries where pigeonpea is an important food legume are Sri Lanka, Myanmar, the Philippines, Indonesia, Kenya, Malawi, Tanzania, and some Caribbean countries. In India, pigeonpea is processed into *dhal,* which is consumed after cooking in water to a desirable softness, but in some African countries, whole pigeonpea seeds are consumed after boiling. The developing green seeds shelled out of harvested green pods are also used as a vegetable in India, and in some African, Latin American, Caribbean, and Asian countries. This paper describes various aspects of the nutritional quality of pigeonpea for use as a human food.

Chemical Composition

Pigeonpea cotyledons constitute about 85% of total seed mass. The embryo contributes only 1% to the total seed mass and the seed coat, 14% (Singh and Jambunathan 1982). Therefore, the chemical composition of the cotyledons greatly influence the nutritive value of whole pigeonpea seed. Pigeonpea cultivars are broadly classified into three groups: early (90-150 days), medium (150-180 days), and late (180-200 days), based on their maturity durations. The starch content of pigeonpea cultivars belonging to different maturity groups ranged between 50.6% and 57.6%, with the mean being 55.0% (Singh et al. 1984a). This study also showed that seasons did not have a large effect on pigeonpea starch and protein contents. Pigeonpea contains considerable amounts of unavailable carbohydrates that are known to reduce the bioavailability of some nutrients (Kamath and Belavady 1980). Crude fiber, ash, and fat contents of various cultivars did not show wide variation (Singh et al. 1984a). Differences in the mineral composition of whole grain and *dhal* were marginal, except for calcium (Sankar Rao and Deosthale 1981).

Nutritional Quality of Vegetable Pigeonpeas

For use as a vegetable, pigeonpea is normally picked when the seeds reach physiological maturity, i.e., when they are fully grown, but just before they lose their green color (Faris et al. 1987). At this stage, the green seed is more nutritious than the dry seed because it contains more protein, sugar, and fat than the mature seed. In addition, the protein and starch digestibility of green seed is better than that of the mature seed. The green seed also contains lower quantities of flatulence-causing sugars, and trypsin and amylase inhibitors (Singh et al. 1984b). Green pigeonpea is a good source of iron (Singh et al. 1984c). Further, these studies reported that since the mature seed of pigeonpea is normally eaten after the removal of its seed coat which provides about 70% of the total seed calcium, green seed, which is normally eaten with its testa, can provide a very good source of calcium. However, it is important to study the bioavailability of dietary nutrients of green pigeonpea seed to determine their nutritional impact on the human diet.

Protein Quality

The protein quality of pigeonpea is primarily expressed in terms of its protein content, the levels of amino acids, and protein digestibility (Singh and Eggum 1984). In most food crops, genetic variability for protein content is considered an important factor for improving protein quality by selection and breeding. The protein content of *dhal* samples of cultivated and wild species of pigeonpea varies widely. At ICRISAT Center, efforts have been made to use genetic variability to improve the protein content in pigeonpea, and high-protein lines with acceptable seed size have been developed (Saxena et al. 1987). However, environment and agronomic practices influence the protein quality of pigeonpea to a considerable extent, and this should be noted while breeding for protein quality.

The sulfur amino acids, methionine and cystine, are the most limiting amino acids of legumes, and very low values for these amino acids were reported in pigeonpea (Eggum and Beames 1983). In legumes negative relationships are usually found between protein percentage and methionine content per unit of protein (Bliss and Hall 1977). However, there was no strong relationship between methionine (g 100 g^{-1} protein) and protein (%) in pigeonpea, indicating that both protein and methionine could be improved (Singh and Eggum 1984). The effect of cooking on protein quality, in terms of amino acids and bioavailability of legume proteins, is important. A slight reduction in lysine content was observed as a result of cooking (Singh et al. 1990). Seed protein fractions play an important role in determining the overall amino acid composition of seed proteins. As in the case of other legumes, storage proteins and globulins constitute about 65% of the total seed protein of pigeonpea (Singh and Jambunathan 1982). Further, the globulin proteins are deficient in sulfur amino acids. Although present in a small proportion, albumin fractions, are a very rich source of methionine and cystine. Glutelin fraction is also a better source of sulfur amino acids than globulin, and hence may be nutritionally desirable.

Protein bioavailability is of increasing interest in grain legumes in general, and in pigeonpea in particular. For this purpose, the biological evaluation of seed protein is essential, as chemical analysis does not always reveal how much of a protein is biologically available. Unfortunately, pigeonpea has the lowest biological value among legumes (Eggum and Beames 1983). Biological value, protein digestibility, net protein utilization, and utilizable protein of cooked whole seed and *dhal* samples of high protein (HP) and normal protein (NP) genotypes of pigeonpea have been reported (Singh et al. 1990). Criteria based on these characteristics have been suggested as useful for evaluating the protein quality of cereals and legumes, and are commonly followed, because human feeding trials are always difficult and time consuming.

True protein digestibility (TD) significantly increased with cooking, and the effect was more pronounced in whole seed than in *dhal* samples. Interestingly, the biological value (BV) of the cooked sample decreased in both whole seed and *dhal*, whereas net protein utilization (NPU) of the cooked samples increased, possibly due to an increase in protein digestibility. A decrease in the BV of cooked samples, of both whole seed and *dhal* might be attributed to heat treatment, which causes considerable nutritional damage to methionine, the most important amino acid in grain legumes (Shemer and Perkins 1975). A comparison of TD of whole seed and *dhal* samples of these genotypes indicated large differences. Average TD was about 60% for whole seed, whereas it increased to over 70% in *dhal* samples. A reduction in TD of whole seed may be due to higher concentration of polyphenols and fiber content, as a majority of these compounds are concentrated in the seed coat. Although TD, BV, and NPU values have shown differences among genotypes, no noticeable differences in the protein-quality attributes of high protein (HP) and normal protein (NP) genotypes were observed. More importantly, the values for utilizable protein (UP) were considerably higher in HP than in NP genotypes of pigeonpea, indicating that HP genotypes are nutritionally better than NP genotypes (Singh et al. 1990).

Antinutritional Factors

Of the various antinutritional factors that are found in grain legumes, trypsin and chymotrypsin inhibitors, amylase inhibitors, polyphenols (commonly referred to as tannins), and oligosaccharides are important in pigeonpea (Singh 1988).

The protease (trypsin and chymotrypsin) inhibitors of legumes have been extensively studied, and their mode of action established. In comparison with soybean, pea, and common bean, pigeonpea offers fewer antinutritional factor problems. Pigeonpea contains considerably higher levels of protease inhibitors than the other commonly consumed Indian grain legumes, but much lower levels than those of soybean (Sumathi and Patabhiraman 1976). Pigeonpea contains considerable amounts of polyphenolic compounds that inhibit the activity of digestive enzymes, trypsin, chymotrypsin, and amylase. These are higher in pigeonpea cultivars with dark seed-coat colors (Singh 1984). Phytolectins are toxic factors that interact with glycoprotein on the surface of red blood cells, causing them to agglutinate. Pigeonpea contains phytolectins which are highly sensitive to heat treatment and hence may be of little nutritional significance. Pigeonpea contains traces of glycosides but not at toxic levels (Singh 1988).

Food legumes are well known for causing flatulence when consumed in large quantities. This property is mostly attributed to high levels of oligosaccharides: stachyose, raffinose, and verbascose. These three sugars together constitute about 53% of the total soluble sugars in pigeonpea, but they show a large variation (Singh 1988). Pigeonpea, chickpea, urd bean, and mung bean, in order of decreasing volume, produced flatus in rats (Kantha et al. 1973). These studies suggest that pigeonpea and chickpea may cause discomfort because of higher flatus production, if consumed in large quantities.

The Effect of Processing on Nutritive Value

Pigeonpea is traditionally processed into consumable forms by methods that can be broadly divided into two categories: 1) primary processing, also called dehulling; and 2) secondary processing, which involves three major treatments, namely, cooking, fermentation, and germination. Dehulling pigeonpea improves its palatability and digestibility. The dehulling process is commonly referred to as the removal of seed coat, and may take place either with the dry, raw, whole seed as dry dehulling, or with soaked grains as wet dehulling. Most common methods of dehulling remove the germ along with the husk and cause noticeable losses of protein, calcium, iron, and zinc, the important dietary constituents (Singh et al. 1989). This study suggested that efforts should be made to develop suitable methods of dehulling to reduce quantitative and qualitative losses in pigeonpea grains.

Of the various secondary processing practices, cooking improves the bioavailability of nutrients, and also wholely or partly destroys some antinutritional factors (Salunkhe 1982). The starch digestibility of pigeonpea and other commonly consumed Indian pulses is improved by moist heat treatment. The enhancement of carbohydrate digestibility in cooked legumes is generally attributed to the swelling and rupturing of starch granules. Although cooking improves nutritional quality, prolonged cooking results in a decrease in protein quality and loss of nutrients such as vitamins and minerals. In this context, soft-cooking cultivars of pigeonpea are preferable. A major beneficial effect of cooking is the destruction of protease inhibitors, which interfere with protein digestibility. Pigeonpea protease inhibitors are completely destroyed when subjected to heat under acidic conditions (Sumathi and Patabhiraman 1976). Preliminary soaking followed by dry heat treatment also results in the partial inactivation of the trypsin inhibitor activity (Contreras and Tagle 1974).

Germination can reduce or eliminate appreciable amounts of phytic acid of legumes, and hence improves mineral bioavailability (Salunkhe 1982). The nutritive values of legume-based fermented foods have been shown to be higher than those of their raw components. Laboratory results at ICRISAT have shown that fermentation increased the levels of soluble nitrogen and soluble sugars in pigeonpea, implying that the digestibility of protein and starch might be improved by fermentation. Trypsin and chymotrypsin inhibitor activity in pigeonpea was significantly decreased by fermentation (Rajalakshmi and Vanaja 1967).

Future Research Needs

Chemical composition in terms of nutritional and antinutritional constituents is the primary determinant of the nutritional potential of pigeonpea. Although there appears to be a small variation in chemical composition among pigeonpea cultivars, little effort has been made to show the effect of environment on such constituents. An attempt should be made to establish whether the phenomenal differences are consistent across a variety of environments. This information would be useful in assessing the potential of pigeonpea in human nutrition. The effects of improved agronomic practices should be more carefully studied, particularly with reference to vitamin and mineral content. In addition, research on bio-availability of various dietary nutrients of pigeonpea should receive increasing attention.

Antinutritional factors of pigeonpea have been extensively studied. Studies are needed on other antinutritional and toxic factors such as hemagglutenins, cyanogenic-glucosides, antivitamins, esterogenic compounds, metal-binding constituents, and toxic amino acids, if these are present in pigeonpea. It is recognized that cooking destroys antinutritional factors, notably trypsin and chymotrypsin inhibitors. It is pertinent to study the biochemical changes in proteins and carbohydrates that result from cooking. Protein digestibility and bioavailability of amino acids remain low even after cooking. Factors that affect protein digestibility need be systematically studied.

Since pigeonpea is consumed in various food forms, the intensity and duration of heat treatment it receives during cooking depends on the method of preparation. A knowledge of the nutritional changes that are caused by various types of heat treatments and other pretreatments such as fermentation and germination, would also be very useful.

Postharvest processing of pigeonpea has received little attention in the past. The methods of storage, and the effect of storage on chemical composition and nutritional quality of pigeonpea have not been thoroughly investigated. Efforts should be made to study these aspects. Desirable grain characteristics of pigeonpea cultivars need to be identified to reduce quantitative and qualitative losses during dehulling. The effects of commercial dehulling (*dhal* mill) and village-level dehulling (stone *chakki*, quern) on nutrient losses should also be studied.

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Utilization of Pigeonpea in India and Scope for Novel and Alternative Uses

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Abstract. *Indian vegetarian diets invariably include pulses. Barring very few desserts and snacks, most of these legumes are used in curried dishes, and side dishes. Green immature pigeonpeas are a delicacy and much preferred in roasted, boiled, and seasoned forms, in soups, and in stews with vegetables. However, no effort has been made to make the processing of green pigeonpea commercially viable in India. Freshly sprouted pigeonpeas, and germinated and malted flours are yet to become acceptable products. Flatulence is one of the key reasons why pulse-based dishes are avoided. Fermented, steamed products such as* dhokla, tempeh, adai, *and* kadabu *eliminate this problem. Pigeonpea mixed 40:60 with cereal and eaten with leafy vegetables is* recom*mended for its nutritional value.*

Pigeonpea has a long shelf-life, but loses protein quality, thiamine, and niacin when insect infestation occurs. Varieties with dark testas contain more polyphenolic *compounds and tannins in their seed coat. The addition of* poly*vinylpyrrolidone reduces enzyme inhibitory action. Dehulling results in the loss of the proteinaceous cotyledon layer. Composite, ready-to-prepare enriched and germinated flours for weaning foods, extrusion cooking, and baking purposes are possibilities for future pigeonpea uses. Varieties with lower solid dispersibility should be used in desserts and snacks as those of high viscosity are preferred in curried dishes. Pigeonpea fractions, such as pure starch for noodles, and protein concentrates for dietetic products, have recently been suggested as novel uses. Flavor, texture and color, in that order determine consumer preference for pigeonpea.*

Introduction

Pigeonpea in combination with cereals improves the nutritional status of Indian diets better than other available pulses. India accounts for 85% of the world's supply of pigeonpea, where it is commonly consumed in the form of *dhal* and supplies most of the protein consumed by Indians in their vegetarian diet (Singh and Eggum 1984).

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Dietary Value

The protein content of pigeonpea ranges from 21.0% to 25.4%. The addition of skim milk powder, essential amino acids, such as methionine and tryptophan, improves its protein efficiency ratio (PER) (Daniel et al. 1965). Similarly, pigeonpea when combined with maize starch has shown improved PER (2.25) and biological value (BV 87) when combined with pigeonpea. A ratio of 60 cereals:40 pulses:20 green leafy vegetables has been suggested as an ideal diet for good health and growth (Devadas et al. 1968; FAO 1979). When consumed by patients suffering from diabetes, pigeonpea lowered their blood glucose response (Giri et al. 1986).

Milling Methods

Khare et al. (1966) have described the fractions and types of losses that occur during milling; they reported that the optimum *dhal* recovery is 76.1%. Incomplete, and non-uniform conditioning of seeds, and the composition with respect to gums, mucilages, moisture, size, shape, and hardness of grains influence milling properties (Singh and Jambunathan 1981). Inefficient machinery used in roller milling removes husk by abrasion method, which if not carried out carefully results in loss of nutrients. Dehusking, pearling, splitting, and flaking reduces the cooking time of pigeonpea (Salunkhe et al. 1985).

Canning

Canning of green, immature pigeonpea is an export-oriented business in some countries. Information is available on varieties suitable for canning, including the desired stage of maturity, color of seed coat, and processing conditions. Kaki, Pinto, Villabba, UASD, and *Cajanus indicus* varieties are commonly used. Mature but green colored pigeonpea seeds are better for canning than starchy yellow seeds. Other important criteria noted were alcohol-insoluble solids, total solids, and color of brine (Sanchez-Nieva 1962).

Dehydration

There are advantages in using green immature pigeonpea throughout the year, but people use them only during the season when they are available. By extending shelf-life through proper preservation methods, pigeonpea consumption can be encouraged at least in the dehydrated form, if not in frozen or canned forms.

Other processing methods

Quick-cooking dehusked *dhal* is reported to be rich in magnesium and pectin, but poor in phytin and dispersed solids (Narsimha and Desikachar, 1978). Higher solids in gravy indicate greater nitrogen solubility and lower cooking time. Germination at 31°C for 24 h and parching at 250°C for 2 min improves PER and utilization as shown by tests on experimental animals. Roasting is not nutritionally desirable but helps in flavor development. Fermentation and germination show no extra benefit. Moist heat treatment is the most acceptable method for improving nutritional value. Increased cooking time enhances flatulence-causitive raffinose sugars (Geervani and Theophilus 1980).

Consumer Preference

Consumers prefer pigeonpea that is round or oval in shape, of medium to large uniform size, and having short cooking time. These characteristics are influenced by genotypes from different maturity groups (Singh 1987). Breeders should consider these factors while making their selections. Among the four types studied, pigeonpea variety T 21 has been observed to have better consumer acceptability than others (Vaidehi et al. 1985).

Information relating to physico-chemical properties and sensory evaluation is required as there is variation in the flavor, cooking quality, and in vitro digestibility of varieties of pigeonpea (Reddy and Gouramma 1984).

Cooking Quality

Cooking improves the bioavailability and utilization of nutrients in pigeonpea. Legumes are boiled in water until they become tender. The time required for tenderization is a highly significant aspect of cooking quality. Organoleptic properties such as taste, flavor, color, and texture of the cooked products govern consumer preference in the choice of variety.

Physical characters like water absorption, solid dispersibility, and appearance are reliable indicators of the cooking quality of pigeonpea. Swelling index and hydration capacity are negatively correlated with cooking time. Physical factors of starch, such as, size, gelatinization temperature, paste viscosity, taste, and total starch content are reported to influence the preparation of fermented and weaning foods (Geervani and Theophilus 1980, Malleshi and Desikachar 1982). Genotypes can be classified as long, medium, and short cooking types. Seed size appears to negatively affect cooking time. The mass and volume of seed, require investigation to confirm their influence on cooking quality (Singh et al. 1984).

Chemical factors such as increased calcium, magnesium, and pectin are positively correlated with cooking time. Protein content is positively, and nitrogen solubility index negatively correlated with cooking time (Singh et al. 1984). Lignin content, thickness of seed coat, and seed maturity all affect cooking time (Salunkhe et al. 1985).

Quick-cooking Treatments

Cooking time is reduced by soaking in alkaline solutions (Chavan et al. 1983). Ions responsible for cellular firmness are replaced by sodium ions or leached out resulting in solubilization of pectic substances by this process (Dev and Jadhav 1984).

Pigeonpea

↓

Split *dhal,* dehusked (150 g)

↓

Soak in water (6 h)

↓

Wash 2-3 times and drain off water

↓

Pressure cook

(15 min; 1 kg cm^{-2})

↓

Mix inoculum, *Aspergillus oligosporus*

1/2 tsp + 1 tsp vinegar (use a bowl)

↓

Spread (1.5 cm) thinly on sterilized tray

↓

Cover with perforated polythene sheet

↓

Incubate

(36°, 12-16 h)

↓

Compact white cake, *tempeh* (225 g)

↓

Slice or cube for use

↓

Dehyrate for storage at 70°C

Figure 1. *Tempeh* from pigeonpea *dhal* (Vaidehi and Rathnamani 1988).

A combination of chemical coatings using various salt and alkaline solutions, and soaking before dehusking also reduces cooking time (Narasimha and Desikachar 1978).

Fermentation

Salunkhe et al. (1985) reported on pigeonpea utilization in fermented products in combination with cereals. *Tempeh, idli, dhokla, dhal* patties, *adai, kadabu, dosa* are fermentated before cooking and could become more popular as health foods. Pigeonpea can be used with or without soybean *dhal* to prepare very good *tempeh* (Vaidehi and Rathnamani 1988). Figure 1 describes the method for *tempeh* preparation. Both fresh and dried *tempeh* can be used to make nutritious snacks and curried dishes.

Baking and Confectionery

Pigeonpea has been little used in baked foods or confectionery products. Legumes are used in bread and cookies for protein enrichment. Nath et al. (1960) prepared biscuits with protein hydrolyzates of *cajanus indicus* having 9.5-15.5% protein. Gayale et al. (1986) reported that physical, sensory, and nutritional characteristics of breads supplemented with pigeonpea flour from 0-25% showed no significant difference (P < 0.05) compared with unsupplemented breads for the characteristics tested. Pigeonpea flour increased the protein, lysine and zinc content of bread. Malted pigeonpea flour can constitute up to 40% (by weight) of flour to make protein-rich cookies of good baking quality (Vaidehi et al. 1985).

Frying, Griddle Cooking, and Boiling

Soaked, drained, fried and spiced pigeonpea is a popular snack item. Griddle-cooked *holige* or *obbattu* delicately flavored with pigeonpea *dhal* is a well known sweet dish in South India. This is a sweet pancake prepared with cooked split pigeonpeas, jaggery (gur), grated coconut, and cardamom powder. The south Indian dish *'bisi-bele-bhath'* is a hot, spicy, dish that combines pigeonpea with rice and vegetables (2:1:0.5 ratio). Other popular south Indian recipes that incorporate pigeonpea, are *sambar* (cream of soup), *bassaru* (kind of a curry), *massoppu,* and *thovve* (mashed *dhal*), which are different types of curries, eaten with rice and chapathis. Some people use specific vegetables and green leaves. The names of these dishes are derived from the spice mixtures and methods of preparation. *Dhal chutney* and stuffed *parathas* are also popular. *Dhal chutney* is made of roasted pigeonpeas, red chillies, garlic ground with grated coconut, tamarind, curry leaves and salt, using a little water. Stuffed *parathas* are made from whole wheat flour dough, rolled and stuffed with cooked dhal, salt and spices, rolled again and griddle cooked.

Green Pigeonpea

The consumption of vegetable pigeonpea in India could increase if more of the vegetable and recipes for its use were available. Green pigeonpea could be used in several Indian dishes e.g., prawns with pigeonpea, green pigeonpea with *paneer, kootu, khurma* (stews cooked with coconut paste/cream and spices and seasoned while boiling), and *samosas* (partially refined wheat flour made into dough, rolled, and vegetable or meat curry is placed on it. It is then carefully folded into a triangle enclosing the curry, and then deep fried in oil). Green pigeonpea is more nutritious than the mature seed. It is more easily digestible and contains less flatulence and antinutritional factors (ICRISAT 1987). The addition of vegetable pigeonpea to minor millets increases the PER of diets (Bressani et al. 1986). Germinated and boiled pigeonpea *sundals* are very good for children and convalescents.

Novelty Products

Presently available machinery for food encapsulation, extrusion methods and pelleting should help in producing creative culinary products. Legumes in processed foods, such as dried soup mixes and multipurpose foods help to improve their palatability and nutritional quality. Malted and germinated flour can be used in sweetmeats, weaning foods, and to make sweet *halwa.* The use of malted pigeonpea in porridge mixes and green maize soup, enriched flour for *chapathis, parathas,* and *tandoori rotis,* deserve the attention of technologists. Extruded *dhal* like analogues of composite flours containing pigeonpea and other lesser known legumes such as soybean, rice bean, winged bean, jack bean and oilseed might yield acceptable products which could extend the use of pigeonpea. Noodle preparations using pigeonpea starch make an attractive product (ICRISAT 1988). These new technologies should be able to offer low-cost, mass-production of nutritious leguminous dishes which would also appeal to consumers of traditional dishes. It should be possible to formulate and produce enriched macaroni, pasta products, biscuits, and dietetic foods that have a good market potential.

Women and Pulse Utilization

Rural women contribute a lot to the process of making pigeonpea utilizable. Dehusking and cleaning operations require fabrication of small, easy-to-operate machinery specifically for use by women. Preparation of composite flours, snacks, malted foods, sprouted gram, processing and packaging of green pigeonpea, etc. could be introduced on a commercial scale. Short-term training in this form of technology transfer is necessary.

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Utilization of Pigeonpea and Other Grain Legumes in Indonesia

D.S. Damardjati and Sri Widowati[1]

Abstract. *Research on utilization of pigeonpea in Indonesia was started in 1984 by the Agency of Agricultural Research and Development (AARD). A survey found that pigeonpea is traditionally grown by farmers, especially in Java, Bali, Madura, and the eastern islands. The use of pigeonpea, however, is still limited. While traditional dishes such as* bongko, brubus, pencok, *and* hiris *were domestically prepared, a major limitation to increased use of pigeonpea was the lack of knowledge about various methods of processing and utilizing the products.*

An evaluation of the physico-chemical properties was carried out on both exotic genotypes and local varieties. Size, shape, color, mass, and bulk density were measured. Protein, fat, crude fiber, and moisture contents were determined. Raw and boiled forms were tested for biological quality, i.e., true digestibility, biological value, and net protein utilization.

Research on processing and utilization of pigeonpea includes improvement of existing pigeonpea food products, such as soybean-pigeonpea tempeh, *and pigeonpea sauce; the development of new products, such as rice-pigeonpea cookies, and extrusion products; and the development of pigeonpea flour.*

Research and development on pigeonpea utilization in Indonesia will focus on the nutritional evaluation of fermented and processed products, the development of new products, the introduction and "scale up" of pigeonpea processing at the farm and home-industry level, and the evaluation of the processing efficiency, economic feasibility, and acceptability of pigeonpea products.

Introduction

Protein-calorie malnutrition is a common problem in developing countries. In rural Indonesia, children under 5 years of age, and pregnant and lactating mothers suffer from protein-calorie malnutrition. In order to solve this problem, new, inexpensive, and acceptable protein sources must be found.

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Pigeonpea is a perennial plant mainly grown as an annual crop. It is resistant to drought and can be grown in various types of soil. It can be grown under even harsher environmental conditions than soybean.

Pigeonpea is a legume that has been cultivated as a vegetable in Indonesia since the 6th Century. Although the plant has spread to almost all islands of the Indonesian archipelago, it was never intensively cultivated. Pigeonpea is usually intercropped with other legumes or food crops, but is rarely grown as a monocrop. Generally, it is sown on dry ridges, or on the dykes of wetland rice fields (Sumarno and Brotonegoro 1987). The results of our survey indicate that pigeonpea can be grown even on marginal soils - e.g., in the Gunung Kidul and Wonogiri areas, where even though yields were low, the plants survived (Widowati and Barrett 1984).

Many local varieties of pigeonpea have been traditionally grown by farmers, especially in Java, Bali, Madura, and the eastern islands of the country. Consequently, pigeonpea has many local names, e.g., *gude* in Central and East Java, *hiris* in West Java, *undis* in Bali, *kacang turis* in Timor, and *kace* in South Sulawesi (Damardjati and Widowati 1985; Sumarno and Brotonegoro 1987).

One of the major constraints to the development of pigeonpea in Indonesia is the lack of knowledge on its utilization. Therefore, we evaluated the physical, chemical, and nutritional characteristics of available varieties and lines, and worked on the improvement of traditional food products, and the development of new food uses of promising varieties.

The major source of vegetable protein in Indonesia has been, and continues to be soybean. Although other legumes such as mung bean and groundnut are grown, they are less popular than soybean in terms of their use as a protein resource. Several soybean products such as *tempeh*, sauces, and *tofu* are well known and acceptable to Indonesian consumers. The demand for soybean increases every year, and to meet this demand the Government has had to increase soybean imports. Pigeonpea has good prospects of further development in Indonesia as a soybean substitute.

Processing and Utilization

Research on utilization of pigeonpea at the Sukamandi Research Institute for Food Crops (SURIF) began in 1984 with a village-level survey to identify the existing varieties, and traditional utilization methods (Widowati and Barrett 1984). The survey revealed that pigeonpea has been traditionally grown by farmers in Indonesia, especially in Java, Bali, Sulawesi, and some of the eastern islands, but that its utilization is limited.

In West Java, people mix the raw young pods and fresh seeds of pigeonpea with ground spices - chili, coconut, sugar, garlic, salt, fried groundnut and kencur (*Kamferia galanga*) to prepare a popular vegetable dish, called *pencok hiris.* Sometimes, pigeonpea is served as a salad or a soup. However, people in this area do not know how to use the mature grain as food. If the pods mature, they are used as livestock feed. Therefore, dry grain is not available in the local markets, except for the small quantity sold for seed.

Some well accepted traditional foods, e.g., *brubus* and *bongko* made from pigeonpea grain are popular in Central Java. *Brubus* is made from green pigeonpea seeds mixed with grated coconut, and ground spices consisting of coriander, coconut sugar, salt, chili, garlic and onion. The mixture is then cooked for about 30 min. If this mixture is wrapped in banana leaf and steamed for about 30 min, it is called as *bongko.* Mature grain is also consumed in such side dishes as *rempeyek* and *serundeng,* and as a snack called *gandasturi. Rempeyek* is made from mature pigeonpea seeds mixed with a concentrated solution of rice flour, egg and coconut milk. Ground spices - coriander, candlenut, salt and garlic are added and then deep fried. *Serundeng* is made by mixing mature pigeonpea seed with grated young coconut, coriander, onion, garlic, coconut sugar, salt, bay leaf, greater galingale (cut pieces of perennial rhizomes which are aromatic, pungent and bitter), tamarind and the mixture is fried. *Gandasturi* is made by mixing soaked green pigeonpea seeds with coconut sugar and salt. The mixture is cooked, made into small balls covered with cassava or wheat flour and then fried.

Physical, Chemical, and Nutritional Qualities

Twenty-three high-yielding cultivars from Australia, and five local Indonesian varieties of pigeonpea, were evaluated for their physical characteristics (seed size, shape, color, weight, and bulk density) their chemical characteristic (protein, fat, crude fiber) and moisture content. Two local Indonesian varieties, Kuningan and Wonosari, were evaluated for their true digestibility (TD) and biological value (BV) using rats (Damardjati and Widowati 1985).

Physical Characteristics

Australian and Indonesian cultivars had seeds of similar size and shape. However, Australian cultivars exhibited slightly higher bulk densities and grain mass than Indonesian cultivars. In general, all Australian cultivars were brownish-red in color, while the Indonesian cultivars were black, brownish-red, white, and variegated (Widowati and Damardjati 1985).

The seed coat of pigeonpea is about 10.5-15.5% of its total seed mass. The embryo contributes 0.6-1.4%, and the cotyledons 83.1-88.9% of the total seed mass (Kurien 1981).

Chemical Characteristics

The seed protein content of Australian cultivars was lower than that of Indonesian cultivars, but the Australian cultivars had higher crude fiber content (Table 1).

Even though the protein content of pigeonpea seed was lower than that of soybean, pigeonpea has better quality protein in terms of amino acid composition (Table 2).

Pigeonpea, soybean, and their products are limiting in the sulfur-containing amino acids, methionine, and cystine, when compared with the FAO pattern (FAO/WHO 1973). The essential amino acid (methionine, cystine, leucine, isoleucine, lysine, phenylalanine, tyrosine, and threonine) contents of boiled pigeonpea and pigeonpea *tempeh* were higher than those of soybean *tempeh* (Sibarani 1982).

Table 1. Chemical composition [g (100 g)$^{-1}$ sample] of Australian and Indonesian whole seed pigeonpea cultivars.

Constituent	Australian[1]	Indonesian[2]
Protein	18.5±0.8	21.8±1.8
Fat	1.9±0.2	1.6±0.3
Carbohydrate	56.6±1.4	55.7±1.5
Ash	3.7±0.2	3.6±0.1
Crude fiber	7.0±0.8	5.3±0.4
Moisture	11.8±0.5	11.8±0.2

1. Mean ±SE values obtained on 23 cultivars.
2. Mean ±SE values obtained on 5 cultivars.

Table 2. Essential amino acid composition (mg g^{-1} N^{-1}) of pigeonpea, pigeonpea *tempeh,* soybean, and soybean *tempeh* compared with FAO pattern[1].

Amino acid	Boiled pigeonpea	Pigeonpea *tempeh*	Soybean *tempeh*	Raw soybean	FAO[2] pattern
Isoleucine	273	344	178	296	250
Leucine	444	437	348	484	440
Lysine	504	499	263	356	340
Methionine	63	64	51	69	220
Cystine	58	57	45	54	
Phenylalanine	469	462	261	309	
Tyrosine	233	238	156	202	380
Threonine	249	252	190	258	250
Tryptophan	74	66	58	72	60
Valine	248	245	179	298	310

1. Dry mass basis. Sibarani 1982.
2. FAO 1973.

Nutritional Quality

The true digestibility (TD) of pigeonpea products could be improved through boiling, or fermentation with a fungus (*Rhizopus* sp). The TD of raw pigeonpea (70.9%) increased to 84.7% after boiling, and to 86.6% after fermentation. However the biological value (BV) of raw pigeonpea decreased from 83.0% to 50.6% on boiling, and 45.6% on fermentation (Widowati and Damardjati 1985).

Like other legumes, pigeonpea seed contains several antinutritional factors, such as trypsin and chymotrypsin inhibitors, but their activities are lower than those of soybean. During *tempeh* production, those enzyme inhibitors are inactivated after the second boiling (Santosa et al. 1987).

Improvement of Traditional Products

Pigeonpea *Tempeh*

Pigeonpea *tempeh* is made by soaking, decorticating, and boiling seed, and then fermenting it with *Rhizopus* sp, a common fungus used in making soybean *tempeh.* Two local Indonesian varieties from Kuningan and Wonosari were used to make *tempeh.* Results of organoleptic tests indicated that pigeonpea *tempeh,* even though less preferred than soybean *tempeh,* was still acceptable to the taste panelists (Widowati and Damardjati 1987).

Indonesian consumers are familiar with soybean *tempeh,* but pigeonpea *tempeh* is a new product, and not yet well known. To improve consumer acceptability of the pigeonpea product, we have successfully developed a method for producing mixed soybean-pigeonpea *tempeh.* Results of organoleptic test showed that there was no significant difference between soybean-pigeonpea (2:1 w/w) *tempeh* and full soybean *tempeh.*

Pigeonpea Sauce

Pigeonpea sauce is made by fermenting dehulled, soaked and cooked pigeonpea seeds with *Aspergillus oryzae* at 30°C for 72 h. Fermentation is continued in 25% sodium chloride solution for 30 days and filtered. The filtrate is mixed with spices and coconut, cooked and refiltered. There are two kinds of pigeonpea sauces - salted and sweet sauce. The techniques used to produce these two kinds of sauces are similar, except for the addition of sugar in the case of sweet sauce (Antarlina and Kusbiantoro 1986).

The quality of soysauce would also depend on its protein content. Grade one sauce should have 6% protein and grade two, 2% protein. Sweet pigeonpea sauce is considered to be of second-grade quality. Salted pigeonpea sauce is accepted by consumers even though its protein content is less than 2% (below second-grade quality). Hermana (1985) reported that some soy-sauces in the market have a protein content of only 1% while laboratory-made soy-sauce contained 3% protein.

Development of New Food Products

Since 1985 research on the development of new products has been conducted at SURIF. Two kinds of new products, cookies and extrusion food, have been produced.

Rice-pigeonpea Cookies

Pigeonpea flour is added to rice flour to produce protein-enriched rice cookies. The process of making cookies is well-known; rice flour, pigeonpea flour, and other ingredients are mixed into a dough, which is kneaded into a flat layer, molded, and then baked (Prasetyo 1988).

Table 3. Chemical composition of rice-pigeonpea flour cookies.

Component	Pigeonpea flour added (%)							
	0%	10%	20%	30%	0%	10%	20%	30%
	Cisadane rice				Semeru rice			
Moisture (%)	2.2	2.5	3.0	3.3	2.0	2.3	2.7	2.6
Protein (%)	6.2	7.0	7.9	8.5	5.8	6.6	7.5	8.2
Ash(%)	1.5	1.5	1.8	1.9	1.4	1.6	1.6	1.8
Crude fiber (%)	0.5	0.6	0.7	1.0	0.5	0.6	0.7	0.9
Fat (%)	16.8	16.8	16.9	17.1	16.7	16.7	17.0	17.1
Starch (%)	72.8	71.5	69.8	68.3	73.7	72.2	70.6	69.4
Kilojoules g^{-1}	1957	1953	1936	1932	1961	1953	1940	1944

The chemical composition of cookies prepared from rice and pigeonpea flour is given in Table 3. Results indicated that for every 10% addition of pigeonpea flour, the protein content of cookies increased by about 12% of total protein, compared to that of the control (100% rice) (Prasetyo 1988).

Extrusion Food

Recently, extrusion food has become popular, mainly among children. Pigeonpea flour is added to rice flour to increase the protein content of this product. Azman (1988) reported that supplementing milled rice flour with pigeonpea flour up to 30% increased the protein content of the extruded product from 9.1% to 13.2% (Table 4). The products were still acceptable to consumers and panelists.

Table 4. Protein content, physicochemical, and organoleptic properties of rice-pigeonpea extruded products.

Properties	Pigeonpea flour supplement (%)		
	0	20	30
Protein content (%)	9.1	12.4	13.2
Protein digestibility (%)	70.0	68.4	66.2
Volume expansion	3.2	3.2	3.2
WAP	8.2	9.4	8.3
Bulk density ($mL\ g^{-1}$)	5.1	5.2	5.2
Organoleptic test score[2]			
Appearance	5.1	4.8	4.5
Crispiness	5.9	5.7	5.5
Taste	4.4	3.7	3.5

1. Water absorption index.
2. Hedonic scale : 1= very poor, 5 = good, 7 = excellent

Research on Pigeonpea Utilization

Pigeonpea has good prospects for development in Indonesia. The products developed by earlier research have been well accepted by Indonesian consumers. However, research on pigeonpea utilization is very limited. Current and future research programs include:

- continuing the development of new products;
- introducing new products to Indonesian consumers;
- transferring research technology to farmers and producers; and
- market study.

Both immediate and long-term objectives should be considered in the research program.

Immediate Objectives

- Determination of the physico-chemical characteristics of selected pigeonpea cultivars;
- evaluation of the nutritional value of selected pigeonpea cultivars; and
- development of new pigeonpea food products.

Long-term Objectives

- Comparison of processing efficiency, economic values, and acceptability of various pigeonpea food products;
- introduction of "technology packages" for pigeonpea production and utilization to various pilot farmer areas;
- dissemination of information on pigeonpea production and utilization; and
- establishment of a well-maintained collection of local and introduced pigeonpea cultivars.

Future Studies

- Continuation of nutritional evaluation of fermented pigeonpea, and evaluation of trypsin inhibitor activity, in-vitro digestibility, and protein properties;
- comparison of existing milling methods to select a suitable method for evaluating flour properties and protein characteristics;
- partial substitution of rice flour by pigeonpea flour in cookies and evaluation of the products for their physical, chemical, and sensory characteristics; and
- introduction of pigeonpea processing to farmers and consumers, and a study of the processing efficiency, economic feasibility, and acceptability of the concerned techniques.

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Composition and Quality of *Tempeh* Prepared from Pigeonpea, and Pigeonpea/Soybean Mixtures

K.A. Buckle and D.H. Iskandar[1]

Abstract. *Five varieties of pigeonpea (702, Hunt, Quantum, QPL 992, and B15B) grown in Australia, were analyzed for moisture, protein, individual amino acids, fat, crude fiber, ash, and carbohydrate content. The protein content varied from 22.0 to 26.8% (dry mass basis) with the Hunt variety containing the highest level. Analyses were also conducted on seeds that were soaked in water for 24 h, or soaked for 24 h and then dehulled, or soaked for 24 h, boiled 5 min, and dehulled; and on seed coats removed from seeds after soaking, and after soaking and boiling.*

Tempeh *was prepared from pigeonpea* tempeh gude, *or soybean* tempeh kedele, *and from mixtures, (1:3,1:1, and 3:1 wlw) of pigeonpea and soybean by soaking the seeds overnight in water, dehulling, boiling, cooking, and fermenting for 24-48 h at 30°C with the mold* Rhizopus oligosporus *strain* $CT_{11}K_2$. Tempeh *samples were analyzed before and after frying for proximate composition, amino acids, Hunterlab color values, and non-enzymic browning.* Tempeh gude *was considerably darker than* tempeh kedele, *but* tempeh *prepared from a 1:1 mixture of pigeonpea and soybean was acceptable in color and other characteristics to a panel of Indonesian panelists.*

Future work will examine the biochemical and chemical changes in the seeds during the soaking process before fungal fermentation; the factors responsible for the unacceptable color of tempeh gude; *the quality of* tempeh *prepared from mixtures of pigeonpeas and other grains and legumes; and the incorporation of pigeonpea flour and dried* tempeh gude *in other traditional fermented and non-fermented foods.*

Introduction

Tempeh is a traditional Indonesian food that is commonly prepared from soybeans by fermenting soaked, dehulled, and cooked seeds, with *Rhizopus oligosporus,* a mold that

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grows not only on the surface but throughout the seeds converting them into a compact cake. During soaking, when bacterial fermentation occurs (Mulyowidarso et al. 1989), and during the subsequent mold fermentation, enzymes from these organisms decompose proteins, carbohydrates, and lipids, thereby improving the digestibility, nutritional value, and palatability of the beans (Steinkraus et al. 1983).

Tempeh is used as an inexpensive source of high quality protein especially in developing countries. Traditionally it is consumed as slices or cubes, which are deep fried until golden brown. *Tempeh* is a good source of minerals e.g., calcium (Ca), phosphorus (P), and iron (Fe), and some vitamins (thiamin, riboflavin, pyridoxine, folic acid, and vitamin B_{12}). Conversion into *tempeh* before consumption reduces the degree of flatulence caused in humans compared to that from consumption of cooked beans, primarily because *R. oligosporus* hydrolyses the flatulence-producing sugars, raffinose and stachyose (Steinkraus et al. 1983). Phytic acid is also reduced by about 30-50% during fermentation, and a further 50% reduction occurs during frying; less than 10% of the phytic acid content remains in the seed after fermentation, frying, and storage (Sutardi and Buckle 1985a, 1985b).

A number of dry seeds, seed fractions, cereals, and mixtures of these products can be substituted for soybean in the preparation of *tempeh* and *tempeh-like* foods. Common *tempeh* products include those prepared from soybean (*tempeh kedele*), winged bean (*tempeh kecipir*), velvet bean (*tempeh benguk*), and solid wastes from *tofu* (soybean curd) production (*tempeh gembus*). Coconut grits or press cake (*tempeh bongkrek*), lupin, yellow pea, broad beans, maize, peas, barley, and wheat are also used.

In recent years pigeonpea has been cultivated in Indonesia in increasing quantities, and studies have been conducted to incorporate pigeonpea into a variety of traditional foods, including *tempeh.* Widowati and Damardjati (1987) examined 23 high-yielding pigeonpea lines from Australia and five local Indonesian varieties for physical characteristics, chemical characteristics, and overall nutritional quality. Dehusked grain was fermented into *tempeh.* They reported that pigeonpea *tempeh* (*tempe gude*) was less preferred by panelists than soybean *tempeh,* but it was still acceptable.

We examined the chemical composition of pigeonpea seeds before and after soaking, and after boiling. We assessed the properties and quality of *tempeh* prepared from pigeonpea and soybean seeds, and from mixtures of these two legumes. The results of this study are reported.

Materials and methods

Materials

Soybean (cv Delmar) was grown in Gunnedah, New South Wales, and used in studies on *tempeh* at the University of New South Wales. Pigeonpea cultivars 702, Hunt, Quantum, QPL 992, and B15B were obtained from E.S. Wallis, Department of Agriculture, University of Queensland, St Lucia, Queensland, and grown in southeast Queensland. *R. oligosporus* strain $CT_{11}K_2$ was obtained from Sutardi (Sutardi and Buckle 1985a, 1985b; 1988).

Methods

Seed preparation. Dry pigeonpea and soybean seeds were ground to a fine powder in a Fritsche mill. Soaked seeds with and without seed coats, and separated seed coats from unboiled and boiled seeds, were frozen to -10°C, freeze dried, and ground to a powder for analysis.

***Tempeh* preparation.** Pigeonpea and soybean seeds were soaked overnight in tap water at ambient temperature and boiled for 5 min in excess fresh water. The cooking water was discarded, the seeds were dehulled by hand, and steamed for 30 min, then placed on perforated aluminium trays to drain off excess water, cooled, mixed in the ratio 3:1, 1:1 and 1:3 (w/w), and inoculated with spores of *R. oligosporus.* One test tube (slant) of spores grown on malt extract agar (Oxoid) was adequate to inoculate 1 kg of seed. After mixing thoroughly with the spores, the seeds were packed into perforated polyethylene bags and incubated for 24-36 h at 30°C. For analysis, *tempeh* samples were dried and ground to a flour.

Analyses

Moisture was determined on 5 g sample of *tempeh* flour using a vacuum oven (24 h at 70°C, < 100 mm Hg pressure). Nitrogen was determined on 0.5 g sample by the macro Kjeldahl procedure using the Kjel-Foss Automatic Analyser, and converted into protein using a factor of 6.25. Crude fat was determined on 5 g sample by the soxhlet extraction procedure using petroleum ether (b.p. 40°-60°C) and diethyl ether. Crude fiber was determined on 2 g sample of defatted seeds as described by Lees (1978). Ash was determined on 5 g sample heated to 550°C overnight in a muffle furnace. Carbohydrate was calculated by difference from 100% of the total of moisture, protein, fat, crude fiber and ash. Composition (%) is expressed on a dry mass basis unless otherwise described. Amino acids were determined by high performance liquid chromatography (Waters, MA, USA). Approximately 50 mg protein was acid hydrolyzed using a modified procedure of Lucas and Sotelo (1982), and 50 µL of the hydrolyzate was used. The HPLC solvent consisted of (flow rate 0.5 mL/min), pH 3.08 citrate buffer for 1 h, then (flow rate 0.5 mL/min), pH 6.45 citrate buffer, with column temperature at 55°C and reaction temperature of 110°C±5°C. Standards (Pierce Chemical Co. USA) were used for identification and assessment of recovery.

Non-enzymic browning (NEB) was measured on 2 g sample according to Buckle and Purnomo (1986), and reported as corrected absorbance at 420 nm x 10^3 g^{-1} solid.

Seed color was measured using a Hunterlab (Model D25A-2) Color and Color Difference Meter (Hunter Associates, VA, USA).

Sensory assessment was conducted using 30 Indonesian students familiar with *tempeh* quality. The panelists were asked to assess color, flavor, aroma, and overall acceptability using a nine-point hedonic scale where 1 = like extremely and 9 = dislike extremely, with 5 = neither like nor dislike.

Statistical analyses were conducted using a Statistical Package for Social Sciences (SPSS) package (Nie et al. 1975).

Results and Discussion

Proximate composition of dry and soaked seeds, and *tempeh*

The proximate composition of the dry seeds (Table 1) is in general agreement with that reported by Morton (1976) and Kay (1979) except that the moisture, fiber, and ash contents in our samples are slightly higher. There were no major differences in the composition of the five cultivars.

Table 1. Proximate composition (% wet weight) of pigeonpea seeds[1].

	Cultivar				
Constituent (%)	702	Hunt	Quantum	QPL922	B15B
Moisture	13.7±0.1	14.7±0.2	15.3±0.1	11.2±0.2	11.0±0.1
Protein	19.8±0.1	22.9±0.1	18.6±0.4	22.4±0.1	19.8±0.2
Fat	3.4±0.1	2.1±0.5	1.9±0.4	2.0±0.1	1.1±0.1
Ash	3.5±0.1	3.5±0.1	3.3±0.1	3.6±0.1	3.1±0.1
Fiber	10.2±0.6	10.0±0.4	10.1±1.1	9.9±0.4	8.6±0.3
Carbohydrate[2]	49.4±0.1	46.8±0.4	50.8±0.2	50.9±0.1	56.4±0.1

1. Mean ± standard error values given.
2. By difference.

Soaking in water for 24 h increased the moisture content substantially, and boiling for a further 5 min increased it slightly. The protein content increased during soaking, boiling and dehulling, while crude fiber and ash contents decreased as a result of dehulling of the seeds as shown for the Hunt cultivar (Table 2).

Conversion of the soaked, boiled and dehulled seeds into pigeonpea *tempeh* produced a fermented cake with a similar moisture content to that of soybean *tempeh*, but with substantially lower protein, fat, and fiber content and a significantly higher level of carbohydrates (Table 2). The protein, fat, and crude fiber content increased as the proportion of soybean increased in the mixture. The proportion of pigeonpea seed in the mixture had no effect on the extent of fungal fermentation that occurred during incubation.

Fresh *tempeh* prepared from Hunt had significantly higher moisture content (68.3%) than that of pigeonpea *tempeh* (55%) reported by Widowati and Damardjati (1986), although the protein, fat, and ash content of Hunt *tempeh* were also significantly lower. Such variations are no doubt due to differences in cultivar, *tempeh* preparation method, mold inoculum, and analytical methods.

Amino acid content of pigeonpea seeds and *tempeh*

The level of the majority of essential amino acids in the five pigeonpea cultivars (Table 3) were lower than those reported, especially for phenylalanine (Salunkhe et al. 1985). In

Table 2. Composition (% dry mass) of pigeonpea Hunt before and after soaking and boiling, and of *tempeh* prepared from pigeonpea/soybean mixtures[1].

Treatment	Moisture (%)[2]	Protein (%)	Fat (%)	Crude fiber (%)	Ash (%)	Carbohydrate (%)
Intact seed	14.7±0.2	26.8±0.0	2.5±0.5	11.4±0.0	4.1±0.1	40.6±0.4
Soaked 24 h	59.4±0.1	26.0±0.1	1.8±0.1	9.9±0.6	3.7±0.1	48.8±0.2
Soaked 24 h, dehulled	59.6±0.1	30.1±0.4	2.1±0.3	3.9±0.4	3.6±0.1	55.2±0.6
Soaked 24 h, boiled 5 min, dehulled	62.7±0.3	32.6±0.4	3.1±0.1	3.6±0.3	2.6±0.1	49.5±0.1
Tempeh (pp:s)[3]						
1:0	68.3±0.6	37.0±0.3	2.5±0.1	4.7±0.6	2.6±0.1	45.0±0.2
3:1	68.9±0.6	43.9±0.6	7.3±0.2	5.2±0.3	2.8±0.1	29.0±0.1
1:1	67.0±0.6	51.2±0.1	10.2±0.4	5.6±0.1	2.7±0.1	20.7±0.4
1:3	66.5±0.6	57.4±0.1	10.8±0.1	5.6±0.1	2.9±0.1	13.6±0.4
0:1	65.3±0.6	62.1±0.6	18.5±0.4	7.5±0.1	2.6±0.1	9.3±0.6

1. Mean ± standard error values given.
2. % wet mass.
3. Ratio of pigeonpea seed to soybean (w/w).

comparison, the Quantum cultivar contained a significantly lower level of most of the amino acids determined. The amino acid composition of fresh *tempeh* prepared from a 1:1 mixture of pigeonpea seed and soybean was not significantly different from that of soybean *tempeh* or pigeonpea seed.

Table 3. The amino acid content (g 100 g^{-1} protein) of pigeonpea seeds[1].

	Pigeonpea cultivar				
Amino acid	702	Hunt	Quantum	QPL992	B15B
Aspartic acid	7.5±0.0	8.0±0.1	6.5±0.3	7.7±0.1	8.7±0.4
Threonine	3.4±0.3	3.3±0.1	2.6±0.1	2.8±0.4	3.5±0.1
Serine	4.1±0.1	4.5±0.1	3.6±0.1	3.8±0.6	4.8±0.1
Glutamic acid	9.310.7	13.1±3.0	7.5±0.0	8.6±1.1	11.9±0.8
Proline	3.6±0.1	3.9±0.0	2.6±0.3	3.3±0.6	4.1±0.1
Glycine	3.0±0.1	3.2±0.1	2.7±0.2	2.8±0.4	3.6±0.1
Alanine	8.2±0.4	3.4±0.1	7.5±0.6	7.5±0.4	7.7±0.2
Cystine	0.3±0.0	0.4±0.0	0.3±0.0	0.3±0.1	0.4±0.0
Valine	3.9±0.1	4.2±0.1	2.6±1.0	3.5±0.5	4.4±0.1
Methionine	1.0±0.1	1.0±0.1	0.7±0.1	0.8±0.2	0.9±0.3
Isoleucine	3.4±0.0	3.6±0.1	3.0±0.2	3.0±0.5	3.7±0.3
Leucine	5.9±0.1	6.2±0.1	5.2±0.4	5.4±0.6	6.6±0.4
Tyrosine	1.7±0.1	3.8±0.1	1.4±0.1	1.6±0.2	2.0±0.1
Phenylalanine	5.7±0.3	5.6±0.1	4.9±0.6	4.9±0.1	5.5±0.3
Lysine	5.6±0.3	6.4±0.1	5.1±0.4	5.7±0.6	7.5±0.5
Histidine	3.2±0.1	3.4±0.1	3.0±0.4	2.9±0.3	3.7±0.2
Arginine	5.2±0.1	6.2±0.1	4.7±0.3	5.0±0.6	6.3±0.3

1. Means ± standard error values given.

Table 4. Non-enzymic browning (corrected absorbance at 420 nm x 10^3/g solids) of fried *tempeh* prepared from mixtures of pigeonpea seeds and soybeans.

Cultivar	Ratio of pigeonpea:soybean (w/w)[1]				
	1:0	3:1	1:1	1:3	0:1
702	92±1	88±3	23±1	11±1	-
Hunt	36±4	25±1	13±1	11±1	-
Quantum	132±2	109±2	62±6	18±1	-
QPL 992	107±4	92±1	73±4	24±1	-
B15B	60±4	58±2	48±1	35±7	-
Soybean	-	-	-	-	10±1

1. Mean ± standard error values given.

Tempeh quality

Pigeonpea *tempeh* was significantly darker than soybean *tempeh,* while *tempeh* prepared from mixtures of the seeds had intermediate color. The color difference was more noticeable to the eye than was reflected in Hunterlab L, *a* and *b* values, although *a* values (-ve = green, +ve = red) decreased with increasing proportion of pigeonpea seeds in the mixture. The darkest seeds (Quantum) gave the lowest *a* value and the highest *b* value (-ve = blue, +ve = yellow).

Non-enzymic browning levels in fried *tempeh* samples (Table 4) increased as the proportion of pigeonpea to soybean increased. The highest level was shown in *tempeh* prepared from Quantum and the lowest in *tempeh* from Hunt. Browning levels in fried soybean *tempeh* were minimal.

Organoleptic assessment of fried *tempeh* prepared from Hunt and from mixtures with soybean (Table 5) showed that Indonesian panelists preferred soybean *tempeh* with respect to overall acceptability, but that *tempeh* prepared from a 1:3 mixture of pigeonpea and soybean was still acceptable, especially with respect to aroma. The color, flavor, and

Table 5. Sensory acceptability of fried *tempeh* prepared from mixtures of Hunt and soybean[1].

Sensory property	Ratio of pigeonpea:soybean (w/w)				
	0:1	1:3	1:1	3:1	1:0
Flavor	3.6±0.2a	4.5±0.4ab	4.6±0.3b	4.7±0.3b	5.3±0.3b
Color	3.8±0.2a	3.9±0.3a	4.9±0.3b	4.9±0.3b	5.0±0.3b
Texture	4.0±0.2a	4.5±0.3ab	4.7±0.3ab	4.9±0.3b	5.0±0.3b
Aroma	3.9±0.2a	4.2±0.3ab	4.9±0.3b	5.1±0.3b	5.2±0.3b
Overall acceptability	4.1±0.3a	4.8±0.3ab	5.6±0.3b	5.9±0.3b	5.9±0.3b

1. Means of 30 replications ± standard error.

Means followed by the same letter are not significantly different (P<0.05).
Rating : 1 = like extremely, 9 = dislike extremely.

aroma of *tempeh* prepared using 50% pigeonpea was significantly different to that of soybean *tempeh*, although these products were still acceptable. *Tempeh* containing 50% or more pigeonpea was marginally unacceptable. The limited data from this study, using Indonesian students as panelists, should be expanded to assess the preferences of a wider cross-section of regular consumers of *tempeh*.

Future Research

We will examine the following areas in future.

- Chemical and biochemical changes (e.g. metabolism of sugars contributing to flatulence) during the bacterial, and fungal fermentations associated with soaking and *tempeh* production.
- Factors responsible for the unacceptable color of pigeonpea *tempeh* (e.g. levels of tannins and formation of NEB pigments).
- Preparation of acceptable *tempeh*-like products from mixtures of legumes and other grains.
- Incorporation of pigeonpea seed flour and pigeonpea *tempeh* flour (ground, dried pigeonpea *tempeh*) into a variety of traditional dishes as has been achieved for dried soybean *tempeh* (Sunaryo 1984).

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Potential of Pigeonpea as Split Dhal in the West Indies

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Abstract. *Pigeonpea has been grown in the West Indies for a long time, as a vegetable, and as a grain legume. However, production has remained stagnant due to inadequate processing and marketing arrangements. The potential of the crop in the dry split form is yet to be tapped. The value of imports of dry peas and beans in the region, on an average, during the years 1981-86 was US $ 12.5 million per year. Trinidad and Tobago alone accounted for 58% of all regional imports. Split peas for use as* dhal, *constitute more than 80% of imports, since they cannot be grown locally. However, dry pigeonpea after processing into* dhal *could be used as a replacement for split peas.*

This paper attempts to evaluate the potential of pigeonpea as dhal *in the West Indies. The present status of the pigeonpea industry in the West Indies is described, based on an analysis of the trends of production, area under the crop, and yields in different countries of the West Indies. Current uses of pigeonpea are also discussed. The potential for processing dry pigeonpea into* dhal *is established by determining the demand based on current consumption patterns and other economic indicators such as population growth and income projections.*

The economics of processing pigeonpea have been worked out, and sensitivity analysis used to determine its profitability. Factors affecting the realization of the potential are examined, including socioeconomic and institutional factors, and government policies. Arising from the foregoing, ways and means to realize the potential are discussed. Areas for further research are identified, and cooperation between regional and international agencies is emphasized.

Introduction

Pigeonpea is the single most important legume in the West Indies. A report by Henderson (1965) indicated that pigeonpea may have been introduced to the West Indies by the slave trade. Jamaica, Trinidad and Tobago, Grenada, and St. Vincent are important producers of pigeonpea, and the crop contributes substantially to local food security and creating

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employment opportunities. Other countries in the region are expressing interest in producing pigeonpea. Production potential for the crop in countries with a large land-base resource, such as Belize and Guyana, is vast, but they lack the necessary infrastructure.

Present Production System

Pigeonpea production in the West Indies is largely carried out by small-holder farmers. The crop is grown as an intercrop. It is sown mainly with local landraces, 75% of production being harvested as fresh green peas. In-field mechanization is very limited; the cost of production is high, and yields are low. The high cost of harvesting inflates total cost. Lacking an organized market, prices are not regulated, though demand is high. While imports can be substituted, the four most important constraints are: a lack of high-yielding day-neutral cultivars for all-year cultivation; the high incidence of pests, mainly pod borers; the high cost of labor for harvesting; and the high cost of technological inputs.

Area, Production and Yield

Table 1 summarizes the area, production, and yield of pigeonpea in different English-speaking countries of the West Indies.

Pigeonpea produced in the region contributes about one-fifth of the total legumes consumed in the region. Acreages and production have both remained stagnant over time. Production is largely restricted to small farms to meet the market demand for fresh green

Table 1. Area, production, and yield of pigeonpea in different countries of the West Indies.

Country	Area (ha)	Production (t)	Average yield (kg ha^{-1})
Antigua and Barbuda[2]	5	2.5	n.a.
Bahamas[2]	80	40	n.a.
Barbados[2]	7	3.5	n.a.
Belize	-	-	-
Dominica[2]	5	2.5	n.a.
Grenada	496	281	691
Guyana[1]	16	7	437
Jamaica	2246	1887	840
Montserrat	-	-	-
Saint Christopher/Nevis[2]	3	1.5	n.a.
Saint Lucia[2]	1	0.5	n.a.
Saint Vincent	218	196.5	900
Trinidad and Tobago	1900	1425	750
Total	4977	3848	

Source for 1. Caribbean Agricultural Research and Development (1978); For others FAO (1988).
2. No yield estimates were available for these countries. A figure of 500 kg ha^{-1} was used to derive the total production.

peas, or as a backyard crop for family consumption. Yields are relatively low, as the production practices followed by small farmers are rather primitive when compared to practices followed for other high-value crops.

Current Consumption Pattern

Pigeonpea is consumed in all the countries of the region in some form or other. The most important use is at the mature green pea stage. Fresh green peas are cooked with spices for about 10-15 minutes; then rice and water are added, and the cooking is continued. Frozen and canned peas can also substitute for fresh peas. Dry whole peas can also be cooked the same way, but they cook faster if they are pre-soaked in water for 8-10 hours.

A popular use of green pigeonpea is mixing it with curried meat dishes. In West Indian restaurants it is usual to find curried chicken or goat meat mixed with pigeonpeas. Dry peas are generally not used with meat. Pigeonpea is also cooked as a vegetable, often along with other vegetables. It is an important ingredient in popular local soups.

Another use of green pigeonpea is re-emerging in the rural areas of Trinidad, where it is used as stuffing for *rotis* (another popular West Indian preparation) instead of pea *dhal*. The green peas are boiled, mashed, and spiced, before they are incorporated into *rotis*.

In spite of pigeonpea's popularity, its consumption in the region is low, and accounts for less than 20% of all the legumes consumed. Moreover, overall consumption of legumes is also low relative to that of cereals and meat products, and varies substantially among different countries of the region. The variations in consumption seem unrelated to income variations. Relative price differences may serve to explain the dominance of cereals over legumes, but this certainly cannot explain the dominance of meat, fish, and poultry over legumes (Mcintosh 1979). The low consumption of pigeonpea in the region may also be due to the non-availability of pigeonpea all year round, and the easier access of other imported legumes.

Potential

The potential of the pigeonpea crop in the West Indies has never been assessed. Various reports in the region have estimated the current or projected demand based on domestic production and imports. In most cases, there has been an under-estimation of demand, as imports in some of the countries of the region have been based on the availability of foreign exchange, rather than on total demand.

There exists a tremendous potential for increased production and consumption of pigeonpea and other legumes in the region. Caribbean Community and Common Market (CARICOM) estimates the potential for growing pigeonpea in the region to range between 18000-27000 tonnes (CARICOM 1980). This potential cannot be realized unless steps are taken to increase the availability of the products at affordable prices. Improvements in the existing system could improve the performance of farmers with small holdings but they can expand the supply only marginally. The processing of pigeonpea into *dhal* to replace imported split peas seems to have a promising future. Neither a canning industry nor the processing of dry pigeonpea can be developed based only on this source of supply. An earlier comprehensive scheme (de Verteiul 1962), promoted by a food processing firm in Trinidad, to encourage small growers to produce large quantities of pigeonpea for an assured market collapsed after 2-3 years of operation. The main reason for the collapse of the scheme was the inability of small farmers following the traditional system of production to provide the minimum quantities of raw material required to sustain the processing industry.

Figure 1 shows the potential in the region for current uses of pigeonpea, its immediate substitution for other foods, and the long-term uses of pigeonpea.

The Impact of Realizing the Potential

The Caribbean region spent about US $ 12 million in 1986 on importing legumes and pulses. Trinidad and Tobago accounted for 58%, and Guyana 19% of total imports. The realization of the full potential of pigeonpea could save the countries of the region much needed foreign exchange, provide food security, and generate employment.

Future Outlook

The potential for pigeonpea in the region was never fully realized. With many Caribbean governments restricting imports due to foreign exchange constraints, diversification of agriculture has received a new impetus in the region. Since pigeonpea has been identified as one of the crops in the diversification program aimed at reducing the food import bill, the legume could reach its full potential.

The Economic Aspects of Pigeonpea Production and Processing

The continuation of pigeonpea production over time by farmers with small holdings in the region is an indication of its profitability, but the availability of land and labor are the major factors limiting the expansion of production. The full potential of pigeonpea cannot be realized unless a dry pigeonpea production system is also developed in the region. The direct costs of cultivation of pigeonpea was estimated at US $ 470 ha^{-1} (Birla and Ariyanayagam 1988). A well managed crop can be expected to yield an average of 1.1 t ha^{-1}, US $ 0.24 kg^{-1} being the cost of production, excluding indirect costs. The cost of cultivation for projected mechanized dry pigeonpea production is substantially lower than that of cultivating green pigeonpea by farmers with small holdings.

From a preliminary analysis, it appears that locally produced and processed pigeonpeas could compete reasonably well with imported split peas. In the initial years, some government intervention may be required in the form of price support and import restrictions.

Research Program

In order to realize the full potential of pigeonpea in the region, an action-oriented integrated research program must be developed involving all the concerned national, regional,

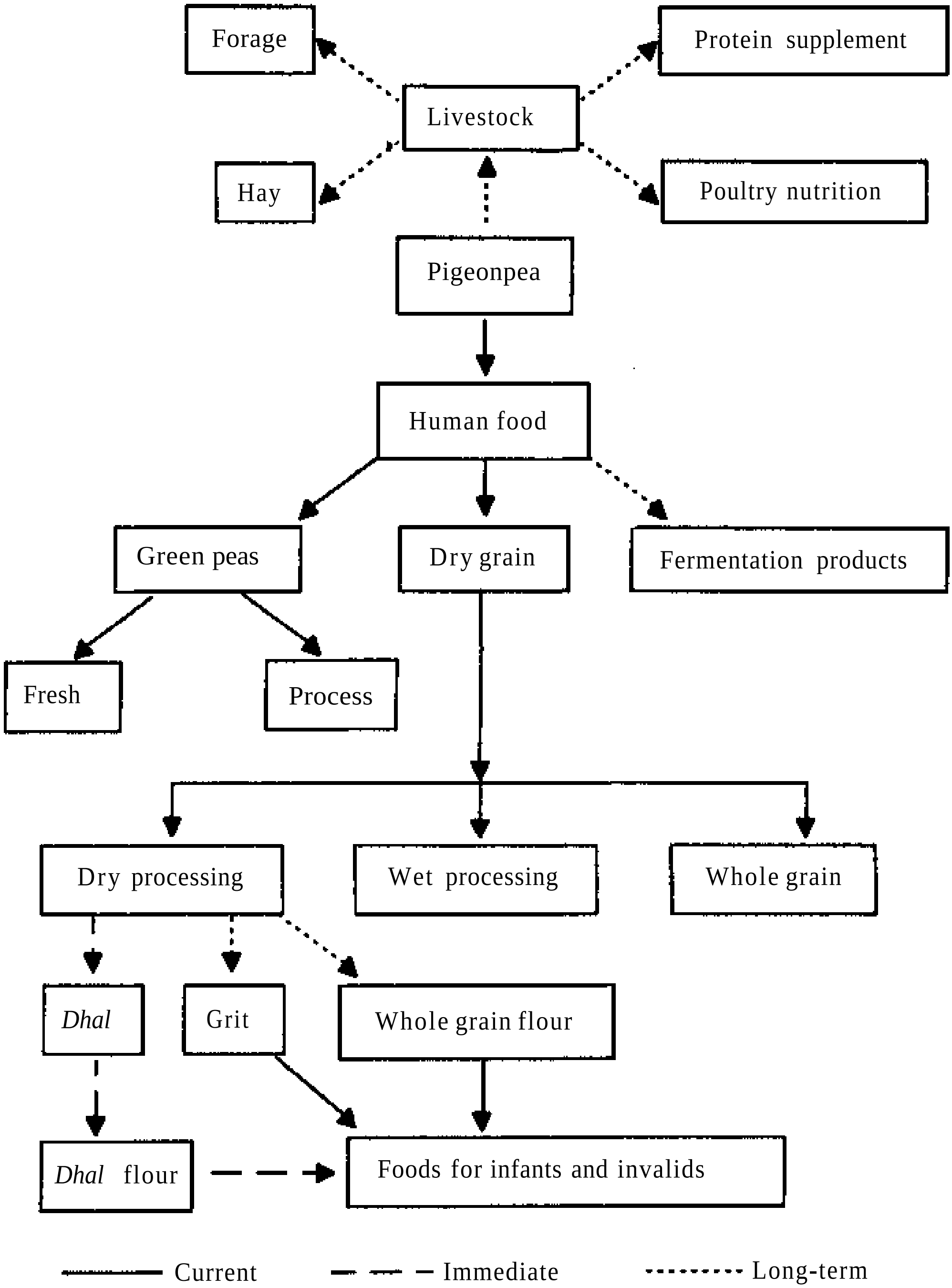

Figure 1. Potential of pigeonpea current uses, immediate substitution, and long-term development.

and international institutions. The main thrust for the future should be targeted at utilizing the crop not only in the green form, but also as *dhal*, flour, and other new products. This will include developing a mechanized system to dry pigeonpeas, and process them into *dhal*. The existing system of green pea production needs improvement in order to meet the growing demand for the product. There is a need to develop a production-oriented program through mechanized system of large scale production of dry and green pigeonpeas for processing. Another area where the crop can be used substantially is as fodder by the livestock industry, which is rapidly expanding.

Establishment of a pilot project to process dry pigeonpea

A pilot project to process dry pigeonpea into dehusked split *dhal* must be set up in the region as a matter of urgency. In view of the climatic factors, and the labor situation in the region, an automatic unit based on improved technology, with a capacity of 0.5-1 t day^{-1} may be most appropriate. It would test the suitability of traditional and improved varieties of pigeonpea for processing, and the market acceptability of the new product.

Development of a mechanized system of dry pigeonpea production

The availability of dry pigeonpea for processing is dependent upon the development of a mechanized system of production for adoption on large estates. Only recently, large Government farms have allocated land to pigeonpea production as part of the policy of governments in the region to diversify agricultural production. Other private estates are also showing interest in pigeonpea production. However, a completely new package of technical know-how, agronomic practices, and a mechanized production system needs to be developed and tested.

Improvement of existing green pigeonpea production

The supply of green pigeonpea is constrained due to the relatively short harvest period. The available supply is not able to meet the demand for fresh and canned green peas in the region. There is a need to introduce and test early and medium-maturing vegetable-type varieties to increase the supply of fresh peas, and ensure their availability.

Nutritional education, information, and development of new products

Pigeonpea *dhal* is a good source of low-cost vegetable protein. Nutritional education is very important in order to replace imported split peas by regionally-produced pigeonpea *dhal*. Moreover, pigeonpea *dhal* is similar to split peas in nutritive value (ICMR 1966). Its use in the region will increase, especially among low-income consumers, as they become more aware of its nutritive qualities, available at reasonable cost. Pigeonpea flour can be substituted for split pea and chickpea flour and used in the preparation of soups and infant foods.

Other Related Projects

Projects which may improve the efficiency of pigeonpea production in the region are listed below.

- A benchmark survey of the current uses in the region.
- A feasibility study to establish a commercial *dhal* mill.
- Benefit-cost analysis of mechanized production.
- Exploring the possibilities of ratooning, especially for dry pigeonpea production after harvesting a crop of green peas.
- Research on sowing and harvesting technology.

The realization of these research objectives can only be achieved through the active cooperation of international, regional and national agencies. In view of the changing socio-economic conditions in the region, it is hoped that the full potential of pigeonpea production and consumption can be realized in the not too distant future.

Acknowledgement

I thank my colleagues, R.P. Ariyanayagam and C.E. Mcintosh of the Caribbean Food and Nutrition Institute for their contributions. The support of the University of the West Indies, Technical Centre for Agriculture and Rural Cooperation (CTA), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which enabled me to participate in the Consultant's Meeting, is greatly appreciated.

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Pigeonpea as a Protein Source in Poultry Diets

Boonlom Cheva-Isarakul and Suchon Tangtaweewipat[1]

Abstract. *The effect of using feeds with high contents of pigeonpea (30-50%), supplemented with methionine on performance, pancreas mass, haematocrit, and mortality rate was studied in 270 7-day-old broiler chickens.*

After 7-day pellet feeding prior to the experiment, birds were randomly allocated to JO treatments, each with 3 replications. Feed and drinking water were freely accessible. The rations contained 12.15-12.57 MJ kg^{-1} with 21% crude protein for birds 1-3 weeks old, 19% crude protein for 3-6 weeks old, and 17% crude protein for birds 6-7 weeks old. The levels of pigeonpea were 30, 40, and 50%, and methionine at 50, 100, and 150% was added above requirement suggested by the National Research Council (NRC). The treatments were compared with the control of 0% pigeonpea, and 50% methionine above the NRC requirement.

No significant mass gain differences were found among the groups at week 7. The feed consumption and feed conversion ratio increased with level of pigeonpea used. The same was found for pancreas mass, while the haematocrit value was not affected. Methionine supplement at the level of 100 and 150% above the suggested level did not improve the performance of the birds fed on high levels of pigeonpea.

Introduction

Pigeonpea has a fairly high protein content (21.3%), relatively low fiber content, rather small seeds and is drought resistant. The crop could be more extensively cultivated in Thailand as a source of vegetable protein for animal feed and as a cover crop to prevent soil erosion in tropical and subtropical areas.

Pigeonpea in Poultry Diets

In recent years pigeonpea has been investigated for use as a component of poultry feed. It was found that 20-30% of pigeonpea could be used in broiler diets, and layer ration at peak

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production without affecting nutritional quality (Tangtaweewipat and Elliott 1988, 1989). In the broiler trial there were no significant differences between the growth rate of birds fed 30-50% pigeonpea and the control, eventhough pigeonpea contains a trypsin inhibitor (Visitpanich et al. 1985a). This might have been due to the concentration of methionine in the feed, which was adjusted to a level above that required by the birds, and its ability to compensate for the non-availability of sulfur containing amino acids caused by the protease inhibitor in pigeonpea (Frost and Mann 1966). This may have resulted in better protein utilization, with no adverse effect on growth, as compared to the control diet that did not contain a trypsin inhibitor (Khayambashi and Lyman 1966). However, the level of methionine in the experiment conducted by Tangtaweewipat and Elliott (1988) might not have been high enough to improve the feed-conversion ratio when pigeonpea constituted more than 30% of the diet; therefore further investigation is needed.

Diet Trials

Two hundred and seventy 7-day-old broiler chicks (Strain Hubbard), were randomly allocated to 10 dietary treatments in a completely randomized design, with 3 replications. Birds in each replication were raised in floor pens 0.9 x 1.8 m^2. Feed and drinking water were supplied ad lib. The diet fed during the 1st week was a commercial starter pellet, containing 21% crude protein (CP). The mash-fed diet during 1-3 weeks contained 21% CP, during 3-6 weeks contained 19% CP, and during 6-7 weeks contained 17% CP. The energy level of all diets was maintained at 12.15-12.57 megajoules (MJ) metabolizable energy (ME) kg^{-1} throughout the experiment. Raw pigeonpea (cv Hunt) was substituted for soybean meal and maize at levels of 30%, 40%, and 50% in the ration, while the control diet (Tl) contained no pigeonpea (0%). All rations were adjusted to contain methionine at 50% above the requirement recommended by the National Research Council (1984) (Tables 1-3), and as the pigeonpea component in the diet progressively increased, methionine was supplemented in the diet at levels of 100% and 150% above the NRC requirement. Body mass and feed intake were recorded at 3-week intervals. At the end of the experiment, when the birds were 7 weeks old, 22% of the birds (one male and one female from each replication) were randomly slaughtered to determine pancreas mass, after blood samples had been taken from two male and two female birds per replication to determine haematocrit value. The data were subjected to an analysis of variance and Duncan's new multiple range test to determine differences among the treatments (Steel and Torrie 1980).

The feeding trial was carried out at the Research and Training Centre, Chiang Mai University from 4 Nov to 23 Dec 1988. The chemical analyses of feed and haematocrit determination were conducted at the Nutrition Laboratory, Department of Animal Husbandry, Chiang Mai University.

Results

Growth rate and feed efficiency

No significant differences were observed among the treatments in mass gain when the birds were 7 weeks old (Table 4). The feed consumption of birds fed diets containing

Table 1. Nutrient composition of broiler diets during days 8-21 (weeks 1-3).

Ingredients	Level of pigeonpea in diets (%)			
	0	30	40	50
Pigeonpea (21.3% CP)	-	30.00	40.00	50.00
Yellow maize (8.9% CP)	50.21	39.20	30.16	26.32
Rice bran (12.0% CP)	19.30	5.00	5.00	-
Soybean meal (44.0% CP)	19.30	10.92	7.90	5.19
Fish meal (57.0% CP)	10.00	10.00	10.00	10.00
Soya oil	-	3.79	5.87	7.47
Oyster shell	0.34	0.23	0.22	0.17
DL-methionine	0.32	0.43	0.45	0.48
L-lysine	0.21	0.11	0.08	0.05
Salt	0.07	0.07	0.07	0.07
Premix (Embavit no. 1 (R))[1]	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Calculated chemical composition (% air-dry basis)				
Crude protein	21.00	20.98	20.98	20.98
ME (MJ kg^{-1})	12.15	12.15	12.15	12.15
Crude fiber	5.68	5.23	5.41	5.41
Calcium	1.00	1.00	1.00	1.00
Available phosphorus	0.48	0.50	0.51	0.52
Methionine	0.75	0.75	0.75	0.75
Lysine	1.23	1.23	1.23	1.23

1. May and Baker products.

Table 2. Nutrient composition of broiler diets during days 22-42 (weeks 3-6).

Ingredients	Level of pigeonpea in diets (%)			
	0	30	40	50
Pigeonpea	-	30.00	40.00	50.00
Yellow maize	67.60	44.96	38.38	28.74
Rice bran	5.00	2.50	-	-
Soybean meal	18.43	8.85	6.12	3.59
Fish meal	7.71	7.71	7.71	7.71
Soya oil	-	4.78	6.66	8.88
Oyster shell	0.56	0.50	0.45	0.40
DL-methionine	0.23	0.29	0.31	0.32
L-lysine	0.11	0.05	0.01	-
Salt	0.11	0.11	0.11	0.11
Premix	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Calculated chemical composition (% air-dry basis)				
Crude protein	19.12	19.00	19.03	19.19
ME (MJ kg^{-1})	12.57	12.57	12.57	12.57
Crude fiber	4.56	4.95	4.96	5.15
Calcium	0.90	0.90	0.90	0.90
Available phosphorus	0.40	0.42	0.42	0.43
Methionine	0.57	0.57	0.57	0.57
Lysine	1.03	1.03	1.03	1.03

Table 3. Nutrient composition of broiler diets during days 43-49 (weeks 6-7).

	Level of pigeonpea in diets (%)			
Ingredients	0	30	40	50
Pigeonpea	-	30.00	40.00	50.00
Yellow maize	67.34	51.25	41.62	33.20
Rice bran	11.00	3.00	3.00	-
Soybean meal	12.98	3.41	0.88	-
Fish meal	7.37	7.37	7.37	7.37
Soya oil	-	3.77	5.98	8.31
Oyster shell	0.70	0.60	0.54	0.50
DL-methionine	0.16	0.22	0.24	0.25
L-lysine	0.08	0.01	-	-
Salt	0.12	0.12	0.12	0.12
Premix	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Calculated chemical composition (% air-dry basis)				
Crude protein	17.23	17.02	17.18	17.82
ME (MJ kg^{-1})	12.57	12.57	12.57	12.57
Crude fiber	4.80	4.78	4.98	5.00
Calcium	0.90	0.90	0.90	0.90
Available phosphorus	0.40	0.40	0.40	0.40
Methionine	0.48	0.48	0.48	0.48
Lysine	0.86	0.86	0.86	0.86

pigeonpea was higher than that of the control, so the feed conversion ratio of the pigeonpea-supplemented diet was significantly higher than that of the control (Table 4). Supplementation of methionine at 100% and 150% levels above the NRC requirement did not improve the feed conversion ratio at any level of pigeonpea incorporation. Although there was a significant difference in bird mortality, it was independent of the pigeonpea or methionine level in the diet.

Pancreas mass and haematocrit value

Pancreas mass, averaged for both sexes, at 7 weeks of age, and calculated as a percentage of live mass gain tended to increase with the level of pigeonpea incorporated in the diet, though this was not significant. Supplementation with high levels of methionine had no effect on pancreas mass. All the groups of birds had similar haematocrit values. Neither incorporation of pigeonpea, nor the high levels of methionine supplement affected haematocrit values (Table 5).

Discussion

The increase in pancreas mass with increasing levels of pigeonpea in the diet might have been due to the presence of a protease inhibitor (Visitpanich et al. 1985). This could be a

Table 4. Production performance of 7-week-old broilers fed diets containing varying levels of pigeonpea and methionine.

Level of pigeonpea in diets (%)	Methionine (%) supplemented above NRC (1984) recommended level	Liveweight gain[1] (kg)	Feed consumption[2] (kg)	PCR[3]	Mortality (%)
0	50	2.25	4.33^{a}	1.93^{a}	0^{a}
30	50	2.17	4.72^{bc}	2.18^{b}	3.70^{a}
30	100	2.15	4.48^{ab}	2.09^{b}	7.41^{a}
30	150	2.22	4.74^{bc}	2.14^{b}	3.70^{a}
	$\bar{X}$	2.18±0.04	4.65±0.14	2.14±0.05	4.94±2.14
40	50	2.22	4.89«i	2.20*	22.22^{b}
40	100	2.03	4.48^{ab}	2.21*	3.70^{a}
40	150	2.17	4.87^{cd}	2.25*	0^{a}
	$\bar{X}$	2.14±0.10	4.75±0.23	2.22±0.03	8.64±11.91
50	50	2.11	4.73^{bc}	2.25*	7.41^{a}
50	100	2.18	4.89^{cd}	2.25*	3.70^{a}
50	150	2.18	5.18^{d}	2.38^{c}	11.11^{ab}
	$\bar{X}$	2.16±0.04	4.99±0.23	2.29±0.08	7.41±3.71
Mean (n=30)		2.17	4.73	2.19	6.30
SE		0.06	0.11	0.05	3.51
CV		4.66	4.07	4.20	96.67

1. No significant differences.
2. Within a column, different superscripts denote significant differences ($P < 0.05$).
3. Feed Conversion Ratio = $\frac{\text{Feed consumption}}{\text{Live weight gain}}$

Table 5. Pancreas mass and haematocrit values of 7-week-old broilers fed diets containing various levels of pigeonpea and methionine.

Level of pigeon-pea in diets (%)	Methionine (%) supple-mented above NRC (1984) recommended level	Pancreas mass[1] (g 100 g)$^{-1}$ live weight	Haematocrit[1] (%)
0	50	0.198	31.18
30	50	0.236	31.29
30	100	0.233	30.90
30	150	0.247	32.31
	$\bar{X}$ (n=3)	0.239±0.007	31.50±0.73
40	50	0.235	33.67
40	100	0.259	32.07
40	150	0.247	35.81
	$\bar{X}$	0.247±0.012	33.85±1.88

Continued

Table 5. *Continued.*

Level of pigeon-pea in diets (%)	Methionine (%) supplemented above NRC (1984) recommended level	Pancreas mass[1] (g 100 g)$^{-1}$ live weight	Haematocrit[1] (%)
50	50	0.246	31.69
50	100	0.248	32.32
50	150	0.260	34.02
	$\bar{X}$	0.251±0.008	32.68±1.21
Mean (n=30)		0.241	32.53
SE		0.019	1.15
CV		13.80	6.10

1. No significant differences.

compensatory effect of the pancreas, which by secreting more proteolytic enzymes counteracts the amount inactivated by the inhibitor in pigeonpea (Schneeman et al. 1977; Struthers and McDonald 1983, and Temler et al. 1984). Khayambashi and Lyman (1966) reported that methionine, with threonine and valine, supplemented to a diet containing a trypsin inhibitor, improved the growth rate of rats. A similar result of methionine supplementation was found in a broiler trial conducted by Tangtaweewipat and Elliott (1988).

The observed higher feed consumption by birds on pigeonpea diets might be due to a compensatory effect for inefficient protein utilization, resulting in a higher feed conversion ratio (P < 0.05). Other reasons that might have aided higher feed intake could be the supplementation of vegetable oil to pigeonpea diets to maintain the diet's energy level. This addition improved the diet's odor and palatability, and reduced dustiness. The higher supplement of methionine at 100% and 150% above the NRC level (1984) did not improve the performance of birds above that of those fed at 50% above the requirement. The level of methionine may be sufficient to compensate for the nonavailability of sulfur-containing amino acids caused by inhibitors in pigeonpea (Frost and Mann 1966). Higher methionine supplementation without adding other limiting amino acids, such as threonine and valine, might cause an imbalance in the amino acid pattern. Surplus levels of methionine will finally be deaminated in the liver (Lehninger 1975). Tangtaweewipat and Elliott (1989) showed that in birds fed a high level of pigeonpea in their diet, threonine deficiency might occur, due to its inefficient use which could have significantly decreased egg production.

The results of this experiment are not in agreement with Springhall et al. (1974) who found an adverse effect on growth when birds were fed pigeonpea at levels of more than 30% in the diet. This might have been due to the fact that they did not take into account the inefficiency of methionine and energy utilization caused by pigeonpea. Also, our results are not in agreement with those of Nambi and Gomez (1983), who found that the highest level of raw pigeonpea that could be incorporated into the diet was 15%. At the 20% level pigeonpea should be autoclaved at 121°C under pressure (1.05 kg cm^{-2}) for 15 min.

Supplementation of 0.2% methionine or 0.2% methionine 0.1% tryptophane to the diet containing 20% pigeonpea did not improve the growth and feed efficiency ratio of birds

(Nambi and Gomez 1983). This might be due to the presence of a higher concentration of inhibitors in the pigeonpea used in their experiment. It might also be due to the insufficient supplementation of methionine and energy balance of the ration.

The result of this experiment seems to agree with the broiler trial conducted by Tangtaweewipat and Elliott (1988). The growth rate and feed conversion ratio of the control group was higher in this experiment than data obtained from a commercial farm. This improved growth rate might be due to better environmental conditions, especially better temperature control and hygiene. There was a significantly higher feed conversion ratio when pigeonpea was incorporated at the levels of 30% than the control, while no difference was found between the two groups in the experiment of Tangtaweewipat and Eliott (1988). However, the feed conversion ratio of the groups fed 30% pigeonpea in the two experiments were comparable. The same tendency was also found at the 40% and 50% level of pigeonpea incorporation.

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Legume Quality Factors Affecting Processing and Utilization

Manel I. Gomez[1]

Abstract. *Much of the plant breeding work on the quality of legumes has been directed towards improving their nutritional quality, notably to increasing protein content, and improving their amino-acid pattern, and the balance and reduction of such anti-nutrient factors such as trypsin-inhibitors and haemaglutinins. Relatively less attention has been paid to quality factors that affect the processing and utilization of legumes. This paper briefly reviews and highlights recent work on the processing quality of legumes, in order to provide pointers to future objectives and strategies in legume improvement programs as they specifically apply to ICRISAT mandate crops.*

Quality factors affecting cooking time and cookability are major determinants of utilization and processing potential. Some of these, such as water absorption, hydration, starch gelatinization, and the effect of processing treatments on these characteristics are reviewed. Postharvest and storage-quality changes in legumes, which cause the hard-to-cook phenomenon and the mechanisms involved, are discussed to illustrate the importance of good storage conditions.

Available processing technologies, such as germination, fermentation, and protein isolation/concentration, as well as newer applications of groundnut and chickpea in such novel foods as beverages and pasta products, are examined in relation to grain and food quality requirements.

Introduction

Most plant breeding work related to the food quality of legumes has in the past been directed towards improving their nutritional quality, notably increasing the protein content, and improving the amino-acid pattern, and balance and reduction of antinutrient factors such as trypsin-inhibitors and heamagluttinins (Bliss 1973, Kelly 1971, Dickson and Hackler 1973, Jeswani et al. 1970).

Relatively less attention has been paid to quality factors that affect processing, utilization, and consumer acceptance of legumes. This paper briefly reviews and highlights more

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recent work on the processing quality of legumes to serve as pointers to future strategies in grain legume improvement and utilization. The review will include work on legumes other than the specific ICRISAT mandate legumes, to illustrate areas of relevant research and investigations with likely applications to the mandate crops: chickpea, pigeonpea, and groundnut. Some selected processing technologies will be discussed to indicate the scope and potential of expanding and diversifying the utilization of these crops.

Cookability

Cookability, as applied to legume seeds, has been defined as 'the conditions by which they achieve a degree of tenderness during cooking, acceptable to the consumer'. In most countries, legumes are commonly prepared for traditional consumption by soaking for varying periods and then boiling. A characteristic property of nearly all dried legumes is the long cooking time of 3-4 h required to attain the required degree of softness and palatability ('doneness'). In high altitude regions, such as the highland plateau of Africa, cooking time is even further increased.

In the semi-arid regions, with shortages of energy resources, notably fuelwood for food preparation, cooking time and cookability are important criteria for domestic utilization.

Traditional processing methods and pretreatments designed to reduce cooking time include soaking in water for periods of up to 24 h, and the use of traditional softening agents, such as *'Magadi'* soda in eastern Africa.

Water absorption is an important determinant of the rate of hydration and of cooking properties. Water absorption is to some extent determined by heredity, but it is also influenced by environmental factors, such as agronomic and storage conditions. Starch and protein are the major components involved in the hydration process, while seed anatomy and cellular structure are just as important. Agbo (1982) demonstrated significant differences in processed food quality between two dry bean strains of the same genotype that differed only in a single gene for seed-coat color. This monogenic difference affected the water uptake and starch gelatinization characteristics.

Initial moisture content, seed-coat thickness, texture and permeability, and storage temperature have been shown to affect water uptake in cowpea (Sefa-Dedeh and Stanley 1979, Moscoso 1981) and dry kidney bean. In several species of legumes, a good correlation between phytic-acid content and cookability have been observed (Kon 1968, Kumar et al. 1978, Mattson et al. 1950). The mechanism proposed is that phytic acid chelates calcium, reduces the formation of calcium-pectic complexes responsible for hard texture, and exhibits a texture-softening effect.

Hard-to-Cook (HTC) Phenomenon

Long storage periods under tropical conditions result in HTC. This phenomenon has been reported in several species of legumes including cowpea and red kidney bean (Jackson and Varriano-Marsten 1981, Sefa-Dedeh et al. 1979). HTC results from deterioration during storage and reduced water absorption (hard shell) and cookability of cotyledons (Sclerema), accompanied by deleterious changes in texture and flavor. Mejia (1979) reported a significant correlation between an increase in tannin content and hardness, attributable to temperature- and humidity-dependent changes in condensed tannins, and continued development of tannin from low-molecular mass nontannin material. The loss of cookability of dry kidney bean in storage has been related to the reduction in phytic acid phosphorus, and changes in the ratio of monovalent to divalent cations in soaked bean. The reduction in phytic acid and monovalent cations results in lower solubilization of pectic substances through chelation and ion exchange during cooking (Moscoso et al. 1984).

HTC is overcome by the use of salt solution for soaking the legumes. Salt alters the configuration and conformation of native proteins, thus increasing their solubility, reducing steric hindrance, and exposing more peptide bonds to hydrolysis. Salts also break the hydrogen bonds between protein and condensed tannins. Salt reduces the calcium- and magnesium-mediated interactions between phytic acid and protein and between minerals and pectin, altering the microstructure of black bean, making them more porous and permitting easier penetration of heat and water (Sievwright and Shipe 1986). Rockland and Metzler (1967) observed that soaking dry bean in food-grade salt reduced HTC.

The foregoing review and discussion illustrates the need to consider and evaluate the following quality factors, as indices to evaluate the processing quality of chickpea and pigeonpea.

- Seed coat thickness and permeability
- Tannins and phytic acid
- HTC
- Starch gelatinization

There is inadequate information on quality aspects of these legumes and research efforts in these areas are indicated.

Processing Technologies and Products

Fermented legume products have been prepared and consumed in the Orient for centuries. Many fermented soybean foods, such as *miso natto* and *tempeh* are consumed as traditional foods, but have also been commercialized in Japan, Thailand, and Indonesia.

Tempeh, the product of a legume fermentation based on a fungal organism, *Rhizopus oligosporus,* is of special interest as a supplement to vegetarian diets, because of its nutritional and flavor characteristics (described as meaty, nutty, and chicken-like). Robinson and Kao (1974) have developed a *tempeh* from chickpea and faba bean, and work on a pigeonpea *tempeh* is in progress in Indonesia. A shelf-stable, palatable, and nutritious *tempeh* was developed from red kidney bean (Gomez and Kothary 1979), which effectively reduced cooking time from 3-4 h to 20 min, and produced a ready-to-eat *tempeh* in a 48 h incubation period. The pilot-scale flow chart of this process is shown in Figure 1 and the following details and features of this process merit special attention.

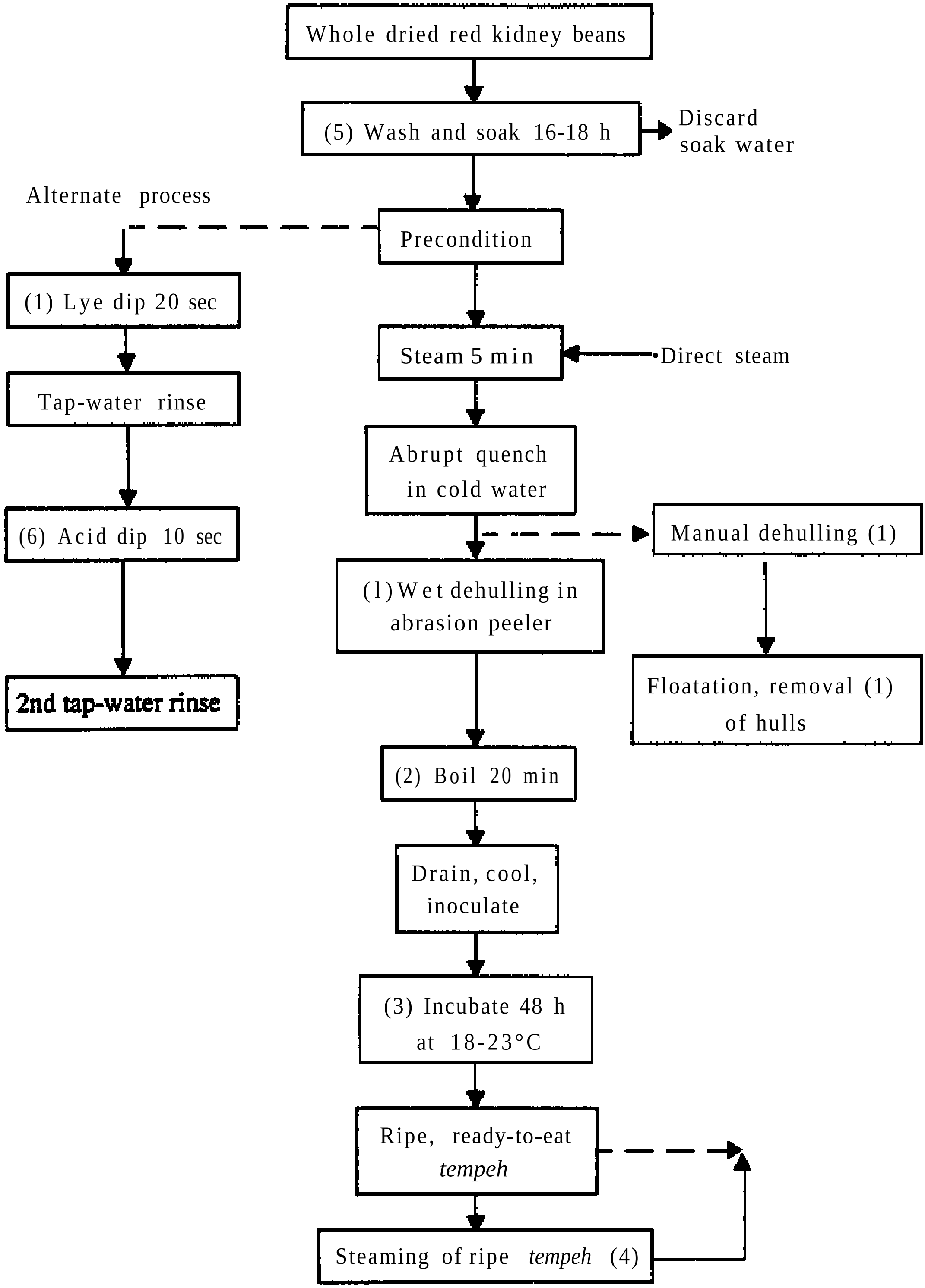

Figure 1. Flowchart for pilot-scale process for red kidney bean *tempeh* production. (Gomez and Kothary 1979).

- Dehulling was found to be essential for adequate penetration and growth of the fungal mycelia. Therefore dehulling pretreatment step by alternative chemical (lye) treatment or physical treatment involving quick steaming and cold-water quench, or mechanical or manual dehulling should be considered.
- Optimization of prefermentation boiling conditions to: (a) sterilize the bean mass; and (b) achieve sufficient starch gelatinization within the cotyledons to soften the starch granules but not to cause their expansion, as otherwise this would fill the interspaces between cotyledons and inhibit the growth and penetration of the mycelia within the bean mass.
- Ambient temperature incubation for 48 h to avoid costly heating/incubating equipment.
- Steaming of ripe *tempeh* to arrest further mold growth (and sporulation) and to pasteurize the product prior to storage 'as is' or oven/sun drying to a shelf-stable moisture content.
- Prevent migration of hull color into cotyledons by (a) presoaking to leach out water-soluble pigments, and by (b) dehulling.
- pH values as low as 4.5 were not inhibitory to mold growth.

The following quality factors are important criteria for the production of legume *tempeh:*

- Ease of dehulling and thickness of the testa
- Testa color and migration behavior of pigments into cotyledons
- Water absorbed
- Amylose content and gelatinization temperature of starch

Germination

Several studies document the improvement in nutritional quality of grain legumes effected by germination. Sprouted legumes, such as mung bean, are widely consumed as fresh and canned products, and are known to have significant nutritional advantages over non-sprouted grain, such as increase in Vitamin C content and decrease in antinutrient factors. Germination of other legumes is, however, not yet widely practised on a traditional or commercial scale. While flavor and functional and nutritional improvements in malted cereals have been exploited in the commercial production of beer, food, and flavor malts, comparatively little work has been carried out in the utilization of germinated legumes.

Mosha and Svanberg (1983) observed an important property of sprouted cereals, i.e., the reduction in dietary bulk accompanying the reduction in viscosity of germinated cereal-water mixtures. This property was used to advantage to increase the nutrient density of cereal-based weaning foods. Marero et al. (1988) have recently applied the same principle to prepare blends of cereal:legume germinated flours to prepare a protein-supplemented weaning food of high nutrient density and digestibility. Blends of 70% cereal (rough rice and maize) and 30% legumes (mung bean and cowpea) were found to provide over 1/3 of the dietary requirements of protein and calories for weaning-age children.

Soaking Pregermination

Soaking, as a pretreatment or pregermination step, has received limited attention as a process. Many studies report only on the net effects of soaking and germination. Since this is a simple no-cost technology applicable at the domestic level, it is worthwhile investigating more extensively the effect of soaking on quality changes in legumes. Soaking is widely practised on a domestic scale as a pretreatment for wet dehulling and grinding, based on the obvious physical benefits of swelling, water uptake, and resultant softening and loosening of seed coats. The hydration process however also brings about the mobilization of enzyme systems, and a differential analysis of only the soaking process could assist in identifying the benefits and advantages of soaking as a pretreatment for boiling, or for preparation of wet-ground, dried legume flours.

In an experimental study on Bambara groundnut, (Gomez, unpublished) for example, a significant reduction in trypsin-inhibitor (TI) activity and phytic acid was noted in the 24-h soak period; TI remained stable over the following 5-day germination period, while phytic acid continued to decrease (Table 1). Similarly, concentration of most amino acids was higher at the 24-h soak time than at germination (Table 2). These results indicate a need to evaluate soaking as a process, more fully for its physical, biochemical, and functional quality changes.

Beverages

The viscosity-reducing property of germinated chickpea has also found application in the production of a legume beverage. A chickpea-based chocolate beverage was developed in Mexico to increase local consumption of chickpea, since most of the chickpea grown is exported. However the product's high viscosity made it unacceptable (Fernandez de Tonella et al. 1981). The beverage from germinated chickpea showed decreased viscosity and improved consistency when compared to a control formulated from nongerminated chickpea, attributable mainly to a 15% reduction in starch (Fernandez de Tonella and Berry 1987).

At the Central Food Technological Food Research Institute (CFTRI) in India, a high-protein drink known as Miltone was prepared from groundnut-protein isolate (Chandrasekhara et al. 1971). In the Philippines, a country dependent on imports of milk and dairy products, a nondairy milk substitute has been produced using nondefatted or partially defatted groundnut using low-cost technology (Rubico et al. 1987) (Fig. 2). Though groundnut milk preparations have been studied extensively (Schmidt and Bates 1976, Beuchat and Nail 1978, Encarnacion and Rillo 1982), process and product optimization is still to be achieved with respect to flavor, texture, emulsion stability, and shelf life. Defects, such as 'chalkiness' and suspension-stability problems, causing 'creaming' or 'layering', have still to be overcome.

Table 1. Changes in phytic acid and trypsin inhibitor units (TIU) because of soaking and germination.

Soaking time	Phytic acid unit (mg 100 g^{-1})	TIU (mg^{-1})
Oh	1095	29.7
8 h	881.2	21.9
12 h	-	19.4
24 h	806.2	16.9
Days after germination		
Day 1	806.2	-
Day 2	731.5	-
Day 4	637.5	-
Day 5	562.5	16.2

Table 2. Amino-acid composition of Bambara groundnut dry, soaked, and germinated, g.(16 g N)$^{-1}$.

	Treatment		
Amino acid	Dry	Soaked	Germinated
Lysine	6.0	15.1	9.7
Histidine	3.5	7.6	5.5
Arginine	6.7	13.3	8.6
Aspartic acid	14.3	19.5	14.3
Threonine	4.5	5.2	4.2
Serine	5.6	6.0	4.7
Glutamic acid	21.9	29.5	23.4
Proline	5.8	6.3	6.1
Glycine	4.7	6.7	5.2
Alanine	5.3	8.6	6.6
Valine	4.8	10.2	8.2
Methionine	1.7	1.1	0.8
Isoleucine	5.2	8.6	5.8
Leucine	8.9	14.4	10.9
Tyrosine	2.4	1.2	0.9
Phenylalanine	6.6	10.5	8.7

Canning

A canned pigeonpea product was attempted by Sammy (1971), but problems of color changes and color migration into the canning medium were encountered. The processing of green pigeonpea, however, has not been reported and is likely to cause fewer problems of color stability and migration since seed coat is lighter during earlier stages of growth. Similar attempts at processing green Bambara groundnut in brine solution gave a highly acceptable canned product. Some of the more important quality requirements in relation to canning are summarized as follows:

- Integrity and reduced tendency to split, break, or disintegrate on autoclaving
- Texture retention

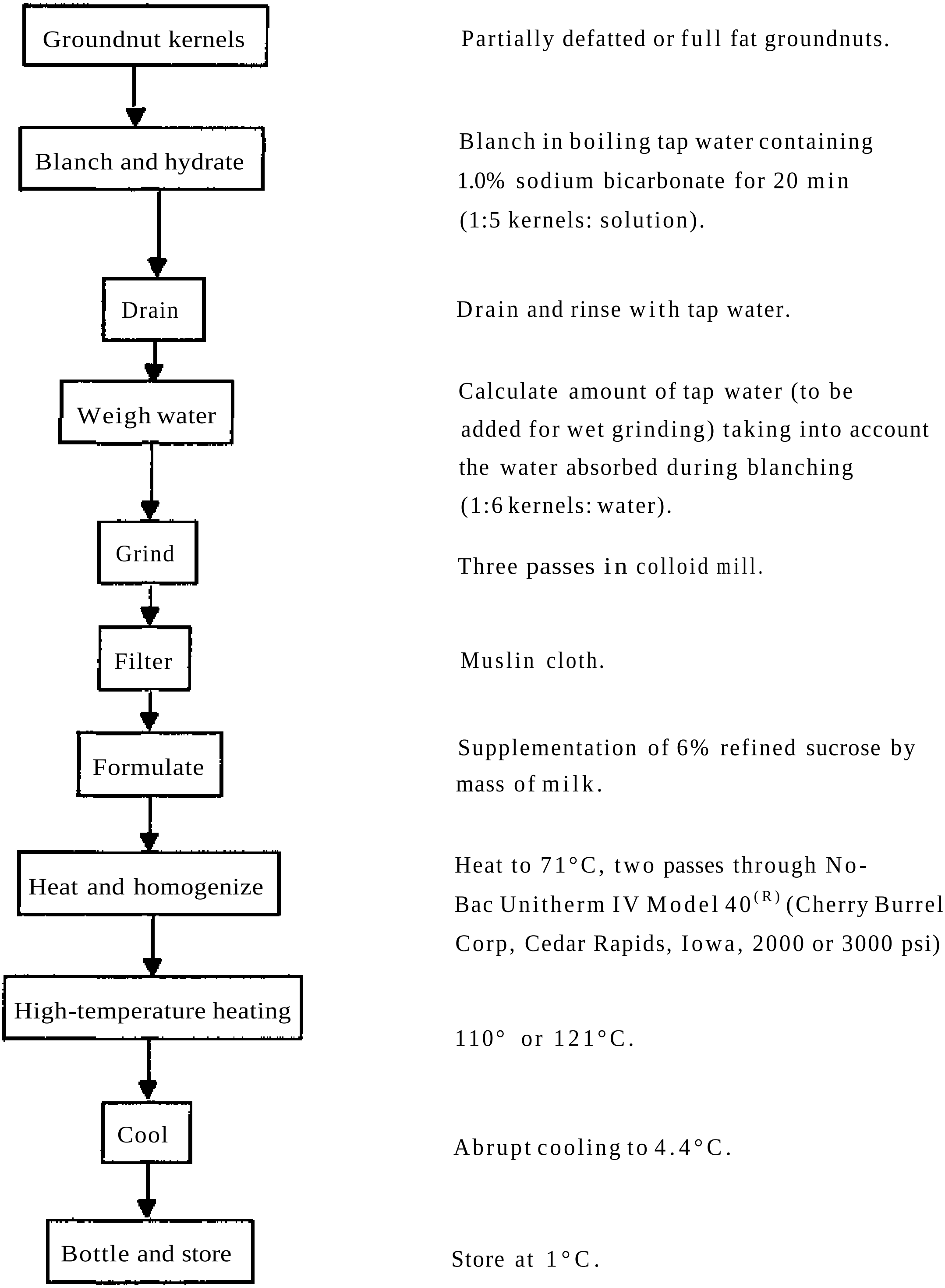

Figure 2. Flowchart for preparation of groundnut beverages.

Source: Rubico et al. 1987.

- Reduced release of starch from starch-protein matrix of cotyledons to canning medium
- Color stability, i.e., minimum color change (fading, browning) and minimum color migration to canning medium
- Starch hydration and gelatinization properties

Gluten-free (GF) Pasta Products

Pasta and noodle products are popular foods in southeast Asia. A mung-bean noodle and vermicelli product is produced commercially in Thailand. In wheat-containing pasta products, the gluten surrounds the starch granules and its viscoelasticity restricts starch swelling, confers cohesion, and prevents leaching during cooking. In GF-pasta products, the starch must provide the network. For this purpose high amylose genotypes are preferred where the high-amylose starch functions in a manner similar to the gluten, providing cohesiveness and integrity, and preventing leaching during cooking. Mestres et al. (1988) working on mung-bean noodles observed that the gluten network is replaced in the GF product by a ramified three-dimensional network of short segments linked to one another by junction zones. The structure and strength of these junction zones is attributable to amylose crystallites, of melting point exceeding 100°C. The starch gelatinization characteristics of high-amylose genotypes need to be evaluated for pasta-type products.

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Grain Legume Protein: Chemistry and Utilization

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Abstract. *Legumes can be roughly classified as rich sources of proteins, carbohydrates or oils. Groundnut is a rich source of oil, while pigeonpea, and chickpea are rich in carbohydrates and proteins, an important property of nitrogen-fixing legumes. Legume proteins are very diverse. Purified seed proteins from legumes were once grouped into legumin and vicilin types, but many legume storage proteins cannot be included in these two categories by ultracentrifugal and electrophoretical studies.*

Recent biotechnological research on legume proteins and DNAs using restriction enzymes and sequencing techniques have revealed details of similarities and differences between legume proteins. However, under practical conditions proteins are not used in a purified form, but along with other substances. Fundamental and analytical studies have produced a partial explanation for the interactions of legume components and their role in legume utilization.

Meanwhile, extending traditional and new utilization methods of some legumes to others seems to be a feasible proposition. There are many legume products, especially of soybean in Japan, which utilize their protein-rich properties. Examples of such products, and expanding applications of the processing mechanisms to other legumes, are described.

Edible Legumes

Approximately 100 species of legumes are considered to be edible from among the over 13,000 legume species found in the world. For 39 species of edible legumes, information is available on area and method of cultivation, chemical composition, and utilization. Groundnut is far superior to the other legumes in seed-oil content (over 45%). Pigeonpea

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and chickpea are high in carbohydrate but low in oil content. The protein content of these three legumes range between 20% and 26%. The importance of legume proteins cannot be over-emphasized in human foods and in animal feeds.

The production and yield data of the main legumes over the last 20 years show a remarkable increase in soybean production, which doubled in the 1970s, and continued to increase gradually in the 1980s. The considerable increase of groundnut production during the same period is noteworthy. Other important pulses showed small but clear increases in the 1980s, after recovering from a decline in production in the 1970s.

Properties of Legume Seed Proteins

The physicochemical properties of legume-seed proteins are summarized in Table 1. Storage proteins of legume seeds have been grouped into legumin (11~20 $S°_{20,w}$) and vicilin types (6~9$S°_{20,W}$) (Derbyshire et al. 1976), although recent studies revealed that this grouping is not suitable for all legume seed proteins. Reported sedimentation coefficients (S) and molecular weights (MW) of legume-seed protein should be compared carefully, because often the expression is not $S°_{20,w}$. Further, the sample varieties, degree of purification, and conditions of measurement are very important factors that affect data. However, when there is a clear difference in protein molecules, this may reflect on the quality of the legume food products. For instance, winged bean seed has oil and protein contents similar to those of soybean seed. It would, therefore be processed into *tofu* or *miso* just like soybean. However, the products from winged bean are not similar to those from soybean (Shurtleff 1978, Ohmachi et al. 1983, Saio et al. 1984). Though this difference may not be the result of the protein configurations, it may be due to the protein characteristics, since the products are protein-rich.

The subunits of legumins and vicilins differ among species, and sometimes among varieties of the same species (Table 1). It is considered, for instance, that the existence of amounts of one subunit (denoted as A_4 or A_5), of glycinin, which is genetically controlled in some varieties of soybeans, is reflected in the hardness of *tofu.* The details of legume-protein subunits have been studied recently (Murasawa et al. 1988; Nakamura et al. 1985).

Optical schlieren patterns of legume seed proteins sedimentated by ultracentrifugation are shown in Figure 1. Major similarities within the same species, and minor differences among the varieties of soybean, winged bean, and haricot bean can be seen (Yanagi 1979, Yanagi et al. 1983, 1984). Winged bean and haricot bean belong to similar families. However, the major proteins of these three legumes react differently to changes in the pH or ionic strength of buffers (Yanagi 1983, 1984). This observation indicates that the behavior of each legume protein during food processing may be different.

Analyses

Data obtained on protein biosynthesis of soybean and winged bean during seed maturation showed that smaller-molecule proteins are synthesized during the early stages of maturity, and larger-molecule proteins are synthesized at later stages (Yanagi 1984). This observation

Table 1. Properties of legume seed proteins.

	Sedimentation coefficient[1] $S^{\circ}_{20,w}$	**Molecuar weight ($\times 10^{-3}$)**	Subunit[2] MW(x 10-3)	Other report
Groundnut				
Legumin type	13.2˜14.7	330~396		
Vicilin type	7.8˜8.7	142~190		
Soybean				
Legumin type (Glycinin)	12.0~14.0	309~380	A_1,A_2,A_3:37 A_4 :45 A_5 B_1, B_2, B_3:22	amino acid N-terminal composition sequence
Vicilin type	6.7~8.0	105~330	**α,α_1:55~62** **β:42~48** **γ:42~48**	amino acid N-terminal composition
Lupin				
Legumin type	11.6~12.6	336~393	15.5, 21,29	
Vicilin type	7.8~8.3	181~204	34.5, 42.5 48.5, 58, 66	
Haricot bean				
Legumin type (acidic pH)	11.6~19.2	340	α:48.5~51	protease digested
Vicilin type	6.8~7.3	125~151	β:47~48 γ.45~46	fragments amino acid sequence
Pea				
Legumin type	12.1~13.1	330~398	α;40 β:20	amino acid
Vicilin type	7.1~8.1	140~151	50(33+16) 33(19+14) 19, 14, 13.5 16(13.5+sugar)	N-terminal sequence
Broad bean				
Legumin type	11.4~13.7	320~410	A_1:51, A_2:49 A_3:36, B_1:23 B_2:20.5, B_3:19	
Vicilin type	7.1	150		
Cowpea				
Legumin type	12.2	320		
Vicilin type	7.3			

Continued

Table 1. *Continued*

	Sedimentation coefficient[1] $S^{\circ}_{20,w}$	Molecuar weight ($\times 10^{-3}$)	Subunit[2] MW ($\times 10^{-3}$)	Other report
Winged bean				
Legumin type	none			
Vicilin type	6.5~7.1			

(Revised and translated from Yanagi 1986. 'Edible legume seeds and their proteins II. (in Jap.)', New Food Industry 28:65-75].

1. $S^{\circ}_{20,w}$ is the sedimentation coefficient at the idealized condition of protein concentration 0% in a solution of ionic concentration 0 at 20°C.
2. The subunit names were used according to each original project.

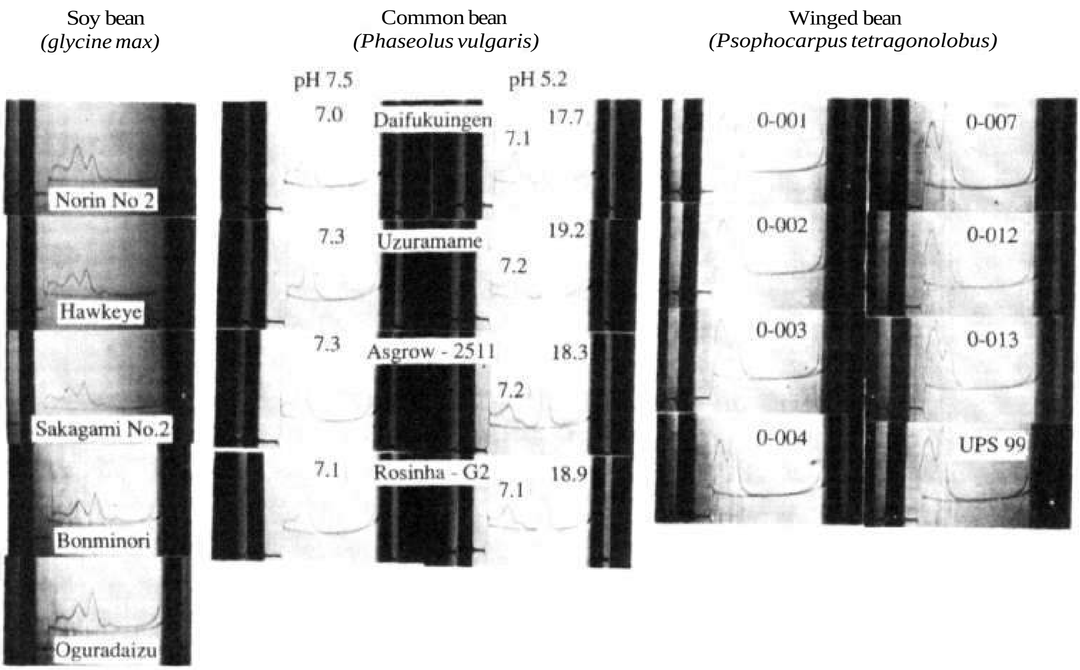

Figure 1. Optical schlieren patterns of legume seed proteins.

Table 2. Common soybean foods in Japan.

Fermented	
Miso	Paste, made from steamed soybean, salt, and *koji* (rice or barley or soybean grain processed and incubated with *Aspergillus oryzae* and *Zygosaccharomyces rouxii),* and fermented with *Candida* sp., *Pediococcus* sp. and other microorganisms. Used widely for soup, seasoning, and pickles.
Shoyu	Soybean sauce, made by compressing *moromi* (steamed soybean, parched wheat grain, and salt, and fermented mostly with *Aspergillus oryzae* or *A. sojae,* and *Zygosaccharomyces rouxii, Candida* sp, and *Pediococcus* sp. An indispensable flavor base used for many Japanese dishes.
Natto	Fermented whole or split soybean grain, boiled, and inoculated with *Bacillus natto.* Generally mixed with boiled rice and eaten with *shoyu.*
Non-fermented	
Tofu	Soybean curd. Soaked and ground soybean steamed, filtered through a cloth, and the extracted soybean milk coagulated with $CaSO_4$ (and/or deltaglucono lactone, $CaCl_2$). Various food products, fresh, baked, fried, or frozen are traditionally made with it.
Soybean milk	Soaked soybean ground, boiled, and filtered through a cloth. Recently used for health drinks. Soybean milk is sweetened and flavored before it is packed and sold.
Yuba	Soybean milk slowly heated in a flat dish/pan, and the solidifying surface film *iyuba)* repeatedly skimmed. Fresh and dried *yuba* is used to make snacks, soups, and other dishes.
Kinako	Parched soybean coarse ground, dehusked, and finely ground. Used mainly for flavoring cakes or snacks, with sugar and other flour.
Other products :	Soybean sprouts, Whole soybean flour, Defatted soybean flour, Cracked soybean, and Soybean oil

has been confirmed by electrophoretic and immunological studies (Yanagi et al. 1978). In a buffer, the ratio of glycinin (soybean legumin, "11 S") to conglycinin (soybean vicilin "7 S") extracted is higher than it is in water (Yanagi et al. 1985). Protein extractability (or proportion of protein) and protein molecular size changes according to the conditions (temperature and humidity) of storage. This observation could be one of the reasons that contributes to the different reactions of stored beans or flour during food processing.

The main soybean foods consumed in Japan are the traditional dishes *tofu, yuba,* and soybean milk (Table 2). Defatted flour, a by-product of oil extraction is a new protein food increasingly used in various snack foods. Other products are prepared mostly from whole beans, but soybean is primarily added to improve their protein content.

Future Research

Various studies have been conducted on winged bean since the publication of the review of the U.S. National Academy of Science (1975). New research in legumes is expected to provide additional knowledge that will give an impetus to the utilization of legumes. Research areas identified include biotechnological studies, amino acid sequence, determination of functional properties, mechanism of biosynthesis, and gene recombination for breeding improved genotypes. Cell and tissue culture and protoplast fusion also offer hope for incorporation of desired characters in legumes.

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Processing and Utilization of Soybean and Diversification of End-uses through Extrusion Processing

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Abstract. *Conventional soybean processing technology is based on solvent extraction, which is a large-scale process involving heavy capital investment and large volumes of raw material. The direct use of soybean in food products is a logical approach to fully harness its protein and energy value. Low moisture, high shear, dry extrusion systems are relatively low in cost and capable of continuously processing soybean and soybean/cereal blends. They generate heat by friction, and are capable of cooking, partial sterilization, expansion, partial dehydration, enzyme inactivation, and to some extent, shaping the product. Dry extrusion of cereal/legume blends in appropriate proportions yields convenience foods of high nutrient density. Products, such as blended foods for nutritional intervention, expanded snack foods, breakfast foods, and ready mixes can be manufactured by dry extrusion.*

Recent research has demonstrated that dry extrusion can be used as a pretreatment for soybean before oil extraction using conventional expellers. This process yields natural oil and high quality low-fat meal that can be easily milled into flour. The concept offers potential to serve as a technology base for medium-scale processing of soybean on a decentralized basis. The technical aspects of dry extrusion, functionality of the potential products, and their applications in food systems are discussed.

The composition of a cereal/legume blend plays a vital role in the nutritional and functional characteristics of final products produced by extrusion. Development of specific products must be approached on a country-specific basis, with due regard to local food habits and preferences. Chickpea, pigeonpea, and groundnut are rich sources of protein. However, they differ in the distribution of fat and carbohydrate contents. The potential for producing low-fat flour from groundnut, and its combination with the other legumes to produce locally acceptable extruded products may be an interesting area of research. The use of soybean in combination with ICRISAT mandate legumes will extend the available supply of the latter.

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Introduction

Soybean is the world's leading grain legume crop. It contains approximately 20% oil and 40% protein. Conventionally, it has been exploited primarily as a source of edible oil for human food, and of protein-rich meal for livestock. Traditional soybean foods have been consumed in Oriental countries for centuries, but this accounts for only a small fraction of the world soybean crop. Many developing countries have recognized the potential of soybean as a source for supplementing the traditional cereal staples with much-needed protein and calories. National-level programs are in place in many developing countries to expand the production potential of soybean. India has already attained a production level of 1 million t year^{1}.

Nutritional Considerations

Soybean is rich in both protein and oil; but contains little or no starch. Soy protein is rich in lysine, which is deficient in cereals, but is somewhat deficient in the sulfur-bearing amino acids, that are contained in adequate quantities in cereals. When soy protein and cereal protein are combined in appropriate proportions, the nutritional value of the product approaches that of casein. This nutritional complimentarity is found to be optimum when cereals and soybean are blended so that 50% of the total protein in the blend is contributed by each of the ingredients (Bressani and Elias 1974). Blends of 70 parts by weight of cereal and 30 parts by weight of soybean on dry-matter basis satisfy this requirement. The direct use of soybean in food products results in the incorporation of oil which increases caloric density. Natural soybean oil is highly unsaturated and contains approximately 7% of omega-3 (alfa-linolenic) fatty acid. Recent research (Kinsella 1988) indicates that omega-3 polyunsaturated fatty acids in the diet may be beneficial for the cardiovascular health of humans.

Appropriate heat treatment during processing greatly improves the nutritional value of soy protein. This is attributed to the destruction of natural anti-tryptic factors and also to the thermal denaturation of proteins (Rackis 1972). Heat treatment also inactivates undesirable enzyme systems, such as the lipoxygenases which produce off-flavor. The process must also ensure adequate tenderization of the bean tissue, which is tougher than those of other food legumes.

Strategies for Food Use of Soybean

In recent times, traditional oriental soy foods have appeared on the grocery shelves in western countries. Products such as soymilk, *tofu,* and *tempeh* find a market conditioned primarily by health considerations. This market may grow, provided inputs are available for advertising, product improvement, and adaptation to suit the new market environments. The technical feasibility of converting soybean into flour and using it to fortify cereal flours has been established for a long time. However, this approach has not found wide application in developing countries where it is most needed. Logistical and pricing problems have been constraints to the wide use of this concept. The technology developed for processed foods, such as meat substitutes and meat extenders, is available. Unfortunately, these products are marketed at about the same price as meat products, and the high cost of production keeps them out of reach of the most needy segments of many populations. Therefore, it is evident that alternative approaches to soybean processing are needed in order to benefit the majority that need better nutrition.

The International Soybean Program (INTSOY) and the Department of Food Science of the University of Illinois have carried out considerable research and development work on the processing of whole soybeans into food products. Through basic and applied research, and through international programs, INTSOY has developed a three-pronged approach for soybean utilization. INTSOY advocates that a successful national program for soybean utilization must concentrate on the development of technology and products appropriate at the home, village, and commercial levels.

Extrusion Processing

Extrusion has become a widely used processing technique for the manufacture of a variety of food products. A variety of extruders have been developed, and they vary in their capabilities and cost. In the simplest form, an extruder consists of a flighted Archimedean screw rotating within a tightly fitting barrel, a device to feed raw material, and a die through which the final product is discharged. The screw and barrel are designed so that the raw material will be carried forward with progressive compression. Part of the mechanical power input for driving the screw is converted into heat by friction. The product finally emerges through a die. The extruder will continuously cook the input material by a high-temperature, short-time treatment. Extruders vary in the design of screw, barrel, and die, and the flexibility of temperature control during processing.

Dry extruders are single-screw, high-shear, autogenous extruders that generate heat purely by friction. The term dry extruder is used because the equipment can extrude raw material at a low moisture content so that the final product needs little or no further drying. The INSTA PRO Model-600 (Insta Pro International, Iowa, USA) is a typical example of a dry extruder. It has a segmented barrel and screw. The screw segments slip over a central-keyed shaft with ring-like flow restrictors called steam locks placed between the individual screw segments. Different screw configurations are achieved by the order of assembly of screw segments and steam locks. Barrel segments slipped over the assembled screw are clamped together to form a continuous barrel. The die is attached to the end plate, which is clamped to the barrel to complete the assembly. The extruder is powered by a 50 horse power motor which turns the screw at 550 revolutions min^{-1} (rpm). The screw and barrel components of the extruder can be run for more than 5000 h before they need to be replaced. A variable-speed feeder enables feeding of the extruder at a desired constant rate. Provision is made for injecting either water or steam into the feed section of the barrel during processing.

Capabilities of the Dry Extruder

Dry extrusion systems are capable of continuously cooking legumes or mixtures of cereals and legumes in a high-temperature, short-time cycle. Residence times of 30-120 sec and temperatures of 140-160°C can be achieved. The operating variables of the extruder and the composition of the raw material can be varied in order to obtain desired product characteristics. These extruders are relatively simple to operate and maintain. However, some skills have to be acquired for trouble-free operation. Since food raw materials are complex multi-component systems, a given blend of raw material has to be matched with a compatible extruder-screw configuration, appropriate moisture content, product flow-rate, and temperature profile in order to obtain consistent product quality.

Dry extrusion is a continuous operation, and relatively large rates of throughput can be obtained for a relatively small capital investment. The equipment is compact and floor-space requirement is minimal. This technique is useful in the decentralized processing of products which have a mass appeal. Dry extrusion incorporates the convenience of ready-to-serve products, and the consequent saving of the housewives' time for more gainful employment. The nutritional value of the products and other quality characteristics can be easily controlled in this operation. In the processing of soybean and cereal blends, the dry extrusion process achieves the following specific functions.

Cooking. The high-temperature short-time cooking cycle gelatinizes the starch and develops desirable flavors with improvement in nutrient quality.

Sterilization. The heat treatment reduces the natural microflora in the raw material.

Expansion. During the flow of starchy material through the extruder, it is subject to heat, shear, and pressure. The material develops into a doughy mass at the die and suddenly emerges into the atmosphere. The sudden drop in pressure expands the product and improves its texture. The moisture content has a profound influence on product expansion. Low moisture content results in a dense product; as moisture content increases, expansion improves up to a point where moisture content is optimum. Excess moisture and temperature results in degradation of starch and consequent loss of expansion.

Dehydration. As the product emerges from the die, there is also flashing of moisture vapor. A considerable degree of drying is achieved simultaneously with extrusion, which improves product stability.

Enzyme inactivation. Trypsin inhibitors and other undesirable heat-labile factors are inactivated during the extrusion process. The degree of enzyme inactivation depends on the time-temperature relationships associated with the process.

Forming and shaping. Within limits, the use of certain accessories with the extruder will enable extrusion of the end products in shapes that improve their consumer appeal.

The dry extrusion system is versatile, and lends itself to the processing of suitable combinations of raw materials to extrude a variety of products. These systems are being

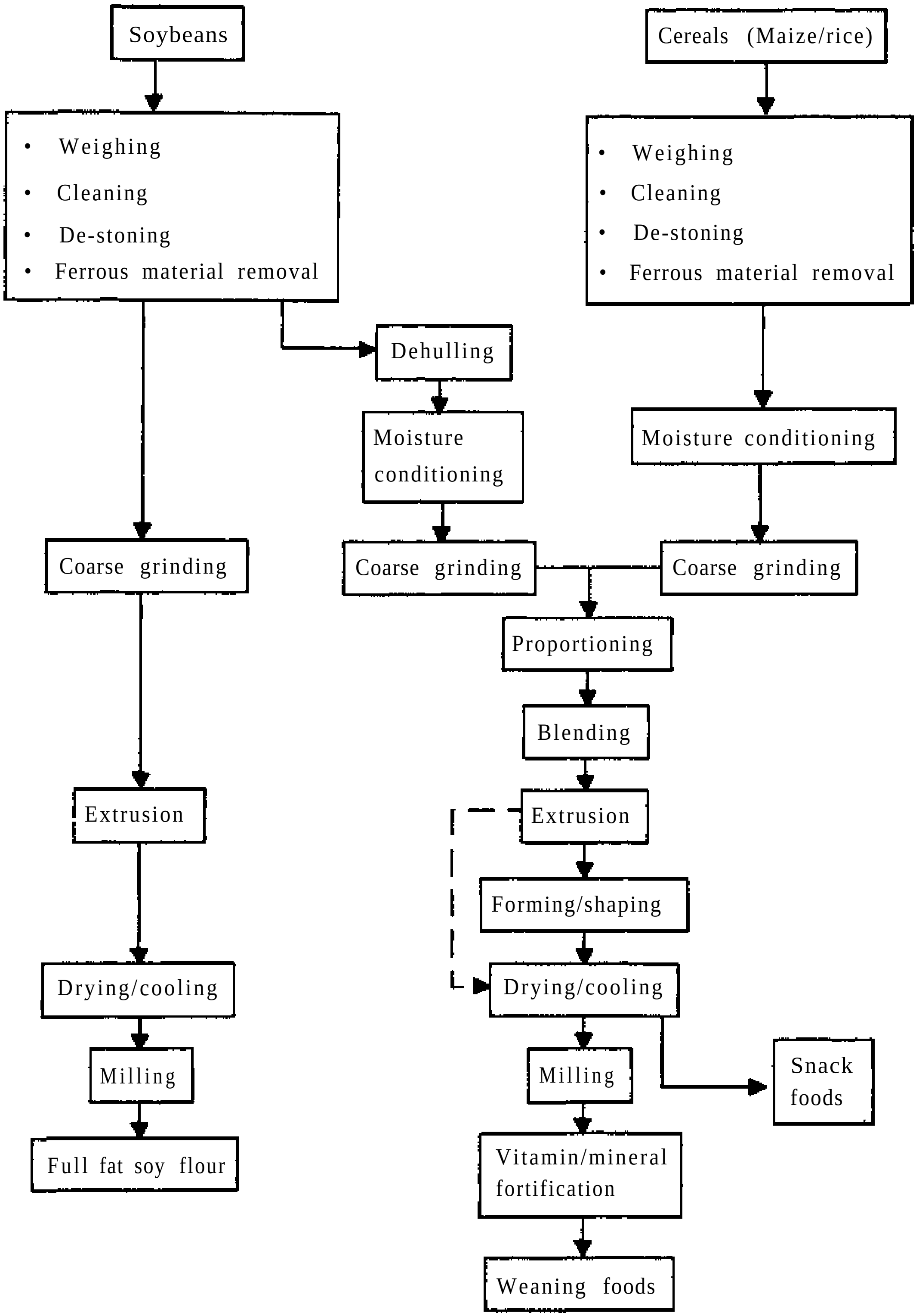

Figure 1. Soybean and cereals processing by dry extrusion.

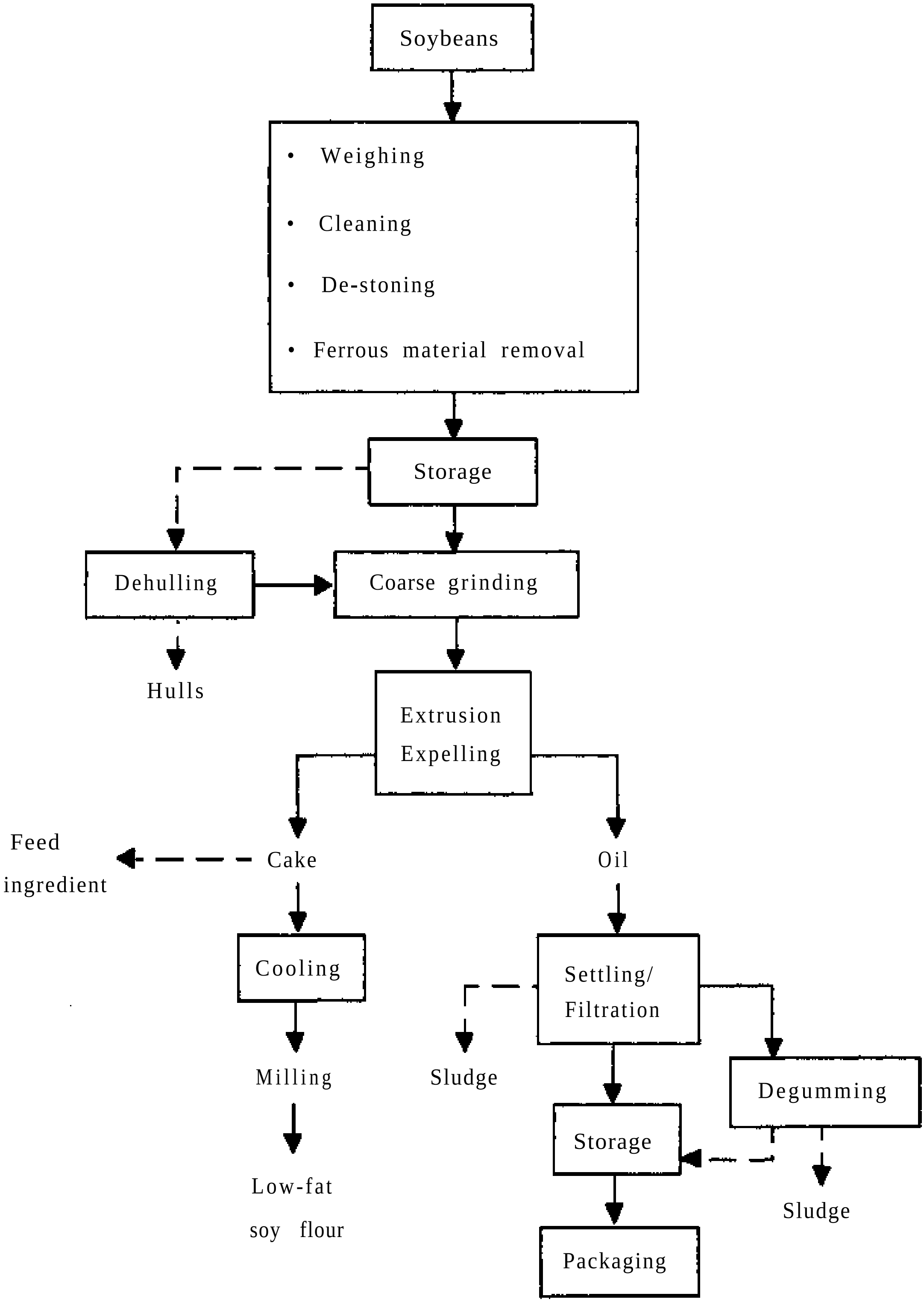

Figure 2. Soybean processing by dry extrusion/expelling.

used for the production of weaning foods from cereals and legumes in several developing countries (Wilson and Tribelhorn 1979). Expanded snack-type products can be produced from combinations of legumes and cereals. Whole soybean can be directly extruded to produce full-fat flour for human consumption, or full-energy soybean for livestock. A flow diagram for the dry-extrusion system is given in Figure 1.

Dry Extrusion as an Aid to Oil Expelling

Recent research at the University of Illinois (Nelson et al. 1987) has demonstrated that dry extrusion facilitates the extraction of oil from soybean by continuous expellers. The process yields fully processed low-fat soy flour and natural soybean oil. The reduced oil content in the extracted cake makes it possible to mill it into flour by conventional milling systems. By virtue of partial drying during extrusion and removal of oil, the protein content of the flour is increased to about 49%. This flour has good flavor and functional properties when used in food systems (INTSOY 1988). The oil extracted by the process is light in color and clear. It has good shelf-life and can be directly used for edible purpose in situations where unrefined oils are traditionally accepted by the consumer. The oil has a tendency to foam during deep-frying applications and this is overcome by degumming. A flow diagram for the combined extrusion and expelling process is given in Figure 2.

The process of extrusion and expelling has the potential to develop into a technology base for small-scale processing of soybean in developing countries where conventional solvent extraction may not be a viable proposition. The process yields two products, low-fat flour and oil which can both be used in food applications. There has been considerable interest from developing countries in this technique, and the process is currently being scaled up for commercial application. Extension of this technique to processing of other oil seeds to produce edible oil and food-grade meal is an interesting area of research.

Extrusion as a Means to Diversify End uses of Mandate Legumes

Food legumes are utilized mainly as primary raw materials in the preparation of traditional products at the domestic level. They reach the consumer with little or no preprocessing. The conversion of these legumes into processed products on a commercial scale will lead to increased utilization and improve the image of legumes, which are often considered subsistence foods. The success of such an approach will depend on the acceptability of the products. Therefore, research and product development must be tuned to local taste preferences.

The proximate composition of the ICRISAT mandate legumes and soybean (Table 1) offers interesting possibilities for the formulation of a variety of blends for extrusion processing. The major functional components affecting extrusion behavior, such as protein, carbohydrates (starch), and fat occur over a wide range among the different legumes. All four legumes are high in protein, but vary in fat content. Groundnut and soybean have high fat contents, while chickpea and pigeonpea have low fat contents. Pigeonpea and chickpea contain starch, while groundnut and soybean have little or no

Table 1. Composition of selected legumes (%).

Legume	Moisture	Protein	Fat	Fiber	Ash	Carbohydrates
Pigeonpea	10.1	19.2	1.5	8.1	3.8	57.3
Chickpea	9.8	17.1	5.3	3.9	2.7	61.2
Groundnut	5.6	27.0	47.5	2.4	2.3	15.2
Soybean	8.0	36.7	20.3	2.4	4.6	28.0

starch. These legumes could be combined with cereals in various proportions in order to obtain blends of desired nutrient density. The variation in composition also offers potential for investigation into developing functional characteristics in extrusion that affect product acceptability. Interactive effects of flavor profiles, expansion behavior, and product density are some important attributes that need to be investigated.

The main cereals currently used in dry-extruded supplementary food products are wheat, maize, and to a limited extent, rice. Little is known of the performance of minor cereals, such as sorghum and millets, in the manufacture of food products by dry extrusion. The incorporation of these cereals, along with the ICRISAT mandate legumes in research and product development through extrusion, can significantly increase their utilization by the food processing industry. Broad product areas that merit consideration are:

- Pre-cooked legume flours.
- Cereal/legume blends fortified with vitamins and minerals as supplementary foods.
- Processed ready-mixes from cereals and legumes as bases for gruels, soups, and gravies.
- Expanded high-protein snack-type products.
- Low-fat flour from soybean and groundnut for fortification of cereal flours.
- Enriched flour blends from low-fat legume flour and minor cereal flours for use in traditional food preparations.

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Development of Cowpea Products for Utilization in the Villages of Northeastern Thailand

Tipvanna Ngarmsak[1]

Abstract. *Research on the utilization of cowpea in northeastern Thailand revealed that cowpea is not regarded as a domestic, household crop, except when grown and eaten as a green vegetable. Village households were taught how to cook cowpea dishes. They were also encouraged to grow and process cowpea for household consumption. A nutritionally balanced diet was designed using cowpea dishes, which were introduced into the diet of villagers in northeastern Thailand.*

A study of current food habits was undertaken; cowpea dishes and a 7-day menu incorporating cowpea dishes were developed and introduced into the villages. Later, a mini dehuller and a pin-mill for village processing of cowpea flour and a new method of cooking cowpea flour in households were introduced, and food vendors were encouraged to make snack foods from cowpea flour. These measures were expected to encourage villagers to grow cowpea for processing in villages.

A third stage was laboratory research on the industrial utilization of cowpea. The functional properties of cowpea flour, cowpea starch, and cowpea protein were studied. Some potentially commercial products were developed on a laboratory scale, tested, and found highly acceptable.

Introduction

The northeast region of Thailand is the largest and poorest region of the country. Eighty-five percent of the people live in villages and depend on agriculture for their livelihood. Most village households have an adequate supply of "bulk" food, in the form of glutinous rice. They have a limited supply of the foods required for a nutritionally balanced diet, namely meat or fish, fruit, and vegetables. Protein energy malnutrition is widespread among the populace, and legumes could provide a good source of cheap, high-quality protein. Prior to the 1980s, soybeans could not grow well in the northeast. Mung bean and groundnut are grown as cash crops. Red cowpea variety 6-1 US has been introduced for intercropping by the Cropping System Project at Khon Kaen University. This cultivar

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gives a higher yield, has a shorter production period than the local variety, and its seeds have attractive red color. Cowpea tolerates heat and relatively dry conditions, growing with little rainfall. The protein content of red cowpea 6-1 US ranges from 23-25%.

There was reluctance on the part of the farmers to grow red cowpeas in this region until they were assured of a market. Therefore, it was important to encourage housewives, food vendors, and food shops in the rural northeast to use cowpeas.

Research on the utilization of cowpea in northeastern Thailand was therefore designed in three stages:

1. Cowpea as a protein food;
2. The use of cowpea flour, and
3. The use of cowpea by the food processing industry.

Cowpea as a Protein Food

Product concept

Because the villagers had several nutritional deficiencies, it was not sufficient just to introduce a single food. It was necessary to introduce a complete diet, incorporating foods already grown or available, supplemented with cowpea for balance. The food presently eaten was developed to a nutritionally balanced diet, and this diet was introduced into villages in Khon Kaen Province.

Food Consumption Pattern

A survey was conducted in 10 villages involving 100 households in Khon Kaen Province. The diet of the villagers in northeastern Thailand was mainly cereals and vegetables. Steamed glutinous rice was the main staple food. Fish was the main animal food consumed, but it was not eaten daily. High fat foods were less frequently eaten, and fat was rarely used in cooking. Green vegetables were the most commonly eaten vegetables. Fruits were eaten infrequently (Ngarmsak and Earle 1982). Various types of legumes were grown and eaten although not in large quantities. They were used as dried seeds and as green vegetables, and cooked in many dishes.

Balanced Diets

Development of cowpea dishes. Two techniques were used in the development of acceptable cowpea dishes. Following the research system used at Massey University (Earle and Anderson 1985), cowpea dishes were developed. This process was divided into different stages; after each stage, there was an evaluation, which is an important part of the design of a food product. Fifty dishes were formulated, out of which 25 were selected for acceptability trials.

Linear programming runs were made for each of the 25 cowpea dishes (Ngarmsak and Earle 1983a). The objective function was protein maximization. The content of 26 nutrients, and the cost of each dish was also calculated. The acceptability of the improved cowpea recipes was tested by a laboratory taste panel. The panel found only one of the 25 dishes to be below acceptable level.

Development of a 7-day menu. A weekly menu was developed for a family of seven persons. The daily menu gave the 26 required nutrients, and conformed to the food-eating pattern of the villagers in northeastern Thailand. A systematic food selection method was used to develop a daily menu, and a weekly selection of daily menus (Ngarmsak and Earle 1983b). All the menus were accepted very well by the villagers, and were rated highly (6.1-6.2 on a hedonic scale 1-7 where 1 is dislike very much, and 7 is like very much) by them.

Introduction of nutritionally balanced diet

There was a need to carefully select the methods for introducing new foods to the villages. The methods were developed through brain-storming sessions and assigning methods for the four stages in the adoption process. Models were made of the process of introducing the new foods, and finally, the methods were evaluated. These methods were selected and tested for effectiveness in six villages (Ngarmsak and Earle 1983b). They were again modified and tested in six other villages, and the final method was developed as shown in Figure 1.

Conclusion of stage one

This study was successful in planning a highly acceptable 7-day menu, and encouraging cowpea growing, cooking, and eating in 16 villages, involving 1118 villagers and 919 households. Growing red cowpea 6-1 US presented some difficulties, such as aphid and other insect pest attack, and crop management difficulties resulting in poor yield and inadequate supply of cowpea seeds. The villagers quickly lose interest in a legume if they have difficulty in growing it. In general, the introduction effect lasted over one year in the first six villages. Though the number of households growing and consuming cowpeas decreased in the second year, the area under cowpea increased. There were some villagers who still cooked cowpea dishes 4 years after its introduction.

The Use of Cowpea Flour

Village processing of cowpeas

Cowpea flour processing. Cowpea flour was prepared by dehulling 1.5-3 kg of cowpea seed for 3 min in a PRL dehuller (1400 rpm), and grinding the dehulled cowpea in a hammer mill, using 0.2 mm screen to obtain cowpea flour.

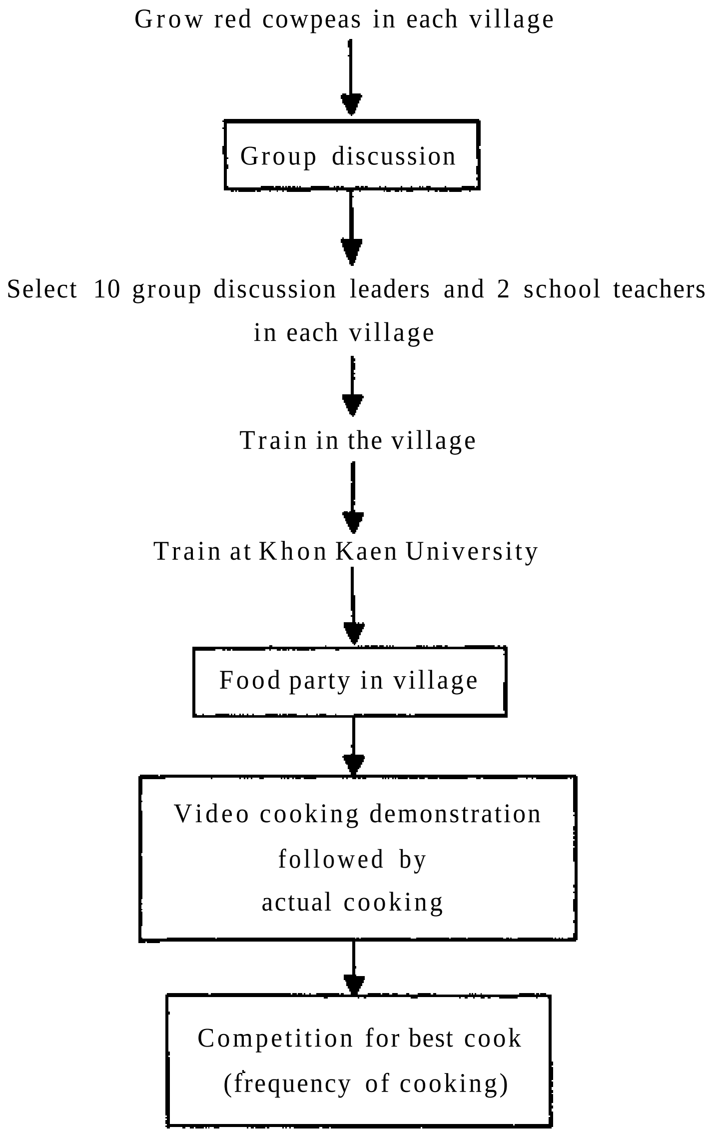

Figure 1. The final method adopted for the introduction of a nutritionallybalanced diet into the villages of Khon Kaen Province, Thailand.

The village mill. A PRL dehuller and a mill were placed in the village where the cowpea was grown and the villagers were encouraged to mill cowpeas for their use. Dehulled cowpeas are used in desserts. A portable mill was also brought to the villages for demonstration purposes.

New Cooking Methods Using Cowpea Flour

The primary objective was to induce increased use of cowpea flour in village households by introducing a new cooking method. Four methods were demonstrated.

1. Cowpea flour batter was used to coat vegetables, such as pumpkin and string bean, and small fish, shellfish, frogs, and insects, before frying them in oil.
2. Sweet fried cowpea balls were prepared by blending cowpea flour with pumpkin and sweet potato, and savory balls, by blending with fish, shrimp, shellfish, and pork. These were fried in oil.
3. Cowpea flour was blended with tamarind pulp, fermented fish, and spices to form a paste which is eaten with steamed glutinous rice or with vegetables.
4. Cowpea flour was blended with fish, chili, garlic, and fermented fish to give a thin sauce, which is served with vegetables.

The cowpea flour batter and the fried cowpea balls would increase the amount of oil eaten. Coating or blending a shellfish with cowpea flour batter would increase the protein intake. Frying in oil would also increase fat intake.

Recipes were developed that incorporated the maximum amount of cowpea flour. The acceptability of products was judged by laboratory taste panels. The level of cowpea flour used in the four cooking methods were: 34% in batter; 21% in a savory ball mixture; 15% in a sweet ball mixture; 13% in tamarind paste; and 9% in the cowpea and fish sauce. The final recipes were found to be highly acceptable in a village inhabited by 30 villagers.

The new cooking methods were demonstrated using a video in the five villages where cowpea was introduced. The housewives were allowed to try the new cooking methods, and cooking competitions were held 2 weeks after the demonstration.

Snack Food from Cowpea Flour. Seven food products of cowpea flour were selected from among the most popular products, based on a survey involving 30 random consumers in Khon Kaen Campus, and a taste panel evaluation in the laboratory involving 10 panelists. The products were then judged by four food vendors. One product was dropped due to its high cost, and the difficulty in its preparation. The six snack products were: *tako* (steamed cowpea gel with coconut cream); *klong kang klob* (boiled cowpea dough in coconut milk); *kanom kloke* (charcoal-baked cowpea flour with sweet batter), *kloy tod* (fried banana coated with cowpea flour batter); *kanom saree* (cowpea sponge cake); and *kai nok kata* (fried cowpea paste). The cowpea flour content of these products ranged from 30% to 70%. The six snack foods were taught to 11 food vendors from the five villages where cowpea was introduced. Then, they were given 2 kg of flour each, and asked to keep records of the products made during a 1-month period, and they were given an additional 2 kg of flour at the end of 1 month, during our visit, and this was repeated once again. Each vendor made two or three of the six products being popularized during the 2-month period. They made more of the product during the 2nd month than in the 1st month, and after that, products were rarely made. Although there was no indication of any problem in making the snack products, vendors were busy making their own regular products, and had no spare time for making new products from cowpea flour due to its nonavailability.

Conclusion

The dehuller and the mill worked satisfactorily in the villages. The introduction of the four new cooking methods using cowpea flour was successful. Most villagers still like to cook cowpea flour whenever it is available. Suitable snack products have been developed for use by food vendors, but they were not made on a continuous basis. A continuous supply of cowpea flour should be available for the vendors, and a method of introducing snack foods needs to be developed.

Industrial Processing of Cowpeas

Cowpea Flour

The red cowpea flour was not acceptable to bakers due to the presence of small red-colored flakes in the flour, and a slight beany flavor. The color of flour was improved by remilling the flour using a finer sieve. However, the beany flavor limited its use as a blend in baked products (Ningsanond 1986). The addition of cowpea flour to wheat flour reduced the stability and strength of the dough, and it was concluded that not more than 10% of cowpea flour could be added to wheat flour for making acceptable bread. Cowpeas may find use in larger quantities in health food bread, where the loss of volume and change in flavor may be less significant to consumers. Further research needs to be carried out before cowpea flour gains acceptance as an additive to enrich bread.

Whole-wheat cowpea-enriched bread was developed using local wheat flour from the northeast region (30%), red cowpea flour (15%), and white wheat flour (55%). Thin slices (3 mm thick) of this bread were buttered, sprinkled with granulated sugar, and toasted in an oven at a temperature of 177°C for 20 minutes. This new product was highly acceptable (Charoenwatana and Ngarmsak 1987).

It was also found that cowpea flour is quite acceptable in cookies, fried crust *(krob kem),* puffed snack *(kao kreb)* and cowpea dried mix for use as a batter.

Cowpea Starch and Cowpea Protein

Ningsanond (1986) separated red cowpea flour into starch and protein fractions by dry and wet milling methods and investigated their potential uses in food products. It was possible to substitute wheat flour with 20% cowpea protein fraction for soft buns, and with up to 35% protein fraction for high protein cookies. Also, high protein puffed snacks from cowpea flour can be produced by replacing tapioca starch with 40% cowpea starch. Cowpea protein could be used as an emulsion stabilizer in fat and water systems, and in meat emulsion systems. Finally, red cowpea starch can be used to produce transparent noodles of the same quality as those made from mung bean starch.

Conclusion

There is a need to carry out further research on the utilization of cowpeas by the food processing industry. A study could be made on the properties of cowpea starch and tapioca starch mixtures to identify possible uses for cowpea starch, and for mixtures of cowpea and cassava starch.

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Processing and Utilization of Legumes with Particular Reference to Mungbean in the Philippines

R.R. del Rosario[1]

Abstract. *A wide range of possibilities exist for utilizing legumes. The products may be classified as consumer products which can be directly eaten, or as ingredients for food preparation.*

In the Philippines mungbean locally called mungo is traditionally used for making sotanghon *or bean noodles; it is also consumed as mungbean sprouts, as a filler for pastries, or as the main vegetable ingredient in sautee'd mungbean. The traditional process of mungbean noodle manufacture may be broken down into simpler processes to produce mungbean starch and protein in dry form. Mungbean protein has considerable prospects as a raw material for the manufacture of many protein products.*

Whole mungbean is an ingredient for food production, as canned sprouts, or as raw material for flour preparation. The whole beans could also be processed into quick-cooking or "instant" mungbeans, or manufactured as a snack food. New technologies, such as extrusion of mungbean alone, or in combination with other raw materials, could yield products of improved nutritional value, ranging from baby and snack foods to textured vegetable protein.

Introduction

Legumes are important raw materials of nutritional importance in developing countries. Many legumes have short cropping cycles ranging from 60 to 90 days, which give them considerable production potential. Their overall yield may not be so high as some cereals, but their protein contents are about two to four times higher, making them excellent sources of proteins. The efficiency of conversion of plant to animal protein is rather low, ranging from five to ten parts of protein in the feed to one part of body protein, but, large quantities are used as livestock feed to produce the meat required in many countries.

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Traditional uses of mungbean

There are four major uses of mungbean in the Philippines :

- Production of noodles;
- Production of bean sprout;
- Filling material for mooncake and other baked products; and
- Boiled mungbean, used as an ingredient in snacks, and desserts, or as a main dish with vegetable, meat, or shrimps.

Mungbean Noodles

Most of traditional dishes made of mungbean are of Chinese origin. The production of mungbean noodles (Sin and del Rosario 1974) is shown in Figure 1. It involves the production of starch from soaked mungbean (Frias and del Rosario 1987). This starch is then formulated into a slurry and extruded to form threads, which are cooked in water. Before drying, the wet noodle strands are placed in cold storage to strengthen them. Production is carried out during winter months to take advantage of the cold weather.

Mungbean Sprouts

Sprouted mungbean can be used as a vegetable during winter, when field sowing is not feasible (Estioko and del Rosario 1986). The process of producing sprouts involves soaking the seeds overnight in water. After soaking, the water is drained off and the swollen seeds are placed in jars or bamboo baskets, lined with banana leaves. The seeds are kept in the dark and watered every 4 h. The process is continued for 3 days, after which the seedlings are harvested and dehulled by placing the sprouts on plastic tray and then soaking it in a basin of water to allow the seed coat to float and be removed.

Mooncake Filling

Mooncake or hopia and buchi are very popular in the Philippines. Mungbean is soaked in water overnight; sugar is added to it and the mixture is cooked until it is almost dry. The sweetened mungbean is placed inside a dough prepared from wheat or rice flour, and then baked.

Other uses

Boiled mungbean is used in many dishes; either prepared with other vegetables or meat garnishing. This is a popular dish eaten on Fridays and during Lent. At other times, mungbean is cooked with coconut milk, and sugar, and eaten as a dessert.

Mung bean

↓

Soaking

↓

Grinding + Water

↓

Sieving

↓

Decantation

↓

Sieving + Water

↓

Decantation

↓

Sieving + Water

↓

Decantation

↓

Centrifugation
or drip drying

↓

Formulation

↓

Extrusion

↓

Cooking

↓

Washing

↓

Refrigeration

↓

Sun drying

↓

Packaging

Figure 1. Manufacture of mung bean noodles.

Case study I. Recovering Protein after Mungbean Noodle Manufacture

The traditional process used in the manufacture of mungbean noodles results in the recovery of starch, which is used in noodle preparation. The protein fraction, which is the nutritionally more important component of mungbean, is discarded. The wash water is channeled to the piggery, and consumed as animal feed.

The use of a dry processing method (Olea and del Rosario 1982) should improve the process. Among the advantages envisioned are: pollution control; recovery of the protein fraction for further utilization; and reduction in water consumption.

Materials and Methods

Green mungbean samples were obtained from the local market. The beans were cleaned and dehulled using the Cecoco bean splitting and dehusking machine and then passed through a pin mill. The resulting flour was air-classified using an Alpine Laboratory Zigzag Classifier A 100 MZR. The separation was set at different cut-size points to determine the segregation of flour components. When the sample is air-classified at a given cut-size point, particulate fractions greater than the cut-size point go to the coarse material receiver, while the rest are deposited as a fine fraction. Dehulled mungbean was pin-milled at around 5-micron cut-size point.

Classification was followed by protein analysis. The moisture content of the different fractions was determined by drying in an air-oven at 130°C for 1 h. Microscopic examination was done to determine relative sizes of protein bodies and starch granules. The starch was differentiated from protein bodies by use of iodine staining (MacMasters 1964).

Results and Discussion

Repeated pin-milling and air-classification resulted in further segregation of protein in the fine fraction. When the technique of dry-processing was applied, a final coarse product residue (S-III) together with three fine-fractions (P-I, P-II, and P-III) were obtained. S-III contained 7.66% protein, with an average yield of 63-64% by mass of the flour. The combined fine fractions (P-I + P-II + P-III), containing 54-57% of the protein constituted the remaining 36-37%. The average yields and analyses of the intermediate and final dry-milled products are presented in Table 1.

When dehulled mungbean was pin-milled and then air classified at around 5-micron cut-size point, 23.90% went into the fine "protein" fraction receiver, and 76.10% was deposited as coarse product S-I. This means that only about 3-54% of the total protein of the mungbean flour was in the fine "protein" fraction, P-I. When the coarse product S-I was processed by combined pin-milling and air-classification with a cut-size point set at 5, a further protein starch separation was observed: 11.10% went to the fine "protein" fraction receiver, while 88.90% was deposited as coarse product S-II. Combining the two fine "protein" fractions gave a total yield of 32.35% "protein" product by mass, accounted for

Table 1. Average yields and analysis of dry-milled mung bean products.

	Protein (%)	Yield by mass (%)
1. First air-classification		
S-I	15.51	76.10
P-I	56.49	23.90
2. Second air-classification		
S-II	12.30	88.90
P-II	56.33	11.10
3. Third air-classification		
S-III	7.66	94.15
P-III	54.59	5.85

by an additional 18-19% total protein shift to the fine fraction. When the coarse product of the second separation was recycled, only 5.85% by mass of S-II was collected as fine protein fraction. The remaining coarse product S-III, is a high starch concentrate containing only around 7.66% protein. This could possibly be used as raw material for starch noodle manufacture. The fine "protein" fractions P-III contained 54.55% protein constituted around 8-9% additional total protein shift. Combining the three fine "protein" fractions produced a total yield of 36.31% by mass of mungbean flour. This means that around 80-81% of total proteins in the flour were shifted into the fine fractions. The fine "protein" fractions with 54-57% protein could be good material for food processing, and used in protein-rich product formulations as textured vegetable protein.

The amino acid profiles of mungbean and the air-classified fraction showed that on the one hand, lysine content of the P-fractions was higher than that of the S-fraction. On the other hand, the proportion of sulfur amino acids was higher in the S-protein than in the P-protein.

Case Study I I : Quick-cooking Mungbean

The preparation of boiled mungbean, either as a vegetable dish or as dessert, requires a cooking time of about 45 min to 1 h. This constitutes a big energy drain on the household budget, not to mention the time devoted to cooking. The development of quick-cooking mungbean preparations would help reduce expenditure on energy and would free the housewife for more important activities. A review of the literature showed the feasibility of developing such a product from mungbean. Based on available information, a general process flow (del Rosario and Gloria 1987) was developed involving soaking and a short high-temperature treatment (Figure 2). The intention was to produce a highly porous, precooked product that would readily reconstitute.

Using the optimum hydration time for mungbean, the seeds were soaked in 0.10, 0.25, 0.50, 0.75, 1.0, 1.5, and 2.0% solutions of sodium chloride (NaCl), citric acid, sodium bicarbonate ($NaHCO_3$), sodium carbonate (Na_2CO_3), and sodium polyphosphate

Mung bean

↓

Cleaning/Sorting

↓

Soaking for 12 h

(2% sodium tripolyphosphate solution)

↓

Draining

↓

Air-drying (2 h)

↓

Roasting for 1 1/2 min in

1:10 mung bean : sand ratio

Initial temperature: 248°C

↓

Cooling

Figure 2. Manufacture of quick-cooking mung bean.

($Na_3P_3O_{10}$). The beans were removed from the solution at the end of the soaking period (12 h), and then drip-dried. The moisture content of the seeds was determined using the Ohaus moisture balance.

The dried beans were roasted for 1-3 min in fine grade sand, at 200-250°C Then, the beans were cooled to room temperature and cooked using boiling water. Estimated cooking time was determined as the time when all members of the panel evaluating the beans agreed that the product was cooked.

Table 2 shows the estimated cooking time of mungbean. Varriano-Marston and De Omana (1979) suggested that during soaking, insoluble pectinates were converted to soluble pectin by removing magnesium (Mg) and potassium (K) from the beans. Ion exchange of sodium (Na) in the soaking water with Mg and K occurred in the intercellular cement. Sodium pectinates are more water-soluble than Mg - pectinates and K - pectinates, and there is an increase in binding of Mg in the $Na_5P_3O_{10}$ solution (Kertesz 1951).

Sensory evaluation of mungbean soaked at different concentrations of different salt solutions was carried out. Only general acceptability and flavor scores of mungbean, soaked in 0.10-0.50% citric acid, were comparable with the quality of the control. This

Table 2. Estimated cooking time (min) of quick-cooking mung bean.

Level (%)	Soaking solutions				
	Na_2CO_3	$NaHCO_3$	$Na_3P_5O_{10}$	Citric acid	NaCl
0.10	19.0	19.0	18.0	14.0	10.0
0.25	17.0	17.0	15.0	15.0	10.0
0.50	13.0	13.0	12.0	15.0	10.0
0.75	8.0	11.0	9.0	16.0	10.0
1.00	4.0	8.0	8.0	17.0	10.0
1.50	0.8	4.0	6.0	18.0	10.0
2.00	0.5	1.0	4.0	26.0	10.0

could be due to the hardening effect observed when mungbean was soaked at higher (0.75-2.0%) concentrations of citric acid. For mungbean soaked in Na_2CO_3 solution, hardening and darkening of the seed coat were observed at 1.5-2.0% levels. Also at these levels, mungbean had a tangy taste and pungent odor. However, at 0.5% levels, no significant difference was obtained in general acceptability and flavor scores when compared with the control. For mungbean soaked in $Na_5P_3O_{10}$, hardening of the seed coat occurred at all concentrations of the soaking solution. However, the quality of cooked mungbean was still comparable with that of the control. With the NaCl solution, enhancement of the flavor was noticed at 0.25% level. The beany flavor was completely eliminated, although the beans were evaluated as slightly hard for all concentrations.

Case Study III: Baby Food

A market survey in the Philippines revealed the absence of a low-cost baby food in the market. Those available are expensive, and manufactured from imported raw materials.

Materials and Methods

We prepared a baby food using rice, mungbean, and other necessary ingredients (del Rosario et al. 1987) as shown in Figure 3.

The amino acid composition of the baby food formulation showed adequate quantities of all the essential amino acids. The product stored at room temperature had a shelf-life of about 1 year. However, the baby food had to be kept dry, otherwise, agglomeration took place, making it susceptible to microbial growth.

Biological assay of the baby food showed that it had high protein quality. Rats fed with the baby food had a mass gain per gram of protein intake (PER) of 2.21, while rats fed with skim milk had a PER of 2.60. Biological value, net protein utilization, and digestibility index of baby food fed to rats were comparable to those obtained with the control diet of skim milk.

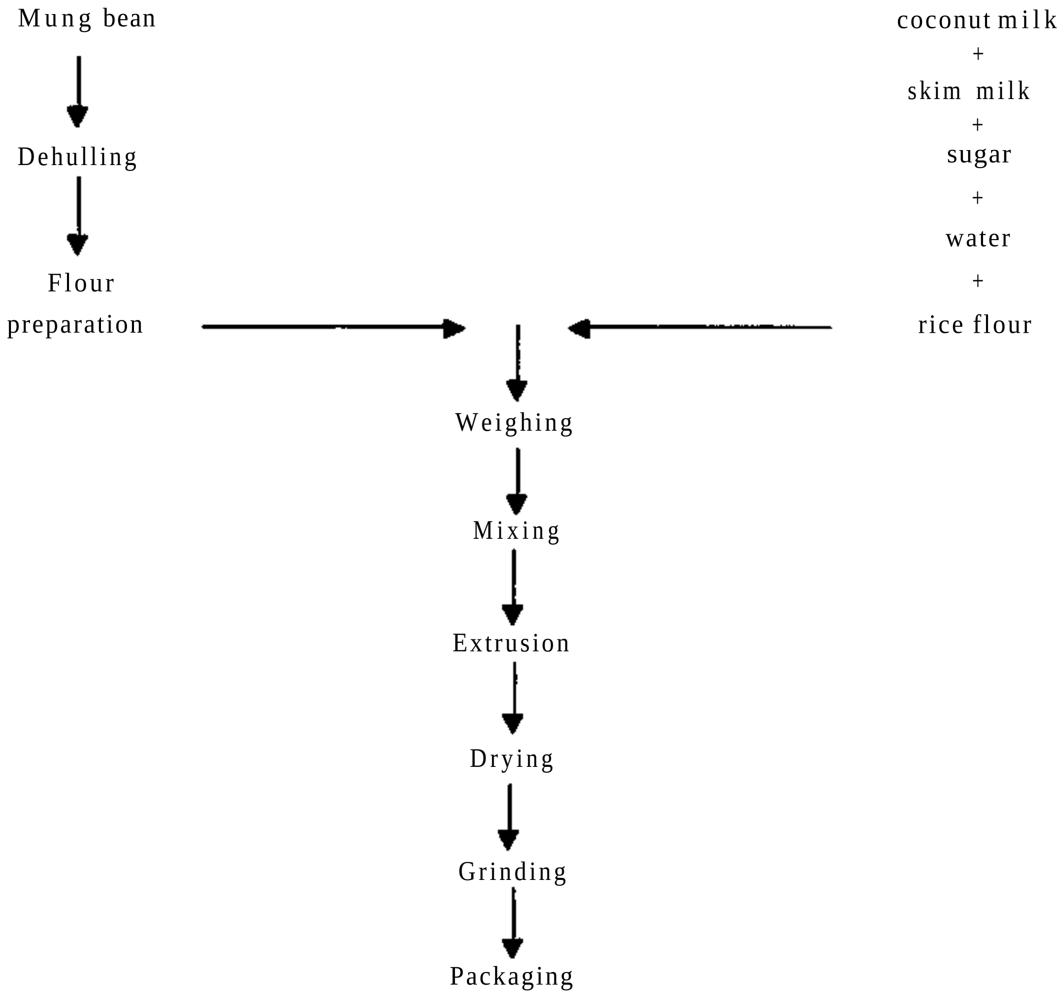

Figure 3. Manufacture of instant baby food.

Case Study I V : Sauce

Sauces are important ingredients in Filipino cookery, the most important of these are soybean sauce and fish sauce. These sauces, especially soysauce, are used in a wide variety of dishes. A study in our institute (Divina, R.D. 1983) revealed that mungbean could be used as a substitute for soybean in preparing sauces. Mungbean has the advantage over soybean of being available in most places in the country throughout the year.

Materials and Methods

Preparation of inoculum. A mixed starter consisting of *Aspergillus sojae, Pediococcus halophilus. Streptococcus faecalis, Saccharomyces rouxii,* and *Torulopsis versatilis* was used as inoculum or *koji*. The starter was incubated for 3 days at room temperature.

After incubation, enough sterile distilled water was added to the medium to dislodge the spores. The suspension was centrifuged for 30 min at 3 000 revolutions per minute (rpm). The resulting spores were dried by mixing with approximately equal quantities of lightly roasted flour. The flour-coated spores were vacuum-dried for 3-4 h at 40°C. The dried starter ready for inoculation was placed in sterile vials. The amount of inoculum used were 0.1, 0.2, 0.3, and 0.4% based on the mass of the boiled mungbean and roasted wheat flour (Figure 4).

Mung bean (500 g)

↓

Soaking in H_2O

↓

Boiling (for 8-10 min) until soft

↓

Draining

↓

Cooling to 40° C

↓

Mixing with roasted wheat flour

↓

Inoculation

↓

Incubation for 3-4 days at 27.5 - 30° C

↓

Cooling after 20-40 h of inoculation
(by stirring)

↓

Washing and aging

↓

Harvesting and pasteurization

Figure 4. Preparation of mung bean sauce.

A brine solution of 18% was prepared, and added to the molded mash in the ratios of 1.1, 1:1.2, 1:1.5, and 1:2 (inoculated mungbean : wheat mixture).

Incubation. Covered trays of inoculated mixture were stacked one above the other, with a gap of about 30 cm between trays, and incubated for 3-4 days. The trays were cooled for 20 to 40 h after inoculation to prevent accumulation of heat. Cooling was done by thorough stirring of the material. This fermented material is called *Shoyu-koji.*

Mashing and aging. The inoculated mixture (mature *shoyu-koji)* was mixed with 18% brine solution in a 3.78L glass jar to form the mash. The volume of salt water added was at the rate of 150-200% of mature *shoyu-koji.* The fermentation was covered tightly with paper and plastic, and fermentated for 4 months at room temperature.

Harvesting and pasteurization. The liquid portion was separated from the mash by pressing. Fermented mash was placed in two layers of cheese cloth tied at the ends to close the opening, and then placed under a screw press until all the liquid was forced out. The filtrate was then centrifuged to remove solid particles.

Raw sauce was distributed to 1 L glass bottles and pasteurized for 20 min in a boiling water bath at an internal temperature of 80-90°C. To aid classification, alum was added at 0.354 g $3.78L^{-1}$. Precipitates or suspended solids were allowed to settle overnight, after which the resulting sauce was decanted and filtered.

Results and Discussion. A comparison of the chemical composition of soybean and mungbean sauces showed their similarities with respect to specific gravity, total sugar content, and total extract obtained. Variations were observed in pH and acidity. The mungbean sauces though of lower pH than soybean sauces had lower titratable acidity. This could be due to the difference in nitrogen content, which provides a higher buffer effect for soybean sauce.

Sensory evaluation of the sauces obtained from two varieties of mungbean showed higher scores for aroma, flavor, and overall acceptability over the soybean sauce (control), though the differences were not statistically significant.

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The Composition, Biological Activity and Utilization of Faba Bean in Human Nutrition

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Abstract. *Faba bean is grown in Egypt as a winter crop for human consumption. While 10% is consumed fresh, 90% is harvested dry during the month of June. The crude protein content of the local varieties varies from 27 to 29%, and is deficient in sulfur-containing amino acids and isoleucine. Sucrose accounts for 25% of the total sugars. The dietary fiber content is about 20% of the whole faba bean seed, but this is significantly reduced by cooking.*

The presence of proanthocyanidins (PA, tannins) in the seed coat of some faba bean varieties poses a serious nutritional problem. Triple White is a cultivar with almost no PA in the seed coat. Processing faba beans into paste (bessara,), *or cakes* (falafel) *involves removal of the seed coat. However, in the preparation of stewed faba beans the seed coat is not removed. PA was completely destroyed by putting faba beans in contact with ammonia vapor. The glycosidic pyrimidines, vicine, and covicine, are antinutritional factors present in the cotyledons of faba beans. These factors can be completely eliminated by soaking beans in 1% acetic acid.*

Environmental factors, particularly location and temperature, affect sucrose content and cooking time. Many physical and chemical attributes of the seed correlate significantly with cooking time.

When faba beans were fed to boys as a part of a mixed diet, Triple White was considered the best in terms of protein, amino acids, mineral digestibility, and biological value. Administration of methionine capsules with the diet improved digestibility of all essential amino acids. The protein quality declined in ammonia-treated cooked faba beans. The group consuming faba bean with high PA contents, excreted stools with higher levels of bile acid and trypsin and amylase activities.

Consumption of different faba bean dishes by control and diabetic volunteers showed reduced blood glucose content, indicating the value of faba beans in the dietary management of diabetes. Because of their unique characteristics, modified and unmodified faba bean proteins could be used in processed foods.

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Introduction

In Egypt, faba bean is sown in October - November. Approximately 10% of the crop is harvested between February and March as green pods, which are consumed as a vegetable or snack. The remainder of the crop is harvested after drying during the month of June. According to statistical data of the Ministry of Agriculture (Egypt 1985), the mean daily per caput consumption of faba beans is 13.4 g, providing an average of 3.0 g of protein.

Chemical Composition

Proteins

Faba bean is a very good source of carbohydrates and proteins, which together constitute about 80% of the total dry-seed mass. Faba bean seed's crude protein content ranges between 24% and 31% (Bond 1970). The storage proteins are vicilin and legumin, which constitute a major portion of the seed protein. Faba bean seed contains two to three times as much legumin as vicilin (Hill-Cottingham 1983).

The variation in the composition of vicilin and legumin among the cultivars can be used to identify cultivars electrophoretically (Barratt 1980). The amino-acid pattern of Giza 3, a local variety, showed that methionine and cystine are the first limiting amino acids,followed by lysine (Table 1) (Hussein, unpublished data).

Carbohydrates

Table 2 presents the soluble carbohydrates in the seed of uncooked and cooked, faba bean variety Giza 3. Slight variations exist when the results are expressed as g (100 g)$^{-1}$ dry matter. The percentage of ethanol soluble sugars was determined in nine varieties grown at two locations with four replications each. A mean figure of 6.45% (range 5.4-7.9%) was

Table 1. Amino acid composition of cooked faba bean variety Giza 3.

Amino acid	Faba bean [g (16 g N)$^{-1}$]	Chemical score
Lysine	5.25	96
Methionine + cystine	2.72	78
Phenylalanine + tyrosine	7.05	118
Leucine	6.85	98
Isoleucine	3.35	84
Valine	4.10	82
Threonine	3.27	82

Table 2. Analysis of whole cooked and uncooked faba bean seeds variety Giza 3.			
Constituent	Uncooked	Cooked	Uncooked[1]
	% dry mass		
Soluble carbohydrates[2]		54	
soluble sugars	7.1		4.5
glucose	0.1		
sucrose	1.5		1.6
raffinose			0.5
stachyose	5.4		0.8
verbascose			2.6
Crude fiber	10.6		8.0
Dietary fiber	20.5	8.2	
Protein (N x 6.25)	27.3	27.0	32.5
Ash	6.3		3.5
Lipid	1.6		1.6

1. Source : G. Hill-Cottingham 1983.
2. Mean values based on dry matter 52.4% in green pods and 54.4% in faba bean sprouts.

obtained. The main ethanol-soluble sugars are sucrose and oligosaccharides, raffinose, stachyose, and verbascose. The dietary fiber concentration of faba bean was 20.5%, and crude fiber was 10.6%. The presence of amylase-resistant starch in many leguminous seeds could possibly be responsible for their high dietary fiber content (Faulks and Timms 1985).

Minerals

The mineral composition of Giza 3 and Triple White are shown in Table 3. The concentration of minerals in faba bean sandwich and faba bean cake sandwich was determined. The authors concluded that both the meals provide the recommended daily allowance of essential minerals, except for calcium (Iskander and Askar 1987).

Table 3. Concentration of mineral elements in whole faba bean seed of two varieties.

Element	Giza 3	Triple white
	mg (100 g)$^{-1}$	
Calcium	103	202
Phosphorus	395	450
Magnesium	140	155
Iron	4.4	4.7
Zinc	3.1	5.3
Copper	1.5	1.4
Manganese	1.4	1.5

Antinutritional Factors

Phytate

Phytate binds to minerals and limits their availability (Kivisto et al. 1986). An analysis of the seeds of 76 different faba bean cultivars for their phytic acid content gave a mean figure of 0.92 + 0.05% for the cotyledon, and 0.76+0.03% for the whole seed.

Proanthocyanidins (Tannins)

The seed hulls of many faba bean varieties are rich in their proanthocyanidin (PA) content. The total phenol content of 22 cultivars varied from 1.4% to 12.8%. The total polyphenols content, estimated by the vanillin-HCl assay ranged from 0.13% to 3.47% (Abdel Fattah, M. 1986). The polyphenols present in seed were almost completely destroyed by spraying the seed with 4% aqueous ammonia solution and sealing it in air-tight containers for 15 days (Hussein and Abbas 1985).

Vicine and Convicine

An analysis of faba bean, at different stages of maturity showed that the concentration of vicine was about 3.0% (based on dry matter) in young green pods, 78 days after sowing. Sixty-two varieties grown in Egypt and Syria were analyzed for their vicine and convicine contents. Variety 123 A/45/76 contained the lowest concentrations of vicine (3.7 mg g^{-1}), and convicine (1.4 mg g^{-1}). Vicine and convicine showed a significant and positive correlation in different faba bean varieties grown in Egypt and Syria.

Vicine and convicine, which are present in the cotyledons, can be eliminated by soaking the whole or the decorticated faba bean seed in 1% aqueous acetic acid at 40°C for 48 h (Hussein et al. 1986).

Traditional Processing Practices

Faba bean is stored in open-air warehouses, in steel drums, or in *matmura* (underground pits) (Watson, 1981). Storing faba bean in this way is reported to reduce cooking time and the carbon dioxide given off by the beans during storage kills the bruchid beetles that are stored product pests. Beans stored as described above are of high quality, and fetch 25-75% higher prices than those stored in jute bags (Watson 1981).

The traditional ways of preparing faba beans dishes include:

- Boiling in a minimum of water over a gentle fire (stewed-*foul medamis*).
- Decortication, boiling in water, squeezing, and preparing as puree (*bessara*).
- Decortication, soaking in water, grinding, mixing with onions, and parsley, and frying in oil (*Falafel, Taameya*).

• Sprouting for 4-6 days, followed by boiling and decortication (*foul nabet*).

Faba bean sprouts have always been an important constituent in Egyptian diets. Unfortunately, there is now a tendency toward decreased consumption of faba bean among some communities which used to depend on sprouts for a substantial part of their intake of vitamins and minerals. The beneficial effects of legume sprouts have been described by Hofsten (1979). Figure 1 illustrates the consumer preference for different faba bean dishes according to income, profession, and location.

The cookability of faba bean was tested in the laboratory under standard conditions using an experimental cooker to define the factors responsible for hard-to-cook seeds. The results showed the presence of varietal differences among cooking times. For example, cultivar 592/1848/86 required 15 min for seed softening. Further, large-seeded local varieties required less cooking time than the small-seeded varieties. Boiling the seeds for 1 min followed by 18 h soaking in water at room temperature is recommended to reduce the cooking time required for seed softening.

Use of Faba Beans in Human Nutrition

Faba bean was fed to preadolescent males as part of a mixed diet. Whole seeds of the Triple White and Giza 3 varieties were used. The composition of the diets was quite similar, except that subjects given diets of Giza 3 ingested 792 mg of proanthocynanidin daily, as compared to 467 mg of proanthocyanidin in the case of those fed on Triple White. It was observed that the digestibility of crude protein was significantly lower in the Giza 3 diet.

For the same reason, the digestibility of almost all the essential amino acids were reduced by varying degrees following the consumption of Giza 3. At the same time, fecal amylase and proteolytic enzymes increased significantly ($P < 0.05$) among the subjects consuming the Giza 3 diet, as compared to the enzymatic activities in the stools of subjects that were fed on Triple White. Fecal excretions of bile acids and proanthocyanidin were significantly higher for the subjects consuming a Giza 3 diet than for those fed on Triple White.

Use of Faba Bean Meals for Diabetic Patients

Leguminous seeds have been widely recommended as part of the dietary treatment of diabetics (Simpson et al. 1981). We studied the effect of different faba bean meals, each providing 50 g soluble carbohydrates when consumed, in the postprandial blood-glucose level of diabetic patients after an overnight fast. Four different forms of faba bean were used; stewed and sprouts, of Giza 3 and Triple White (Table 4). Faba beans gave a flatter blood-glucose profile when compared with meals containing the same carbohydrate content from other sources such as chickpea, or from 50 g glucose.

Different reasons are proposed to explain the mechanism by which legumes influence the slow release of sugars. Phytic acid, polyphenols, amylase inhibitors, and resistant

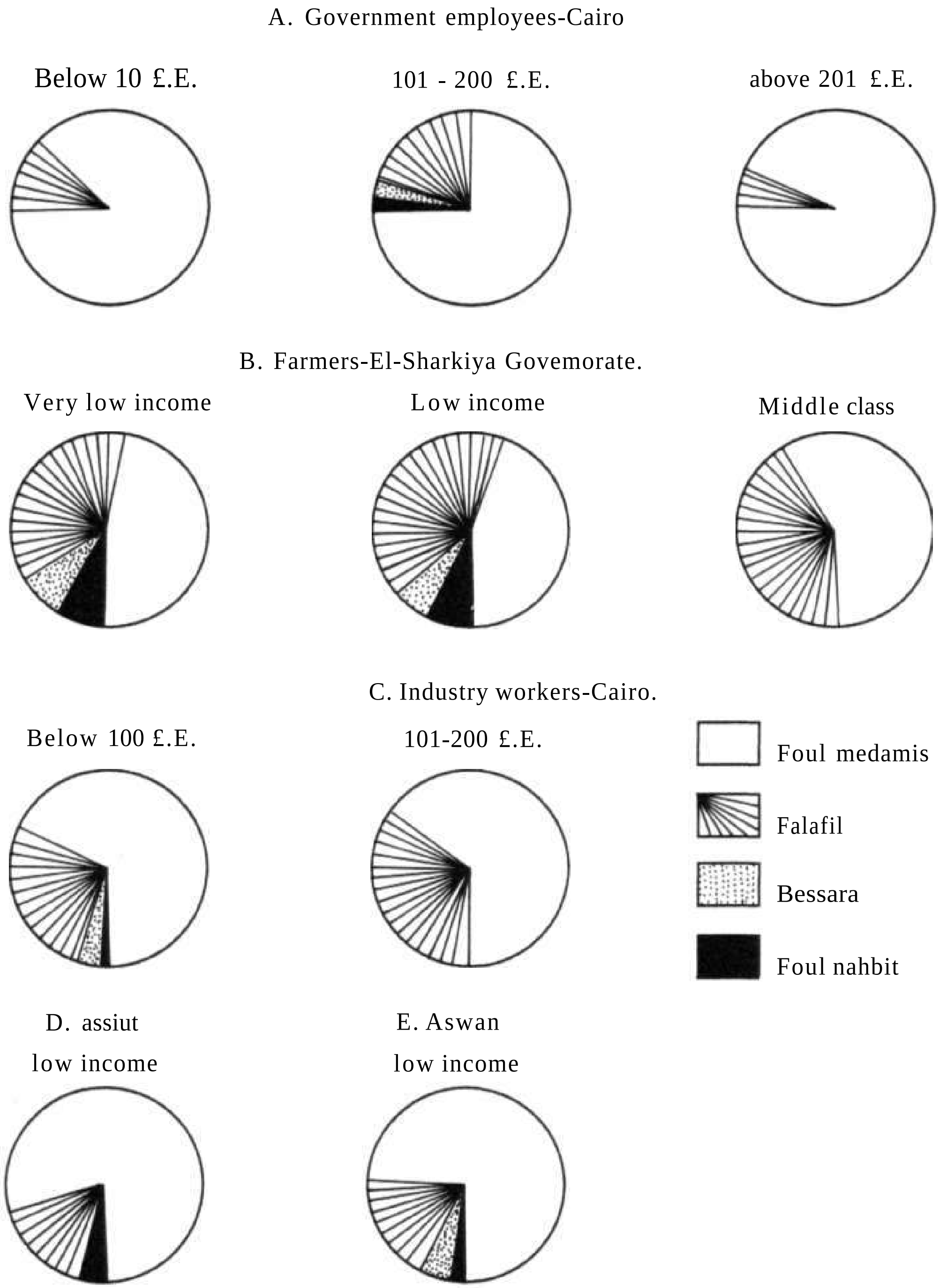

Figure 1. Patterns of faba bean consumption among Egyptians. (Note: £.E.= Egyptian pounds)

Table 4. Glycemic index of some leguminous foods when served to non-dependent and insulin-dependent diabetic patients to provide 50 g carbohydrates.

Common name of the meal	Description of preparation	Amount served[1] (in g)	Glycemic Index[2] Insulin non-dependent	Insulin dependent
Glucose	Dissolved in 200 mL H_2O	50	100	100
Stewed *Foul medamis* Giza 3	Boiled gently until seed softens	320	45	
Triple White	Boiled gently until seed softens	240	18	
Foul nabit	Faba bean sprout	198	21	126
Hommos	Roasted chickpeas	100	35	94
Bessara	Decorticated faba beans, boiled, squeezed into puree		42	118

1. To provide 50 g carbohydrates from glucose or from different leguminous sources.

2. Glycemic index = $\dfrac{\text{The area of increase in blood-glucose 2 h after the ingestion of test leguminous seeds}}{\text{The area of blood glucose 2 h after the administration of 50 g oral glucose}} \times 100$

starch are reported to play a role in the mechanism (Jenkins et al. 1984). Abdalla (1988) showed that a flatter blood-glucose profile was seen after eating stewed faba beans in non-insulin dependent diabetics when compared with diets of rice, potatoes, or glucose. This beneficial effect is restricted only to non-insulin dependent diabetics. The postprandial blood-glucose values of insulin-dependent diabetics were almost the same after consuming glucose sugar, faba bean sprouts, or faba bean paste, providing 50 g soluble carbohydrates. The use of faba beans as an ingredient in baby-food formulae is not encouraged in Egypt, due to the presence of the haemolytic factors: vicine, and convicine.

Processing and Functional Properties

Simple methods, such as air classification and ultrafiltration have been described for the production of faba bean protein concentrates and isolates (Bramsnaes and Olsen 1979). By using a combination of pin mill and air classification methods, dehulled faba beans yielded about 48% of protein flour.

A wet process involves mixing dehulled and dry milled faba beans with cold water and results in about 85% of the protein being extracted. The extract is clarified before ultra-filtration or acid precipitation. The cost for the ultrafiltration process was reported to be similar to that of the traditional acid coagulation procedure (Bramsnaes and Olsen 1979).

Protein can be isolated by extraction with a sodium chloride solution of 0.2 to 0.8 ionic strength, and precipitating the protein by dilution with water (Murray et al. 1981).

Modification of Faba Bean Proteins

Succinylation dissociated the globulin proteins, vicilin and legumin, into subunits, shifted the solubility minima to pH 4.0, increased the water absorption capacity by 25%, and the oil absorption capacity by 40% (Feeney and Whitaker 1985). Acetylation of faba bean proteins increased the swellability, viscosity, and brittleness of the preparation in aqueous solutions (Schmandke et al. 1982).

A faba bean concentrate prepared by air classification reduced the cooking losses of broiled meat patties, when 30% of the meat was substituted by the legume concentrate (Bramsnaes and Olsen 1979). It has also been suggested that starch, which makes up to 20-25% of the air-classifed faba bean products could be responsible for their water-and fat-binding properties (Bramsnaes and Olsen 1979).

Faba bean protein concentrates or modified products, are usually mixed with other proteins, meat, milk, or wheat. Faba bean flour concentrates, or isolates may therefore be used directly as protein enrichers in pastas and baked foods.

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Research on Utilization of Food Legumes: Convergence between Private and Public Sectors

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Abstract. *In the last two decades, class differentiation in societies in Asia assumed recognizable characteristics. In most countries, middle classes have evolved, constituting sizable groups with buying power, and distinct consumption patterns. In general, the middle classes tend to consume less staple food and more luxury goods, including snack and processed foods. The development of the animal-feed sector is a major indicator of this process, as is also the further development of the snack and process food industries. The demand for crops that lend themselves to large-scale processing (soybean, maize, cassava, and perhaps grain legumes) has risen quite sharply. It is timely to analyze demand for specific market segments, supplied by various types of raw produce. Research on utilization aspects should follow the lines of commercial product development, rather than the methods for determining national food requirements in aggregate terms.*

It has become clear over the last few years that budget allocations for national agricultural research systems remain geared to research for maintaining and expanding basic foodstuffs. Although grain legumes vary in importance from country to country, in general they do not enjoy significant budgetary support in Southeast Asia. Recognizing the limited resources allocated, increasing institutional flexibility in conducting research on a project or contract basis is recommended. A relatively high proportion of national research on food and grain legumes has been financed by international and bilateral sources. Lately, in various countries, private-sector companies have indicated an interest in securing stable supplies for processing, resulting in a need for contract research.

Introduction

In considering utilization research of chickpea, pigeonpea and groundnut in Southeast Asia, several matters need to be highlighted. These concern the institutional development

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of international and national research agencies as well as the private sector, in particular agri-business. Research on utilization implies taking a far-reaching and meaningful step for any institution dealing primarily with research on production of commodities. This paper looks at utilization of the above three crops from a purely commodity aspect.

Considerations on Utilization Research

The inclusion of research on utilization in an institution focusing on production research, appears to be a step with several important implications. Most CGIAR institutions view their contribution to world agriculture primarily in terms of making improved seed and technologies available to the national research and development systems. Benefits are usually expressed in terms of increased food availability, increased farm income and more efficient agricultural production systems. Research activities, sometimes labelled "postharvest" which could cover a wide range of subjects, are usually limited to reducing losses and to providing links with national markets. They deal primarily with village and farm level methods of drying and storage. However, the route of commodities from production to consumption is long and complicated. Mechanisms of marketing, price formation, quality identification, distribution, and demand determine the behavior of farm produce as economic goods. This observation has relatively recently met with recognition by the international research community in several ways.

In farming systems research, a first step was the recognition of interdisciplinary research among the technical branches of agricultural science. More recently, this research assumed a more applied and developmental character by including the economic environment. This concept, by including location-specific action and development research, actually reflects the need for links with the economic and social environment. For example, a food legumes workshop held in Khon Kaen, Thailand, recognized the importance of socioeconomic factors in production and included among its recommendations; "that research into socioeconomic factors influencing the production, marketing, processing and use of food legumes within Asian farming systems be expanded as a matter of urgency" (Wallis and Byth 1986). Market identification was also indicated to be very important.

Recognition has also come from institutions engaged in food policy which have long followed an approach of identifying food needs with the aim of indicating gaps in food production, and the need for self-sufficiency in primary foodstuffs. In Southeast Asia, a strong political determinant after the Second World War has been the focus on rural development and stabilizing rural economies. A reader published by the Economic Development Institute (EDI), entitled: "Food policy, integrating supply, distribution and consumption" covers the classical tool-kit of government interventions in the policy sphere, ways to define problems, and recognizes distribution and marketing as important mechanisms (Gittinger 1987). This analysis suggests that efforts of the international research community in both food production and food policy converge in the area of marketing and distribution, or in utilization. It underlines the fact that development, at least in Asia, means business.

It could be argued that with utilization we are dealing with a matter which could be best addressed by private business and the national system, because consumption patterns and consumer preferences tend to be country-if not area-specific. Also, research on specific utilization deals with business propositions, where the financial viability of the operation is the most important characteristic.

However, several facilitating roles do exist for production-oriented research institutions. A supporting function of an international agricultural research center (IARC) could lie in making available, a range of processing options. These technologies should originate from a large number of countries and cultural areas resulting in a range of documented options. Identification of national sources could be incorporated with ease in existing network activities (Kaul 1987).

A second option for an IARC is to engage in research to develop general know-how on utilization options. This research would add to the documented range of utilization technology. This task could be undertaken as a collaborative effort with national agricultural research centers (NARCs).

A third option would be to select a food processing technology on the basis of an identified market, existing prices and identified demand, and distribution network. It would deal with the development of a business proposition which may be the primary domain of the private sector. However, on an ad-hoc basis such an activity could be included as a component in development projects, which are mostly funded by governments or development institutions.

In the case of ICRISAT with its comparatively narrow range of crops and field of utilization, it seems viable to work on the first activity of documentation of technology options, and perhaps develop new technical options. The third activity would remain the domain of national researchers and the private sector.

In undertaking utilization activities, the role of research institutions assumes a "developmental" character. This role could have beneficial effects for the ultimate user, and for the research institutions, which are relatively isolated from private sector developments.

Contract Research: a Meeting Point of the Public and Private Sectors

Several important transitions can be identified in the public and private sectors in Southeast Asia in the last 20 years (Bottema et al. 1988). In food processing, the rapid and recent development of the animal feed industry during 1980-86 is most significant. Since 1980, demand for luxury foods such as meat, eggs, poultry, snacks and expensive vegetables developed rapidly. This growth has been supported by the establishment of sizeable middle classes with an impressive buying power.

The increased demand for luxury foods led to changes in animal feed composition, and increased the production of animal feeds and horticultural crops. Initially many animal feed industries were started on a small scale to supply feed to producers of poultry, eggs, and milk, and piggeries. Large-scale enterprises soon discovered this important growth market and their involvement resulted in the establishment of some large-scale animal feed factories and related facilities for processing cassava, soybean, and maize. Meanwhile, the horticultural sector has expanded production to satisfy the growing demand for high-value vegetables, fruits and other horticultural produce for processing.

These developments, which have occurred in most countries in Southeast Asia, have resulted in a healthy horticultural sector and well developed animal feed industries, which have received little government support. This interesting phenomenon needs to be viewed in conjunction with the development of national financial markets, pension funds, and real estate. As a significant sociological phenomena in Asia, it indicates a further differentiation of society and, a widening gap in income between small landholders and the urban lower classes, peasant producers, and the middle class.

During the same period, the majority of national agricultural research and development systems have become dependent on funding from bilateral or multilateral sources for their development budgets. Food sufficiency in major staples is still the most important element in government agricultural plans, and the consequent budget allocations. As a result, agricultural development funds have largely been channeled into irrigation and infrastructure projects, and into rice and wheat development. Institutions with less well-endowed mandate crops have had difficulty in making ends meet.

However, an interesting parallel development has taken place. From 1975 onwards, private investments in agri-business have increased. Private sector industry undertook research in tandem with commercial activities, and established their own research capacity. The establishment of collaboration with public research institutions was only a matter of time. In many cases public institutions dealing with crops considered less important from a food policy perspective, but being extensively used in the food processing industry—notably cassava, soybean, maize, and horticultural crops—have been the first to work with the private sector.

National research agencies and universities are increasingly engaged in contract work, in collaboration with the private sector. This development has occurred in all countries in Southeast Asia. An interesting example is provided by the Republic of Vietnam, where government institutions operate on a contract basis with other government agencies and cooperatives. A research institution mandated to conduct basic research may keep itself going through production of seed for cooperatives. Rather than a weakness, this situation reflects the strength of the NARS, namely their versatility to engage in producing contractual benefits. It should be appreciated that collaborative project and research arrangements with national organizations, multilateral and bilateral organizations, and IARCs, have opened the doors for this development.

In viewing the societal process, one can conclude that the basic ingredients are available for profitable collaboration between the private sector, food processors, and public sector researchers. The discussion on utilization is appropriate because it not only involves the development of international organizations, but also because it is directly connected with a long-term internal process in developing countries.

Utilization Research: Starting with the Consumer and the Market

Research on the utilization of agricultural produce is much younger than production research in agriculture. It started having an impact on processing and agricultural production during the period 1930-50. Since the 1960s the big food corporations have expanded their capacity, and the private companies remain leaders in the field.

In Asia where private industries are initiating research on utilization, there are fundamental differences in approach, objectives and justification between research on utilization and research on production. While research goals of production relate to increased farmers' benefits, justifications about the activities of government and international agencies are expressed in terms of sector development, area development, food supply, and stability. Utilization research developed by the private sector has entirely different goals, and these are more specific in nature.

Utilization research is defined in terms of consumer behavior, which is dependent on both market size and market segment. It is based on direct financial benefits to all participants in the process. This fundamentally different approach necessitates very specific research methods, and basically involves identification of all costs and benefits of each of the components of the process.

Recently, several market and distribution-oriented food processing companies have been successful with large-scale, guided production projects on small farm holdings. Nestle, Ciba-Giegy, Cargill, and Unilever have started operations in Malaysia, Thailand, the Philippines, and Indonesia. They indicate the capacity and the willingness of the private sector to invest not only in processing facilities, but also in the production of raw produce. This development should rapidly gain pace with increased investments by national companies to produce animal feed, and horticultural and food crops. The high proportion of successful projects from national and international companies is best explained by the fact that processing and market links were firmly established in advance of establishing production.*

While the importance of utilization, marketing, and distribution is recognized by IARCs, the private sector moves to assist production on small farm holdings, by putting the consumer first.

Utilization, Marketing, and Distribution

In considering research on utilization one should distinguish between the concepts of marketing and distribution as understood by the international and national agricultural research and policy organizations on the one hand, and the private sector on the other.

In the public sector, market research has been defined in terms of market capacity and efficiency. Primary indicators are margins and profits accruing to participants in the marketing chain, price integration, and the volume of transactions as related to production fluctuation and storage capacity. Assessment of social and economic efficiency has been the primary aim of public-sector research.

Traditionally, the absence of private-sector capacity in marketing major staples has supported the foundation of national marketing boards and cooperative systems for marketing and distribution of foodgrains in Southeast Asia. Individual and product-specific research on market segments within a range of possible utilizations has rarely been the object of research. However, in research and development projects, such activities have been, and still are, part of the research approach.

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* Personal communication from numerous food processing company representatives. This interesting issue has not yet attracted concerted attention.

In the private sector the concepts of marketing and distribution have a totally different meaning. Private sector research has been traditionally related to product-specific development and market-specific know-how. Market size, strength of competitors, wage rates, and costs of investment, are primary indicators for defining general market profits and specific benefits, in considering product development. Distribution usually refers to the despatch of processed produce to either wholesalers or retailers.

Figure 1 depicts the whole process from production and product transformation to consumption. It is clear that the meaning of marketing depends on the place of the actor in the chain. For example, from the farmers' point of view, selling produce to assembly traders may be marketing; from the point of view of the food processing sector, it is part of the purchasing system. It is shown that typically the private sector defines research starting from the demand side, while public sector research (including NARCs and IARCs) starts from the production side.

Utilization is a relatively new concept, which refers to technological options in the processing of produce, and development of specific consumer goods. In the private sector it is called product development. In research, it is used in the narrow sense of a technological option. However, the term is often used to refer to the whole complex operation of market identification and the development of a business proposition. It implies an approach that starts with end uses, and focuses on selection of technology that can produce a product with one or more intermediate or end uses, as in the case of meals and other ingredients used in animal feed. Many meals e.g., sorghum and soybean meal, can be substituted for one another in feed mixes with a slight variation in additional ingredients. Companies manufacturing animal feeds have developed least cost programs to evaluate the financial benefits of various substitutions. In the alcohol and sugar industry similar substitution of intermediate products takes place.

An implication of research in utilization is that business economics becomes part of the approach. This means that although the concepts of marketing, distribution, and utilization are used in various ways, they basically belong to the same cluster of activities that add value to agricultural produce. Another conclusion is that the justification for research on utilization is expressed primarily as creating market opportunities rather than directly benefiting producers or farmers. The indirect benefits for producers are in the sense of establishing a market, and adding to their production options.

Chickpea, Pigeonpea, and Groundnut in Southeast Asia

Looking at the FAO production statistics for the period 1977-88, it becomes clear that in Southeast Asia among chickpea, pigeonpea, and groundnut, only groundnut is a crop of national importance in Indonesia, Myanmar, The Philippines, Thailand, and Vietnam. Area development in Indonesia and Myanmar seemed to fluctuate considerably during 1985-87, but no great increase in area is noticeable (Table 1). Vietnam, however, has rapidly expanded groundnut cultivation between 1980-85. In Thailand the area seems to be stable at 120 000 ha.

Imports of groundnut have grown steadily in Singapore, and constitute a US$ 25 million market. Groundnut imports to Indonesia fluctuated after a rapid expansion in the early

Table 1. Groundnut in shell ('000 ha).

Country	Area harvested									
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Myanmar	563	523	456	490	555	540	524	620	549	577
Indonesia	514	473	506	519	461	484	538	510	601	520
Laos	7	11	11	11	12	12	12	12	13	15
Philippines	48	54	55	39	56	57	46	50	50	55
Thailand	8	100	100	117	118	136	131	121	125	118
Vietnam	100	91	108	115	129	140	170	270	280	286

Source: FAO 1987.

1980s. ICRISAT's mandate crops are in an essentially different position in Southeast Asia as compared to South Asia or Africa where they are used for subsistence. In this region, groundnut is primarily a snack, while the other mandate crops show some potential as side dishes as in Indonesia, or as animal feed depending on relative prices, especially of maize and cassava.

In the case of groundnut in Southeast Asia we are dealing with an established crop with a variety of end uses. R & D activities could therefore be directed to: (a) increase the efficiency of the existing system; and (b) to expand the range of end uses through selection of technology based on market research.

Chickpea and pigeonpea in Southeast Asia are essentially new crops, although they are grown in limited quantities. The utilization patterns of groundnut in Southeast Asia are well known, because the crop is of importance throughout the region. It is possible to assess the volume and forms of imported groundnut to identify market rewards for various groundnut cultivars. A study conducted by staff of the Directorate of Post-Harvest and Farm Management, Ministry of Agriculture, in Indonesia, indicated that there were clear market rewards for good quality, large-sized groundnut which indicates that the private sector has established a processing capacity requiring raw produce of specific quality (Altemeier et al. 1989). The potential rewards and benefits for groundnut producers are sufficiently large for them to adapt some production to meet the requirements of the private sector.

In the case of production of chickpea and pigeonpea, except in Myanmar, no statistics are being kept in Southeast Asian countries. In considering the viability and feasibility of introducing new crops, the utilization approach seems to be useful. The procedure identifies several major end uses of comparable crops, which could be partly replaced by the new crops. It estimates market size and the initial market share. Based upon market assumptions, the potential of the new crops can be identified. It is of great importance to calculate the benefits farmers derive from new crops, and the comparative advantage of the various production options. An example of utilization research in new crops, which established potential use in Southeast Asia, is the ACIAR/CRIFC pigeonpea research program, and a Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Roots, and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT) study on the potential for pigeonpea in Thailand, Indonesia, and Myanmar (Wallis et al. 1988).

The Centre has also conducted studies on pulses in Nepal and Bangladesh (CGPRT nos. 6, 11, 12, and 18). The findings indicate that compared to competing crops, yields of pulses are too low to be attractive for large-scale and wide-spread cultivation by farmers. Those reports also show that there still is a fairly well-developed demand for pulses, including chickpea and pigeonpea, but that this demand is not associated with high prices, because the demand is primarily located in the lower income classes. In that case, the identification of new higher valued end uses seems a fruitful activity to pursue. The other option of increasing productivity and lowered prices of pulses is not certain to significantly increase demand. This matter needs research. Both options do not exclude one another.

Conclusion

This paper recognizes the rapidly strengthening research capacity of the private sector and the increasing collaboration between the NARSs and the private sector, as well as the commercial nature of utilization research. Activity in utilization would strengthen and expand research links with the private sector. In considering utilization, the author recommends that one distinguish between utilization in a narrow sense of identifying food technology (or product development), and utilization in a general sense, which includes market-oriented research.

In establishing program activities, it is recommended that activities to document a range of technologies as connected to intermediate- and end uses be taken up, while product-specific research could be implemented in a project framework. Innovative collaborative structures are necessary to link production know-how with market realities.

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Development of Postproduction Systems Research to Increase Legume Utilization

E.J. Weber[1] and P. Pushpamma[2]

Abstract. *Success in promotional efforts for any food crop depends on developing location-specific production, and postproduction technologies. Increased demand in local, regional, and international markets is the major motivating factor for increased production. Though legumes have a place in most cropping and food systems in the semi-arid tropical (SAT) regions, various constraints along the chain from production through harvesting, threshing, drying, storage, primary, and secondary processing, product development, and marketing are limiting their current consumption.*

International agricultural research centers (IARCs) can play a key role in encouraging expanded utilization of legumes by promoting overall research strategies that include: market studies to define needs and opportunities; strategic food-system thinking and research; methodology adaptation and training to include postproduction issues; promoting integration of research and development (R and D) postharvest and production activities of national and international institutions; and providing continuity through long-term commitment. Pilot testing of both production and postproduction technology components as combined solutions to identified problems is encouraged.

Introduction

Legumes are an important constituent of diets in most parts of the world, especially in the semi-arid tropics. Traditionally, they are grown and utilized in combination with other food crops, like cereals and root crops, which complement them ecologically and nutritionally. For many of the poorest people they are a major source of protein, and hence have been referred to as "poor man's meat". Nutritionally, the proper combination of legumes and cereals or tubers, when consumed in adequate quantities, satisfies the calorie and protein needs of an individual. Because legumes are an integral part of many existing food

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ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1991. Uses of tropical grain legumes: proceedings of a Consultants' Meeting, 27-30 Mar 1989, ICRISAT Center, India. Patancheru, A.R 502 324, India: ICRISAT.

production and consumption systems, the emphasis of crop improvement efforts should be to encourage increased and more varied utilization of those legumes that are presently grown, rather than on major new introductions. An exception to this is in higher-income urban markets where costlier processed products are affordable. Constraints which limit expanded consumption can be classified as production, postproduction, and nutritional factors.

Production Constraints

Despite being well integrated into many traditional food systems, legumes suffer a number of constraints which limit their potential for greater exploitation and benefit by producers and consumers alike.

In some traditional legume-consuming countries, stagnation in productivity and area under production of legumes contributes largely to their lower availability. Greater research and promotion efforts made on wheat, rice, and maize, and supportive economic policies have pushed up the area as well as productivity of these cereals, giving them an advantage over legumes in overall terms. Thus, increased cereal availability at lower prices has increased cereal consumption, consequently reducing the ratio of pulses to cereals in diets.

More convenient processing and products also benefit utilization of cereals. What effect this has had in nutritional and income terms is not clear. However, maintaining or increasing the ratio of legumes in producton and consumption patterns would have benefits in terms of income, food variety, and nutritional status.

Postproduction Constraints

Constraints to the postproduction systems of food legumes are encountered at all stages, including harvesting, threshing, drying, storage, primary and secondary processing, and marketing. Non-availability of appropriate technology and techniques appears to be a serious impediment in promoting utilization of legumes.

In legumes postproduction research, the problems, and systemic and component interactions are as complex as those in the crop production system. There are also mutual effects influencing technology performance in both production and postproduction sectors that require identification for setting research priorities. Further, both production and postproduction systems function within an overall economic and policy environment, which influences decisions on what technology to use and what product to buy. A broader consideration of factors in the context of the total food system could lead to more effective identification of research problems.

Handling and Drying

The need for improved methods of postharvest handling and drying of groundnut used for producing salted nuts and peanut butter was recognized in the Philippines, where thousands of farmers grow groundnut on small scattered patches. Major quality problems, especially aflatoxin contamination, prompted a comprehensive study of the whole groundnut industry and market system to identify key areas for improvement in a systematic way. The results of the study[1] showed no major single solution to the problem or any key intervention point. Improvement of the system, product quality, and farmer income were found to combine several of the following:

- aflatoxin-free and higher-yielding varieties;
- adjustments of agronomic practices;
- more rapid, controlled drying;
- better seed selection, storage, and preparation;
- insect infestation control;
- development and introduction of methods for selection and grading of nuts before storage or sale; and
- identification of the effective points to introduce these changes into the market chain from producer to assembly agents, primary processors, commercial processors, wholesalers and retailers.

Storage

In the Household Grain Processing Project, conducted at the Andhra Pradesh Agricultural University, Hyderabad, a study was made on the food system in dryland regions (Pushpamma and Chittemma Rao 1981). Though legumes are well integrated into the dietary pattern of the populace in SAT regions, several other constraints limit their consumption. One of these is lack of appropriate small-scale technology to facilitate longer storage. The producers of the legumes are compelled to dispose of their grain soon after harvest or incur heavy storage losses. For this reason, their legume consumption drops in the lean season when they have to buy back processed legumes in the market at a much higher price. The pricing policy adopted by the Government also restricts the consumption of legumes, as cereals are supplied at subsidized prices but not legumes. The lack of suitable storage and processing facilities at the household and village levels, pricing, and marketing systems play a large role in the utilization of legumes. This study suggested the desirability of greater research emphasis on all aspects of postproduction systems

Legumes are susceptible to storage pests, and under poor storage conditions to qualitative losses as well. Insects and rodents cause major physical losses and leave unhygienic residues which reduce grain quality. Legumes harden during storage, resulting in increased fuel costs and cooking time. In a 1983 survey carried out by the Institute of Nutrition for Central America and Panama (INCAP) in Guatemala, hardening-related losses accounted for 3-32% of total production (INCAP 1983). This problem deserves greater attention in both Africa and Asia.

1. Unpublished project documents and reports.

Processing

Legumes are often converted into intermediate products by dehusking, shelling, splitting, milling, and oil-extraction processess. While large-scale processes and equipment are available for centralized plants, usually in urban areas, village-level, small-to intermediate-scale technologies appropriate for village-level processing need to be developed. This will encourage greater legume processing, utilization, and consumption close to where it is produced.

A simple groundnut sheller motivated farmers to expand groundnut production in Thailand, illustrating how understanding and improving postproduction operations can affect crop production strategies[1]. On- farm or local groundnut shelling was identified by engineers in Thailand as a means for farmers to realize part of the trader/processor margin, and consequently increase their income. A simple, inexpensive shelling machine was developed and supplied to small farmers. The machines were little used, however, until seed preparation time when they allowed farm families to shell more groundnut than could be done by hand. Since additional land and water were available, more groundnut was sown. In analyzing the use of the shellers by farmers, researchers became aware of other constraints to production and income. Development and testing equipment to improve the efficiency of digging, stripping, and drying to reduce on-farm losses were identified as important needs.

The same sheller was evaluated in Malawi[2] where it proved to be too large and expensive for farmer needs, even though hand shelling is a major postharvest constraint. An inexpensive wooden sheller was locally developed and tested, and an interchangeable component was incorporated to adapt it to various groundnut sizes, shapes, and shell toughness, thus increasing its versatility. Postproduction constraints and requirements vary, depending on end uses of the food, and the economic, social, and cultural scenario.

Promotion of Legume Consumption

In regions where legumes are traditionally part of the diet, the quantity consumed could be augmented by: increasing availability; reducing prices; improving culinary characters; improving storage and handling both on and off the farm; developing appropriate processing technology for different markets; diversification of products; marketing strategies to suit changing trends; and shifts in eating habits.

It is important to identify and develop special approaches for new markets where legumes and cereals are not traditionally utilized. Where products of a specific legume, or combination of legumes are already entrenched, it is more effective to expand on existing products and uses, and to identify constraints, bottlenecks, and new opportunities in the established system.

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1. Groundnut Mechanization (Thailand) III 1987. Department of Agricultural Engineering, Khon Kaen University, Khon Kaen, Thailand, IDRC project no. 3-P-87-0041.
2. Department of Agricultural Research, Ministry of Agriculture, IDRC project no. 3-P-86-0275.

Market research to identify potential consumers and their preferences can provide valuable information for diversification and expansion of legume products. Urban markets provide better entry points for these alternative or substitute products. Successful substitution technologies are related either to cost reduction or product quality improvement. Consumers resist substitution if eating quality characteristics override economic considerations. The prohibitive cost of traditional legume preparation is usually lowered by diluting the recipe, rather than by replacing it with a less expensive one.

Income elasticity for legume consumption appears to be quite low[1]. Therefore increased production and utilization requires a strategy of product diversification, alternative uses, and new market development. Such a strategy requires careful consideration, however, if it is to be effective.

Most initiatives to extend legume utilization have either developed new products or incorporated legumes into foods consumed on a regular basis. In either case, or in replacement of one legume with another without a clear consumer benefit, the product will remain in the laboratory as an academic achievement.

Identification and creation of demand in urban markets should be based on carefully designed market research to assess the needs of urban consumers, especially with a view to changing life styles and trends in eating habits. Snack foods, convenience foods, and health foods seem to have potential for greater demand. Commercial marketing promotion techniques may hold a key to successful introduction of new foods in urban markets. For nutritionally upgraded foods to meet with success in the market place, attention needs to be paid to such attributes as physical characteristics, status value, and attractive packaging.

Promotion of any food crop depends on yield potential, and on creating market demand at the same time. Markets and consumer needs vary according to circumstances. While emphasis has been placed on urban markets, legumes are also essential in rural diets. This segment of the market, though more difficult to cater to, should not be ignored. Some stratification of potential markets for product and strategy development will help focus research efforts more precisely. Factors such as levels of income, population density, and present consumption patterns suggest four possible market sectors:

- household/local/semi-subsistence;
- village;
- low income mass market/urban; and
- higher income/urban.

Potential Role of IARCs

Based on cassava utilization experience in Colombia, involving the Centro Internacional de Agriculture Tropical (CIAT) and national agricultural research systems, the following key entry or influence points for IARCs were identified.

1. Household grain processing (India) II and Food Enterprises (India) HI. Andhra Pradesh Agricultural University, Hyderabad, India. IDRC project no. 3-P-80-0210, and 3-P-86-0035.

- Market orientation
- Strategic thinking and research
- Market orientation
- Strategic thinking and research
- Methodology adaptation and training
- Integrated and catalytic research and development (R & D)
- Continuity

Market Orientation

Assumptions about beneficiaries should be specified in order to set precise research objectives. It is important to identify clearly where in the system new technology is best introduced, related to what are usually multiple objectives, including improved food intake and variety, and increased income and job opportunities.

IARCs could place more emphasis on market research to better identify product and process opportunities related to rural and urban market sectors with emphasis on low income consumer needs.

Strategic Thinking and Research

Food consumption patterns shift and change, even among low-income consumers, as new knowledge and products become available to them. These changes may involve greater variety in diets, more processed and convenience foods, a growing market for snack foods, and the demonstrated effects of higher-income consumption patterns. It is therefore important to identify and assess legumes and legume-based products with new and expanding market potential, as well as those with a declining market share.

Often, processes and products are location and environment-specific. Identifying the basic production and postproduction technology around which variations can be evolved, according to local needs and specifications, could be very productive both for IARCs and NARs.

Methodology, Adaptation, and Training

Farming systems research and applied on-farm trials are accepted as part of the IARC research domain to provide feedback on problem definition and performance of modified technologies under operating conditions. A parallel or analogous approach in the post-production system would improve the possibilities for interaction and definition of problems spanning both sectors. A possibility is to build on already existing knowledge of agroclimatic-based production zones and consequent food systems.

Integrated and Catalytic R & D

Postharvest research capability in most developing countries is scattered throughout many institutions, departments in ministries, universities, and the private sector. No dissemination and promotion structure exists as for agricultural production technology. This is especially true for the needs of thousands of small-scale urban and rural postproduction enterprises. IARCs have an opportunity to promote greater linkages, strategic thinking, and studies with researchers in these institutions. Postproduction research networks could evolve as components of already existing production-related networks. Implicit in this structure are opportunities for training.

Continuity

The ideas and approaches suggested will take time to develop in an evolutionary and experimental way. This requires steady long-term commitment and effort. Unfortunately, national institutions, especially in poorer countries, often cannot, or do not provide this longer-term stability in personnel or priorities. A core group of scientists concentrating on basic legume-utilization problems will assure maintenance of knowledge and a focus for future research.

Finally, research on operational topics is as necessary as laboratory science. Pilot projects in both production and postproduction sectors and their interaction are a crucial means of testing technology under real conditions. There is a role for selective IARC participation here as well, although most have hesitated to move into commercial-level operations, viewing this as clearly a national prerogative. Unfortunately, in the postproduction area, there are few national institutions with the mandate or capability to carry out this integrative pilot activity. Pilot projects can be key research efforts to fine-tune and evaluate technology constraints, gain experience in organization, train researchers and program managers at the national level, and provide crucial information and impetus for full-scale development projects to follow.

It is not our intention to suggest that IARC-based legume-research programs launch into postproduction programs on a scale to rival that of their production-related activities. This is clearly not feasible, or viable. We do feel, however, that with some reorientation of existing resources and alliances, it would be possible to incorporate a broader postproduction systems perspective and strategy. This focus could serve both IARCs and national programs alike, in deciding how scarce research-support resources can best be applied to solving problems and, to providing low-income people more opportunities in the broader food system.

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Discussions

- The use of integrated pest management, i.e., host plant resistance accompanied by judicious use of insecticides was suggested as a means of controlling the pod borer *Helicoverpa armigera.*
- In clarifying the adoption of short-duration dwarf genotypes, and their relationship to food production, it was noted that the wood yields per unit area in short- and long-duration types are similar.
- Pigeonpea cultivation is not expanding in the West Indies because split peas are cheaper and available. The University of the West Indies is interested in more information on pigeonpea utilization.
- When introducing a new crop, initially only one variety should be tried. After it has been found successful and stabilized another variety can be introduced. This procedure was successful in introducing cowpea in Thailand.
- Pigeonpea millers generally prefer bold, white-seeded material for high *dhal* recovery.
- Storage conditions and length of storage periods may increase the cooking time of legumes. To obtain quick-cooking mung bean, an alkaline pH and short heating time at high temperature should be used, because this retains most of the amino acids.
- The need to find alternative uses for pigeonpea is justified because of pigeonpea's global potential for use in nontraditional areas.
- About 60% soybean could be substituted by pigeonpea in *tempeh* preparation without affecting its overall quality.
- Soaking pigeonpea seed before fermenting improves the quality of *tempeh.*
- The economic aspects of *tempeh* production merit further examination.
- Protein concentration increases in fermented *tempeh,* but the reasons for this are not clear. It could be due to the conversion of nonprotein nitrogen into protein by *Rhizopus oligosporus* and other flora. Trypsin inhibitor activity is reduced by calcium.
- A rice and mung bean mixture, flavored with milk, vanilla and sugar is now sold in the Laguna area in the Philippines. This formulation is also being test marketed in southern Philippines. After starch extraction, there is scope to utilize mung bean protein as texturized vegetable protein which otherwise goes to waste (in Thailand). Sale of this product could partially offset the price of mung bean noodles. Only about 40-43% of mung bean seed is recovered as starch, and there are no varietal differences. Starch extraction rates in laboratory and commercial methods are comparable. Such studies on pigeonpea should also be conducted.
- During the extrusion of soybean complete inactivation of lipoxygenases is not achievable because the protein would be seriously damaged by scorching. Steam injection results in higher deactivation of heat-resistant enzymes.
- In remote villages in Myanmar, people still use pigeonpea as a medicine and this has been confirmed in a book written on the medicinal uses of plants.
- Canning of pigeonpea is important and is a major activity in the Dominican Republic and Puerto Rico.
- Parameters that influence the quality and acceptability of vegetable pigeonpea need to be identified.
- Pigeonpea is also used for the preparation of lac in Thailand which is formed by scale insects.

Recommendations

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Rapporteurs U. Singh and K.B. Saxena (ICRISAT)

Participants

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- Members felt that the pigeonpea group was not representative of the countries providing consultants to this meeting since there were no delegates from Africa, perhaps a reflection of the lesser importance of pigeonpea in that continent.
- There were considerable information gaps identified by the Group, reflecting their lack of knowledge, their inability to identify where such information is available, or the fact that such information is not yet available. It was suggested that data gathering from a variety of sources, including Australian Centre for International Agricultural Research (ACIAR), was required, perhaps including grass roots surveys. Surprisingly little appears to be available on some fundamental aspects of pigeonpea and pigeonpea processing, and this data must be obtained, some of it in the field.
- Most problem areas were considered as relatively minor as compared to the overriding difficulty of lack of production, both in the Indian subcontinent to provide sufficient immature seed for vegetable use and dehulled seed for *dhal* production, and in countries such as Indonesia and Thailand where it is a relatively new crop and markets are not yet established.
- Economic expertise was not available within the Group and this may have affected the priority of some recommendations.

Aspects of pigeonpea processing and use were considered within the following areas:

Postharvest handling and storage;
Primary processing;
Secondary processing; Animal feeds;
Extracted products.

Priorities for future work considered were:

- increased production of both green immature seed and mature dry seed,
- the need to examine in more detail the dehulling of seeds and the associated problems of yield, functional properties, and modification and development of small-scale equipment and its effect of grain quality, and eating quality,
- fermented products,
- noodles and protein-based products from seed fractions, and

- animal feeds from whole seed or by-products.

Problem areas were considered in the context of traditional or current products *vs* novel products as follows:

	Traditional		Novel
South Asia	Dehulling efficiency and seed quality for *dhal* production.	Southeast Asia	Fermented foods. Animal feeds. Noodles/*tofu.*
Eastern Africa	Cooking characteristics, functional properties.	Rest of Asia	Convenience foods based on improved efficiency in *dhal* production. Animal feeds.
		Africa	Possibly as Asia but at a later stage.

Identified R & D Needs

Postharvest Handling

This was considered to include storage before primary processing. Processes included village-level drying, threshing, and green pea shelling. Various problems that relate to product quality were identified. It was believed that much information relevant to postharvest practices is currently available (e.g., in ACIAR documents), and that the priority is to gather and review the data from these sources, identify gaps in knowledge, and obtain missing data at the village or grass roots level.

Primary Processing

Immature whole grain (vegetable)

- Examine known data about green peas and assess information relevant to pigeonpeas.
- Determine compositional factors that affect eating quality.
- Determine effects of grain maturity on sensory quality.

Dehulling/decortication of mature whole seed

- Examine effect of grain characteristics and quality on dehulling efficiency.
- Examine effect of seed variety on dehulling efficiency.

- Examine nutrient losses during dehulling.
- Adapt small-scale cereal dehulling equipment for pigeonpea dehulling.
- Examine mill characteristics and their effects on product characteristics and hence quality.
- Examine current processes for *dhal* processing and selection of appropriate modifications.
- Examine relative merits of dry vs wet dehulling (i.e. Indian vs Indonesian methods).

Secondary Processing

Whole grain, dry processing (roasting, grinding, frying)

- Examine the functional properties and special features of pigeonpea flour.

Whole grain, wet processing (soaking in water, sodium bicarbonate solutions, salt solutions, boiling/steaming)

- Examine and improve cooking characteristics, and nutritional implications of adopted practices.

Whole grain, germinated

- Fundamental work is required to determine technical and market potential, especially in Asian countries where bean sprouts are more popular.

Whole grain, fermented (*tempeh*, sauces, *dhokla*)

- Determine *tempeh* product characteristics and quality, consumer preferences, nutritional quality, effects of raw material type (whole vs split seeds), availability of fungal cultures, use of dried *tempeh*, i.e. secondary foods (e.g., weaning foods, extended products, etc).
- Determine feasibility of sauces preparation to simulate current products.
- Prepare standardized instant mixes ready for fermentation, for the preparation of *dhokla*.
- Determine relative costs of soybean and other grain legumes, and of pigeonpea in the countries concerned.

Canned green immature/mature seeds (low priority)

- Explore suitability of alternative packaging materials to reduce energy costs of processing.

Animal Feeds

- Determine nutritional benefits on animals, including poultry, of pigeonpea fractions derived from processing (e.g., dehulling losses), particularly with respect to anti-nutritional factors.

Extracted Products

- Determine relative merits of extracting starch and/or protein from pigeonpea.
- Examine production and nutritional quality of *tofu*-like products from extracted protein.
- Examine production and nutritional content of noodles made from pigeonpea starch.

Summary

Priorities for future work were summarized as follows:

Process	Priority
Postharvest handling	1
Primary processing	
High-moisture harvesting	1
Dehulling	1
Secondary processing	
Dry processing	3
Wet processing	1
Germination	3
Fermentation ± drying	1
Canning	3
Animal feeds	2
Extraction	
Starch	1
Protein	2

Collaborative Research and Training Needs

These aspects were not considered by the Group. It was considered that collaborative research needs would depend on the ultimate priorities established by the consultants and ICRISAT for pigeonpea research, and this in turn would determine training needs. Such requirements were likely to overlap with those relevant to chickpeas and/or groundnuts.

Session Ⅳ

Production Aspects of Groundnut and Future Prospects

S. N. Nigam[1]

Abstract. *Groundnut seeds are rich in oil (36-54%), and protein (21-36%), and have a high energy value 2363 KJ $(100g)^{-1}$ of seed. They are used for oil extraction, as food, and in confectionery products. The cake remaining after extraction is processed for animal feed and human consumption. The haulms are valued as fodder. Cultivated groundnut, a native of South America, is grown on 20 million ha in about 80 countries, with a total production of 21.5 million t. The approximate geographic limits of present commercial production are between latitudes 40°N and 40°S. Groundnut is mostly grown in Asia followed by Africa, North, and Central, and South America. Groundnut crops are found on farms at all levels of development - from bush clearings in Africa to the highly mechanized high-input farms of North Carolina and Georgia in the USA. Productivity varies accordingly -from 300 kg ha^{-1} to 10 t ha^{-1}. The key to high yields is identifying and overcoming the constraints to production.*

Introduction

Groundnut is a native of Bolivia and northeast Argentina on the eastern slopes of the Andes mountains in South America. The crop is now grown throughout the tropical and warm temperate regions of the world. Although groundnut is predominantly a crop of the tropics, the approximate limits of present commercial production lie between lattitudes 40° N and 40° S.

Groundnut is rich in oil (36-54%) and protein (21-36%) and has a high energy value of 2363 KJ.100 g^{-1}. Seeds are used for oil extraction, as food, and as an ingredient in confectionery products. After extraction, the residual cake is processed largely for use as animal feed, but also for human consumption. The haulms are valued as fodder.

Groundnut Production

Production of groundnut in the semi-arid tropics (SAT) exceeds that of any other legume and comprises 70% of the world production. It is grown on an average 18.8 million ha in

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about 103 countries with a total production of 18.5 million t (Various issues of FAO Production Year Book from 1974 to 1986). The crop is mainly grown in Asia followed by Africa, North, Central, and South America. Average crop yields are highest in North and Central America (2.5 t ha^{-1}) and lowest in Africa (0.8 t ha^{-1}). Average yields in Asia are 1 t ha^{-1}. Except for Europe, average yields in other regions are low in comparison with those from the USA (3.3 t ha^{-1}) and much lower than the potential yields of over 10 t ha^{-1} reported from research farms in Zimbabwe.

Groundnut is cultivated on farms at all levels of development - from bush clearings to the highly mechanized high-input farms of North Carolina and Georgia in the USA. The crop is also grown in different cropping patterns, i.e., as a mono-crop, mixed- or inter-crop.

In the rainfed SAT early- and medium-duration varieties are grown mainly for oil, but also for use as food and fodder. Where supplemental irrigation is available or the growing season is long, medium- and long-duration varieties are grown for oil and confectionery uses. Under a high-input system, confectionery types are normally preferred; the early types are grown in a residual moisture situation. The productivity of the crop varies with the farming system. There is need for research to identify and overcome the factors responsible for low yields.

Constraints to Production

Major constraints to groundnut production are:

- damage by diseases and pests;
- unreliable rainfall patterns, with recurring drought;
- nutritional stresses;
- poor agronomic practices with limited use of fertilizers; and
- lack of high-yielding adapted cultivars.

Groundnut Research at ICRISAT Center

At ICRISAT we are integrating plant breeding, plant pathology, entomology, microbiology, physiology, and cytogenetics research to produce high-yielding adapted cultivars with stable resistance or tolerance to the major stresses presently limiting production. Our groundnut scientists cooperate with economists, cropping systems specialists, and agronomists to develop crop management systems applicable to the small farmer. The world collection of groundnut and wild *Arachis* germplasm provides the basis for crop improvement efforts.

The problems of growing groundnut all over the world are studied intensively at ICRISAT Center. Problems more specific to particular regions are worked on in ICRISAT regional programs or through cooperative research with national programs. The program at ICRISAT Center works closely with the ICRISAT Regional Groundnut Program for Southern Africa, set up in Malawi in 1982, and the West African Program based at the ICRISAT Sahelian Center in Niger that started in 1986. There is regular flow of improved germplasm between the Center and regional programs, and networks have been established for effective evaluation of cultivars.

Diseases

Foliar diseases. The world collection of over 12 000 accessions has been screened for resistance to rust *(Puccinia arachidis* Speg.) and late leaf spot *[Phaeoisariopsis personata* (Berk. & Curt.) v. Arx] diseases at ICRISAT Center. There are 78 lines with good resistance to rust, 34 with resistance to late leaf spot, and 31 combining resistance to both diseases (Branch and Csinos 1987). Interspecific hybrid derivatives with high levels of resistance to rust and/or late leaf spot have also been bred. The sources of rust and late leaf spot resistances have been used in a breeding program, and lines combining these resistances with good agronomic characters are now in international trials. A groundnut variety, ICCV 87160, with resistance to rust and tolerant to late leafspot has been released in 1990 for rainy-season cultivation in India.

An epidemic of early leaf spot at ICRISAT Center in 1987, and establishment of a collaborative field resistance screening project at Pantnagar in northern India, have accelerated the work on this disease. During 1987, 33 out of 618 germplasm lines, 3 out of 641 breeding lines, and 5 out of 1665 interspecific hybrid derivatives showed satisfactory levels of resistance to early leaf spot at ICRISAT Center. Of these promising lines, 13 genotypes were found to be resistant even at Pantnagar during 1988 (Waliyar et al. 1990). Some of these lines are also resistant to rust and late leaf spot.

Studies continue on the influence of environmental factors and agronomic practices on development of foliar diseases.

Diseases caused by soil fungi. Field screening of germplasm lines under naturally occurring outbreaks of a pod rot complex caused by *Fusarium* spp, *Macrophomia phaseolina* and *Rhizoctonia solani* has identified several resistant lines, some of which are also resistant to pod and seed invasion by *Aspergillus flavus.*

More recently, field screening of germplasm and breeding lines against *Sclerotium rolfsii* with artificially enhanced inoculum levels has identified susceptible and moderately resistant material (Branch and Esinos 1987). Stem and pod rots caused by *S. rolfsii* are most serious in groundnut grown on Vertisols, and it is important that advanced breeding lines be screened to eliminate unduly susceptible material before release.

Aflatoxin contamination. Factors influencing the invasion of groundnut pods and seeds by the aflatoxigenic *Aspergillus flavus* have been studied in relation to genetic resistance and cultural control measures. The importance of drought in relation to pre-harvest contamination has been confirmed, and drought stress used to enhance resistance screening methods (Mehan et al. 1988). Several germplasm lines with resistance to seed invasion by *A. flavus* have been identified (Mehan 1989) and used in a breeding program, and some breeding lines have good levels of resistance (Rao et al. 1988). Crosses have been made to combine seed coat resistance to *A. flavus* infection with low capacity to support aflatoxin production. A data base on published information on aflatoxin in groundnut is in preparation.

Virus diseases. Bud necrosis disease (BND) caused by tomato spotted wilt virus (TSWW) affects the groundnut and is economically important in South and Southeast Asia. Several high-yielding germplasm and breeding lines with resistance to the thrips (latin name) vector of BND (ICRISAT 1987) have been tested for resistance to TSWW, and ICGV 86029 and ICGV 86031 have been found tolerant (ICRISAT 1988). Peanut mottle virus (PMV) disease is of worldwide distribution and can cause significant yield losses (Demski et al. 1975). Several germplasm and breeding lines showing non-seed transmission and tolerance to PMV have been identified (ICRISAT 1988). Serological tests have been developed for the detection of peanut clump virus. Soil solarization was found to be effective in controlling this disease (ICRISAT 1987). Peanut stripe virus is currently recognized as one of the most important diseases affecting the groundnut crop in Southeast Asia (Rao et al. 1988). Screening for resistance to this disease through international cooperation is in progress in Indonesia.

Pests

Particular emphasis has been placed on the development of pest control strategies that do not involve the use of pesticides, or that rationalize their use. The prime aim is to introduce pest resistance into zonally adapted varieties. Germplasm lines with resistance to major pests that attack the leaves and stems of groundnut plants (jassids, thrips, leaf miner and *Spodoptera litura)* and to some soil insects that attack below-ground parts (termites and pod borers) have been identified, and are being used in breeding programs (Amin et al. 1985, ICRISAT 1988, ICRISAT 1989). Progress has been made in defining the mechanisms of pest resistance. The feasibility of combining host-plant resistance and natural control by the use of parasites and predators are being investigated, their aim being to keep pest populations down to levels that do not reduce yields. Effects of cropping patterns—monocrop, multicrop, intercrop—on pest populations are also being investigated. Studies are being conducted to determine the damage thresholds of *Spodoptera litura.* Collaboration between entomologists and virologists has led to an increased understanding of the role of thrips as the vector of TSWV.

Drought

Research on the physiological basis for genetic differences in drought response has had considerable impact on drought screening at ICRISAT Center. Drought-tolerant lines have been identified and used in breeding for improved drought resistance. Some lines with resistance to foliar diseases have also shown drought tolerance. The greatest opportunity for improving genotypes for use in drought-prone areas lies in capitalizing on the ability of some cultivars to recover from mid-season drought. This attribute is therefore being used in screening breeding materials. Research is focussed on root respiration and growth, the mechanisms determining recovery from drought, and on water use efficiency. Photoperiod also influences drought responses (ICRISAT 1988), and genotypes are being screened for photoperiod insensitivity (ICRISAT 1989).

Nutrient Stresses

Biological nitrogen fixation is not usually a limiting factor to groundnut production in locations with a history of groundnut cultivation. Genotypic differences in the rate of nitrogen fixation are dominated by leaf area effects (90% of variance), and the differences directly attributable to genotypes are small (2-6%) (Nigam et al. 1990).

Iron chlorosis has been shown to be caused by two mechanisms, high soil pH and periodic waterlogging. Genotypic differences in susceptibility to iron deficiency exist in groundnut (Hartzook et al. 1974, Hartzook et al. 1972), and limited screening of breeding lines has been initiated at ICRISAT Center.

Calcium deficiency is a major limiting factor for groundnut production in some countries. Research is in progress to investigate reported genotypic differences in the calcium uptake efficiency of pods. Consistent and significant genotype x drought x gypsum interactions have been demonstrated (Rajendrudu and Williams 1987).

Plant Improvement

Major thrust areas in the groundnut breeding at ICRISAT Center have been identified.

Zonalization of groundnut growing environments. Based on biotic and abiotic stresses and agroclimatological data bases our investigations include identification of the important combinations of stresses and the required maturity duration in different regions. This exercise is undertaken in collaboration with the Agroclimatology Unit of the Resource Management Program.

Development of varieties/populations adapted to specific environments and requirements. Early-, medium-, and long-duration varieties with resistance to relevant combinations of stress factors that will fit well into existing farming systems, and that are attuned to consumer preferences are being developed.

Most of the progress so far has been made in breeding cultivars which are high yielding under no-stress situations, or which have resistance/tolerance to single stress factors. It is now intended to develop varieties with multiple resistances.

In addition to supplying early-generation populations, ICRISAT also offers international trials of advanced generation breeding lines to cooperators. Several ICRISAT-bred lines are in the advanced stage of testing in various national programs or have been released by them. Jamaica has released one of improved germplasm line Tifrust 2 (ICG 7886) as 'Cardi-Payne'. The Republic of South Korea has released ICGV 87127 as 'Jinbungtangkong'. Pakistan has released 'BARD699', a composite of ICGV 87187 and ICGV 27128). Releases in Malawi, Zambia, and Nepal are awaited.

In India (ICGV 87123) and ICGV 87128 have been released and are increasingly becoming popular with Indian farmers. More recently ICGV 87141, 87119 and 87160 for rainy season cultivation and ICGV 87187 for postrainy season cultivation have been released for various groundnut zones in India. The variety ICGV 87121 has been released in Uttar Pradesh state of India for rainy season cultivation. Progress has also been made in developing cultivars for confectionery purposes, and several lines have shown good performance in international trials (ICRISAT 1989).

Agronomy and Crop Production

ICRISAT groundnut scientists cooperate with those of the Resource Management Program in providing cultivars and advice to enable national program scientists/extension workers to put together management systems appropriate to local conditions.

The Legumes On-Farm Testing and Nursery Unit (LEGOFTEN) of the Legumes Program actively cooperates with the scientists and extension workers in India to demonstrate the potential of improved technology and varieties of groundnut in farmers' fields. The results of the past two seasons have been highly encouraging. They have clearly shown that the potential of high-yielding varieties and improved technology is within the farmer's reach.

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Groundnut Quality Characteristics

R. Jambunathan[1]

Abstract. *India is one of the world's second largest producer of groundnut, and the most important use of the Indian crop is for its oil content. Nearly 66% of the groundnut produced in the world is crushed for oil. At ICRISAT, screening groundnut germplasm accessions has demonstrated the large variation in their protein and oil contents. Storage stability of oil is an important factor, especially in developing countries, where storage conditions are not ideal. The concentration of oleic and linoleic acids in groundnut oil affects its stability.*

A variety of food uses of groundnut are known, and peanut butter is one of the most popular products in several countries. Low-fat groundnut is also receiving increased attention for use by calorie-conscious consumers. Flavor components of groundnut are very important in determining the acceptability of groundnut products, and this is a complex area, relating objective measurement to subjective evaluation. Protein quality and the junctional properties of isolated groundnut protein have been extensively investigated, and a number of efforts have been made to utilize groundnut protein ingredients for human food. Groundnut protein is about 74% as high as the casein quality that is used as a reference for rat bioassay procedures.

Groundnut hulls form a sizeable proportion (about 25%) of total groundnut production. Various ways of using these hulls have been developed, particularly as a supplement to cattle feed, and attempts have been made to improve hull digestibility.

Introduction

Grain quality is a broad term which encompasses physical, chemical, and functional properties. The quality and properties of groundnut have been described in earlier publications (Cobb and Johnson 1973, Ahmed and Pattee 1987). The quality attributes that are important for end uses of groundnut vary among the developed and developing countries. In developed countries, groundnut is mainly used for making peanut butter and consumed as roasted groundnut or in confections, while in several developing countries, it is mainly

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processed for its oil. The cake obtained after oil extraction is not utilized to the best advantage though it is a good protein source. Groundnut oil is relatively more stable than safflower and sunflower oil, which have higher content of polyunsaturated fatty acids and consequently groundnut oil has a longer shelf life. In this paper, a brief description on the quality of groundnut is given and, where available, data obtained on groundnut cultivars developed at ICRISAT are reported. The paper also indicates future research areas in groundnut.

Chemical Composition

Groundnut is primarily used for its oil and protein, which are major products of the crop. Rapid and reliable methods are available for the determination of protein content, and for the nondestructive determination of oil content using nuclear magnetic resonance spectrometry (Jambunathan et al. 1985). At ICRISAT, groundnut accessions grown in various parts of the world have been collected, cataloged, and stored for further use. We analyzed groundnut germplasm accessions and observed that their oil and protein contents varied considerably indicating the possibility of selecting germplasm accessions for higher oil or protein content (Fig. 1 and 2). It is important to ascertain if these characteristics are stable in the selected accessions before they are used in a breeding program.

Five groundnut cultivars developed at ICRISAT-ICGS 1 (ICGV 87119), ICGS 5 (ICGV 87121), ICGS 11 (ICGV 87123), ICGS 21 (ICGV 87124), and ICGS 44 (ICGV 87128)-and Kadiri 3 and J 11 as controls, were grown in the postrainy season 1985/86. They were analyzed for their proximate composition (Table 1). Among these cultivars, Kadiri 3 had the highest protein and lowest oil contents. Both Kadiri 3 and J 11 had lower seed masses than other cultivars. The amino acid composition of whole seed showed that the major

Table 1. Composition of selected groundnut cultivars, ICRISAT Center, postrainy season 1985/86[1].

Cultivar	Protein	Oil (%)	Starch (%)	Soluble sugars (%)	Crude fiber (%)	Ash (%)	Moisture (%)	100-seed mass (g)
ICGS 1	24.9	48.3	11.8	4.6	2.2	2.3	7.3	56.2
ICGS 5	25.7	48.2	12.3	4.6	2.3	2.3	6.8	60.7
ICGS 11	25.0	48.3	11.8	4.6	2.2	2.3	6.7	57.3
ICGS 21	24.2	50.0	11.3	5.0	2.0	2.3	6.8	69.3
ICGS 44	25.4	49.1	12.2	4.4	2.1	2.2	7.1	65.1
Controls								
Kadiri 3 (Robut 33-1)	29.2	46.4	11.2	3.6	2.1	2.2	5.0	48.1
J 11	25.8	47.2	13.7	5.2	2.1	2.4	5.1	31.0
SE	±0.61	±0.44	±0.32	±0.19	±0.03	±0.03	±0.36	±4.71

1. Means of three determinations.

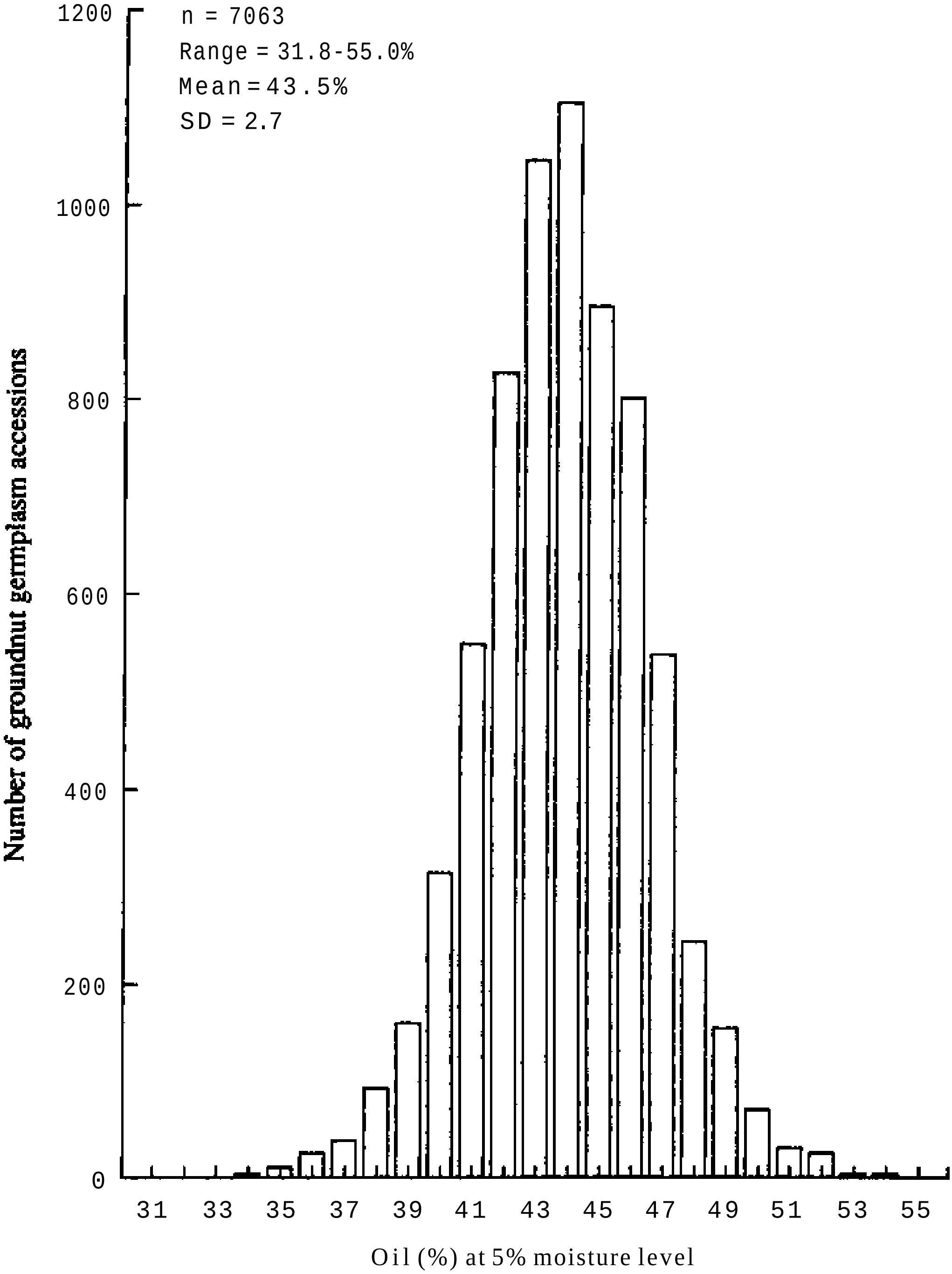

Figure 1. Distribution of oil content in ICRISAT groundnut accessions.
(Note: For easy comparison, all oil values have been expressed at a uniform moisture level of 5%).

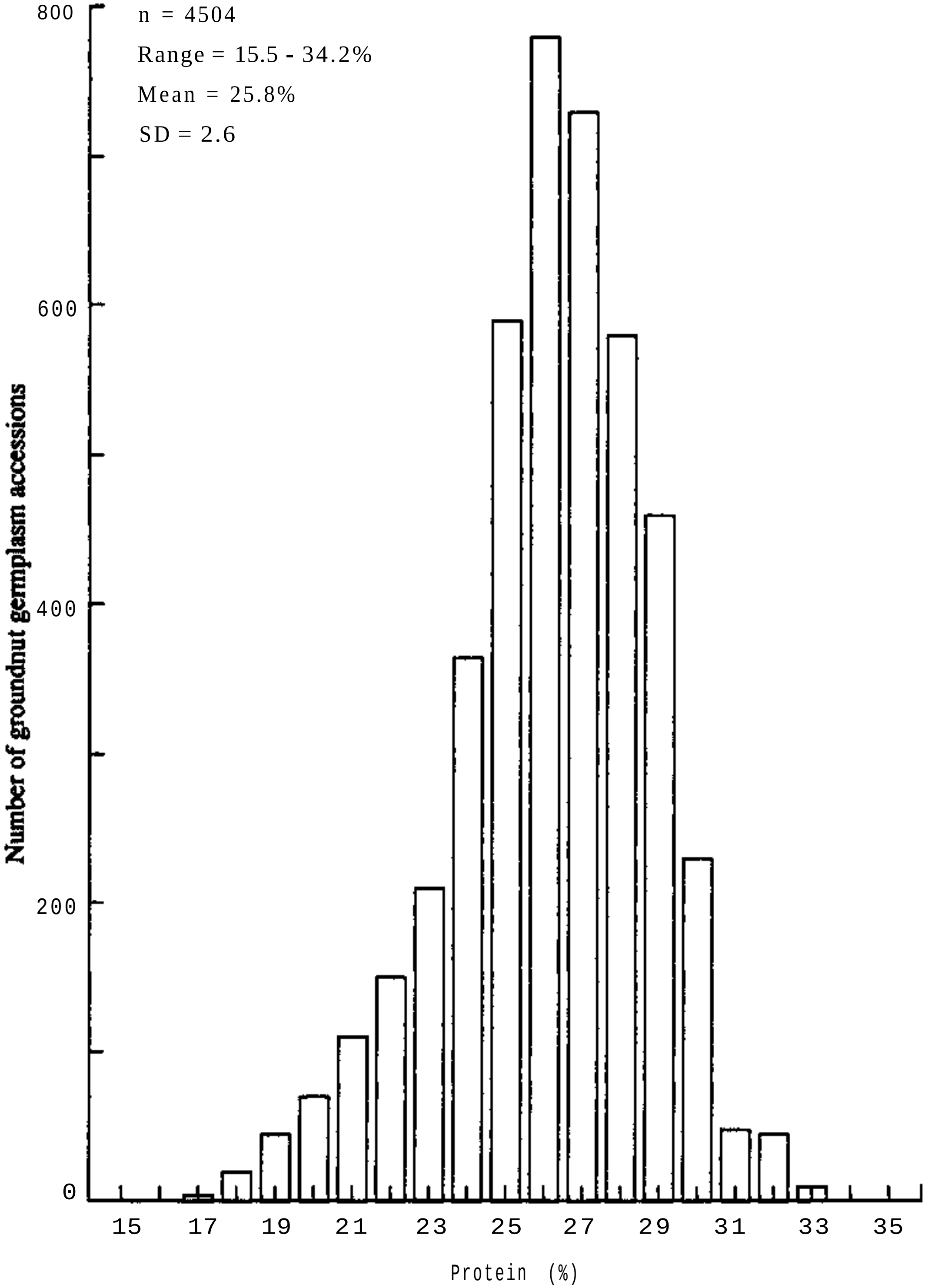

Figure 2. Distribution of percentage of protein content in ICRISAT groundnut germplasm accessions.

Table 2. Essential amino acid composition (g 100^{-1} g^{-1} protein) and protein contents of groundnut cultivars[1], ICRISAT Center, postrainy season 1985/86.

Amino acids	ICGS 1	ICGS 5	ICGS 11	ICGS 21	ICGS 44	Kadiri 3[2] (Robut 33-1)	SE	FAO/WHO (1973) pattern
Lysine	3.98	4.03	4.07	4.06	4.09	3.81	±0.042	5.5
	3.23	3.09	3.32	3.10	3.14	2.90	±0.058	4.0
Valine	4.65	4.80	4.51	4.66	4.69	4.27	±0.076	5.0
Methionine + cystine	2.95	2.65	2.38	2.55	2.65	2.18	±0.107	3.5
Isoleucine	3.73	3.86	3.76	3.66	3.64	3.49	±0.051	4.0
Leucine	6.92	7.27	6.84	7.17	7.24	6.26	±0.155	7.0
Phenylalanine + tyrosine	10.17	10.49	9.77	10.10	10.32	9.90	±0.108	6.0
Protein content (%)	49.60	49.10	49.70	49.80	49.00	52.20	±0.479	-

1. Means of duplicate determinations.
2. Control.

deficient amino acids were methionine and cystine, lysine, threonine, and valine when compared with the FAO/WHO (1973) provisional amino acid scoring pattern (Table 2).

Rat bioassay of ICRISAT cultivars was carried out and the digestibility of groundnut protein was comparable to that of the reference protein, casein (Table 3). It was interesting to note that the protein of one cultivar, ICGS 21, was even more digestibile than casein. However, in all the cultivars, the biological values and net protein utilization were much lower than casein. The protein efficiency ratio was determined by feeding these cultivars to rats for a period of 4 weeks. Results indicated that the average protein value of these cultivars was about 74% of the casein value.

Table 3. Biological evaluation of selected groundnut cultivars, ICRISAT Center, postrainy season 1985/86[1].

Cultivar	Biological value (%)	True protein digestibility (%)	Net protein utilization (%)	Protein efficiency ratio
ICGS 1[2]	53.5	96.3	51.5	2.41
ICGS 5	52.7	95.4	50.3	2.42
ICGS 11	51.5	98.2	50.7	2.35
ICGS 21	56.6	99.2	56.1	2.33
ICGS 44	47.7	96.4	46.0	2.28
SE	±1.69	±0.55	±1.83	±0.026
Casein (standard)	76.0	96.4	73.3	3.24
SE	±0.57	±1.05	±1.12	±0.07

1. Means of five determinations.
2. Means of four determinations.

Table 4. Fatty acid composition of hexane extracts of groundnut cultivars, postrainy season 1985/86[1].

Fatty acid (%)	ICGS 1	ICGS 5	ICGS 11	ICGS 21	ICGS 44	Control Kadiri 3	SE
Palmitic	12.1	11.9	12.1	11.3	11.9	12.1	±0.13
Stearic	2.3	2.1	2.3	2.8	2.71	2.9	±0.13
Oleic	36.7	37.2	36.8	42.9	38.9	38.9	±0.95
Linoleic	40.5	40.5	40.6	35.1	38.4	38.0	±0.88
Arachidic	1.4	1.3	1.4	1.4	1.5	1.5	±0.03
Eicosenoic	1.4	1.4	1.4	1.3	1.4	1.4	±0.02
Behenic	3.2	3.1	3.0	2.9	3.0	2.8	±0.04
Lignoceric	1.8	1.7	1.8	1.5	1.7	1.8	±0.04
O/L ratio	0.91	0.92	0.91	1.23	1.01	1.03	±0.05

1. Means of three replicates.

Oil Quality

The stability or shelf life of oil is important in both developing and developed countries, but deserves more attention in developing countries where storage conditions are not optimum. A major influence on oil storage stability is its fatty acid composition, especially the proportion of unsaturated to saturated fatty acids. The fatty acid composition of ICRISAT cultivars showed that the oleic (O) to linoleic acid (L) ratio (0:L) varied between 0.91 and 1.23, and the highest ratio was obtained for ICGS 21 whose ratio was significantly higher than the rest (Table 4). For groundnut, an 0:L ratio of 1.6 and above is desirable for longer shelf life. A minimum 0:L ratio of 1.6 has been recommended for groundnut by food processing industry purchasers in the UK (Hildebrand 1987, personal communication).

Flavor Quality

The flavor of roasted groundnut plays a very important role in its acceptance by consumers and other users. This is a complex area as more than 300 compounds have been detected in roasted groundnut (Ahmed and Young 1982). It is important to standardize the tests used to evaluate the acceptability of roasted groundnut by conducting sensory evaluation and relating the findings to the presence or absence of various volatile compounds, and the concentrations in which they are present. Recent studies indicate that hexanal concentration is one of the eight compounds that gave an objectionable flavor to groundnut and it was correlated with a professional flavor profile panelists' evaluation (Young and Hovis 1990). Characterization of flavor compounds by gas chromatography would enable breeders to identify those cultivars that have a good flavor profile for further development. Sugars in groundnut also play an important role as precursors in the production of the typical roasted groundnut flavor.

Groundnut Utilization

A variety of food uses of groundnut are known, and peanut butter is one of the most popular products in several countries. However, except for peanut butter and roasted groundnuts, the desired confectionery quality parameters have yet to be clearly defined for selecting groundnuts suited to individual end uses in developing countries. For example, when groundnut pods are boiled in salt water and the boiled seeds consumed, various factors are involved in the process. The water permeability of the shell and the ease of uptake of salt water by the seed may play a role in influencing cooking time. This is one of several areas where additional information is needed to define quality characteristics that are required to make the best end products.

Some interest has been evinced in the introduction of a low-fat groundnut which is now being sold under the 'Weight Watchers®' label (Anon 1988). Low-fat groundnut is made by a commercial process that squeezes out about 50% of the oil from raw groundnuts which then regain their shape after being squeezed. The groundnuts are then soaked in hot water, and roasted in oil for 5 min. The water steaming out of the kernels prevents roasting oil from entering them resulting in a crunchy groundnut with 50% less fat than normal. This low-fat groundnut is gaining in popularity among health-conscious consumers.

Groundnut has been used to improve the protein content and quality of several cereal-based food products in India, Kenya, Malawi, Nigeria, Senegal, and Zimbabwe (Natarajan 1980). In India alone, there have been several agriculture-based products with groundnut as the protein-enriching medium. While using groundnut protein in food products, it is important to understand the characteristics and functional properties of this protein so that the product is acceptable to consumers when used as an ingredient in a food system. The important functional properties of protein ingredients are solubility, viscosity, emulsification, elasticity, adhesion, water and fat absorption, foam formation and stability, gel formation, and fiber formation (Natarajan 1980). It is a challenging task to relate functional properties with end products, as there do not seem to be any generally accepted tests for evaluating the several functional properties of protein.

Groundnut Hull

Of the several million tonnes of groundnut that are produced in the world each year, hulls form about 25% of the total mass produced, and their utilization thus becomes very important. At present the majority of groundnut hulls are either burned, dumped in forest areas or left to deteriorate naturally (Kerr et al. 1986). However, there have been some efforts to use groundnut hulls in cattle feed, as a carrier of insecticide, in the manufacture of logs and production of pulp, and as a fiber component in human diet (Kerr et al. 1986). One of the major potential uses of groundnut hull is as a component in cattle feed. Hull digestibility is quite low; research efforts are being directed to improve it. Hulls contain more than 60% fiber. Inoculation and biodegradation of hulls have been tried but these efforts have not been successful. A combination of chemical and biological pretreatments may offer hope to increase hull digestibility by ruminants (Kerr et al. 1986).

Future Research Needs

In developing countries, the method of oil extraction has to be made more efficient and hygienic, so that the groundnut cake available after oil extraction can be profitably used as a supplement to weaning food and in other processed cereal foods where additional protein would be advantageous. The concentration of aflatoxin should be determined before groundnut cake is used in any formulation or diet; if there is any contamination of the cake at all, it should not be used, because the end product will be toxic.

There is a need to identify the important flavor components that are either desirable or objectionable to consumers. The factors that contribute to a good confectionery type groundnut, and appropriate screening methodologies for these factors need further development. Market and consumer demands should dictate the development and setting of standards.

Blanching quality is important because of the energy involved in removing the seed coat. An economic laboratory method to screen germplasm and breeding material for blanching quality is needed if commercial varieties or genotypes with better blanching quality are to be developed. For this purpose, the relationship between the laboratory and commercial blanching methods must be established.

The physical, chemical, and functional properties of groundnut that relate to specific end products have to be determined and refined to facilitate screening breeding material for such properties. Also, methods have to be developed so that hulls and other by-products can be better utilized.

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Utilization of Groundnut in India and Scope for Novel and Alternative Uses

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Abstract. *Groundnut is one of the important oilseed crops in India. More than 80% of the production in the country is used for oil extraction by screw or expeller pressing. The cake obtained by this process contains 6 to 8% residual oil, and is mostly used as animal feed. A small proportion of groundnut production is consumed as roasted, salted, or fried nuts, or as meal in various recipes. After pigments and the residual oil are removed, cake meal can be substituted for 10% of the wheat flour in bakery products such as cookies. Groundnut milk, to the extent of 20%, can be substituted for whole cow's milk in the preparation of acceptable ice cream. Groundnut kernels or meal could be used to make peanut butter, fermented products, composite flours, milk, and milk products. Based on consumer acceptance and the suitability of the varieties grown in India, the technology for such products needs to be developed.*

Research is needed to improve the efficiency of the oil extraction process; to partially refine the oil and consequently improve its quality and storage stability; to utilize cake as a source of protein in foods; to standardize the technology of roasted, salted nuts; and on the use of groundnut in the preparation of various unconventional products.

Introduction

Groundnut is a major oilseed crop. India, the Peoples Republic of China, and the USA are the major groundnut producing countries in the world (Adsule et al. 1989). Nearly 30% of the total world production of groundnut is in India (FAO 1985). The crop accounts for more than 56% of the total production of oilseeds in India. The utilization of groundnut differs significantly in developed and developing countries. In the USA, a greater proportion of produce is processed for direct consumption in the form of peanut butter, salted peanuts, and high protein meal. In India more than 80% of the produce is processed to obtain cooking oil with groundnut cake as a byproduct. A small proportion of the groundnut produced is used for culinary purposes, consumed as salted and fried nuts, and as an ingredient in snack foods.

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Utilization

Groundnut is an unique plant in that it has a wide range of uses. Groundnut oil is mostly used as a cooking medium, and the residual cake is used as cattle feed or manure. The shelled nuts are consumed after toasting, frying, salting, or boiling, and in the preparation of confectionery products. For some people, groundnut eaten with jaggery forms a cheap and sustaining food. The shells are largely used as fuel. Sometimes, shells are used as a filler in fertilizer and stock feed, and flour made from ground hulls has potential for use as a dietary fiber.

Groundnut Oil

Commercially, oil is extracted from groundnut by three methods; hydraulic pressing, screw pressing, and solvent extraction. The solvent extraction process gives a higher oil yield than the other methods. Groundnut oil is generally used as a cooking medium, and it may be processed into a variety of products. It is hydrogenated to give *vanaspati* or vegetable ghee. To some extent, groundnut oil is used in soap-making. In Europe and the USA, groundnut oil is used in the manufacture of margarine.

Roasted Groundnut

Roasting groundnut with 1-4% common salt is a very common practice all over the world. Groundnut is roasted either by applying dry heat or using some vegetable oil. Dry roasted groundnut is used in the preparation of peanut butter, confectionery, or bakery products. Roasting reduces the moisture content, develops a pleasant flavor, and makes the product more acceptable for consumption. The reduction in moisture content during roasting prevents molding and reduces staling and rancidity. Excessive heating during roasting lowers the nutritional quality of proteins.

Cake and Meal

Groundnut cake is obtained as a byproduct after oil extraction. The cake when powdered gives defatted groundnut meal. The market-grade groundnut cake obtained in mechanical screw pressing is dark grey in color, it has a bitter taste, and is rich in fiber, because whole kernels with skins and 1-2% shells (crushing aid) are crushed to obtain the crude oil. Such cake is unfit for human consumption and is mainly used as animal feed.

Defatted groundnut meal contains about 43-65% protein, and 6-20% fat, depending upon the method of oil extraction, and some B-group vitamins. Defatted groundnut meal has a higher protein efficiency ratio (PER), net protein utilization (NPU), and digestibility than full-fat groundnut meal (Kabirullah et al. 1977). The chemical score of groundnut flour can be improved by blending with other plant proteins. These blends could be used in bakery products.

Traditional Products

Groundnut is used to prepare such indigenous products as *laddu* and *chikki*. To prepare *laddu,* groundnut kernels are roasted and deskinned, the separated cotyledons are mixed with thick, hot, jaggery syrup. Small portions of the mixture are pressed by hand to obtain balls, or *laddus*, about 3-5 cm in diameter. *Laddus* may also be prepared from roasted and decorticated groundnut kernels, which after coarse grinding to obtain particles of about 1-5 mm diameter, are mixed with a small quantity of crushed jaggery.

Chikki is a very popular product in western India. It is prepared by mixing roasted and decorticated groundnut kernels with a hot slurry of sugar. The mixture is spread in a 1.0-1.5 cm thick layer on a tray or similar flat surface. After cooling, the product is cut into small pieces and packed. Roasted groundnut is also used in the preparation of various other traditional recipes such as *khichadi, guradani, barfi,* and vegetable curries in India.

Novel and Alternative Uses

Peanut Butter

Peanut butter is prepared by grinding roasted and blanched kernels to which 1-4% common salt is added. Its flavor is a major factor in determining the acceptability of the product.

Protein Isolates

The technology now exists for the production of groundnut proteins in the form of concentrates and isolates which are acceptable for human consumption. These isolates have a potential application in many types of food products, and impart beneficial characteristics to food in which they are incorporated. Groundnut protein isolate can replace about 80% of milk solids without changing the texture, and about 60% without loss of flavor, color, or overall acceptability in the preparation of frozen desserts (Lawhon et al. 1980). Protein isolates with high protein solubility, bland taste, and a desirable light color were obtained from groundnut by combining the aqueous extraction process (Rhee et al. 1972) and the membrane isolation process (Lawhon et al. 1981). Presoaking split groundnut kernels in 4% sodium chloride (NaCl) solution overnight, followed by hot water washing, helped to wash out much of the water soluble and flavor components.

The protein isolate thus obtained had high solubility, and white color, and was free from a nutty flavor. Groundnut protein isolates and oil could be used in the manufacture of cheese analogs. Replacement levels of 40% and 50% were found to be optimum in producing cheese analogs (Chen et al. 1979).

Fermented Products

Groundnut cake or meal can be used for human consumption after partial hydrolysis of the component protein by fermentation using certain molds. Such products are readily digestible, tasty, and nutritious. *Oncom* is a fermented groundnut press cake, and is a popular product in Indonesia. Worthington and Beuchat (1974) reported the elimination of sucrose, raffinose, and stachyose during the first 24 h of fermentation of groundnut with *Neurospora intermedia.* The fungus *Rhizopus oligosporus* was less effective in eliminating these sugars. Fermentation does not change the fatty acid composition, or the protein content of groundnut (van Veen et al. 1968).

Milk

Groundnut milk is traditionally prepared by soaking kernels in 1% sodium bicarbonate solution for 16-18 h, draining off the water, and grinding in the aqueous medium. The wet mash is steeped for 4-5 h, and filtered through cheese cloth to recover the product. In India, production of toned groundnut milk called Miltone®, is a commercial reality. Miltone® consists of groundnut milk extended with buffalo milk. A yogurt-like product has been prepared from Miltone® by using a lactic culture (Swaminathan and Parpia 1967). Beuchat and Nail (1978) demonstrated that fermented groundnut milk can be substituted for buttermilk in maize muffin recipes without altering the product's sensory characteristics. Our preliminary studies have shown that groundnut milk to the extent of 20%, can be substituted for whole milk in the preparation of ice cream.

Composite Flours

Groundnut flour can be used in the preparation of groundnut: cereal composite flours. Such composite flours have a higher protein content and nutritive value than either wheat, maize, sorghum or millet alone. Whole wheat and maize flours were supplemented with 10, 20, and 30% level of 1:1 mixture of groundnut and chickpea flours (GCF) (Khalil and Chughtai 1984). Supplementation increased the protein content of wheat and maize blends by 20-61%. Significant increases were observed in lysine and other proximate constituents. The chemical score of wheat flour increased from 53 to 72, and that of maize flour from 49 to 71 with 30% GCF. Biological evaluation of wheat breads at 10% protein level, and maize bread at 8% protein level in the rat diet showed significant improvement in the protein quality of GCF supplemented breads, as judged by gain in body mass, PER, NPU, biological value, and utilizable protein content. A supplementation level of 20% was considered adequate to achieve the desired nutritive benefits (Khalil and Chughtai 1984).

Bakery Products

Groundnut cake meal, or defatted meal, can be used to prepare acceptable bakery products (Table 1). Breads, biscuits, cookies, and other products could be excellent vehicles for enhancing the utilization of groundnut protein in Indian diets. Our studies have shown that the cookies prepared from a composite meal, containing 5% cake meal, had comparable sensory properties to those of the control (Table 2). By changing the proportion of

Table 1. Acceptability of different bakery products prepared from wheat:groundnut meal blends.

Flour blend	Acceptability[1]				
	Bread	Bun	Cup-cake	Cookie	Doughnut
Control, 100% refined wheat flour	4.4	4.8	4.8	4.9	4.8
Wheat: PDM[2]					
90:10	4.1	*42*	4.3	4.5	4.4
80:20	3.6	3.6	4.0	4.0	3.8
70:30	3.1	3.0	3.2	3.4	3.1
Wheat: CDM[3]					
90:10	4.1	4.1	4.6	4.7	4.4
80:20	3.5	3.3	4.0	4.3	3.8
70:30	2.7	2.8	3.5	3.7	3.2
CD. at 5%	0.70	0.64	0.66	0.54	0.74
SE values	±0.25	±0.22	±0.22	±0.19	±0.26

1. Acceptability was judged by the panelists for taste, flavor, texture, and appearance. The mean values are reported.
2. Partially defatted flour.
3. Completely defatted flour.

Score : Excellent 4-5; Good 3-4; Fair 2-3; Poor 1-2; and Very Poor 0-1.

Table 2. Sensory evaluation of cookies prepared from various blends of refined wheat flour and groundnut cake meal.

Flour blends	Color and appearance	Texture	Flavor	Taste	Overall mean	Spread factor (Width/ Thickness)
Control (100% refined wheat flour)	5	4.8	4.8	4.8	4.8	6.4
Wheat: Cake meal						
95:5	4.0	4.4	4.4	4.4	4.3	6.4
90:10	3.4	3.6	3.8	3.6	3.6	6.8
80:20	2.8	3.4	3.2	3.0	3.1	5.6
70:30	2.2	2.6	2.2	2.0	2.3	5.7
60:40	1.2	2.4	2.0	1.6	1.8	5.6
SE	±0.23	±0.23	±0.23	±0.21	±0.23	±0.11
CD at 5%	0.68	0.65	0.67	0.63	0.66	0.33

Sensory evaluation score: Very pleasant 4-5; Good 3-4; Fair 2-3; Poor 1-2, and Unpleasant 0-1.

Spread factor score: Higher the score, better the quality of cookies.

Table 3. Sensory evaluation of cookies prepared from refined wheat flour + groundnut cake meal 90:10 (w/w) using different formulae.

Flour blends	Color and appearance	Texture	Flavor	Taste	Overall mean	Spread factor (Width/ Thickness)
Control (100% refined wheat flour)	4.2	4.3	4.4	4.5	4.4	6.24
Composite flour (Refined wheat flour + Cake meal) 90: 10 w/w						
Formula 1[a]	4.2	4.8	4.2	4.4	4.4	6.96
Formula 2[b]	3.3	2.8	3.2	3.0	3.1	7.64
Formula 3[C]	3.5	3.5	4.0	3.4	3.6	7.16
SE	±0.09	±0.26	±0.14	±0.23	±0.18	±0.09
CD at 5%	0.29	0.81	0.42	0.71	0.54	0.26

a. Formula 1 : Flour 250 g, hydrogenated fat 150 g, ground sugar 125 g, liquid glucose 50 g, cow milk 50 ml, maize flour 12.5 g, liquid ammonia 2 ml, sodium bicarbonate 1 g, and orange color.
b. Formula 2 : as above, except hydrogenated fat 125 g and ground sugar 150 g.
c. Formula 3 : as Formula 1, except ground sugar 150 g.

Description of scores given under Table 2.

ingredients, acceptable cookies can be prepared from composite flours containing 10% cake meal (Table 3).

Research Needs

Extraction of Oil

The extraction of oil by the traditional method leaves a residue cake containing 6-8% oil. Hence, it is necessary to improve the efficiency of the extraction process. Moreover, the resultant cake is dark grey in color, rich in pigments, phenolic compounds, and fiber, and hence unfit for human consumption. As the cake contains 45-50% good quality protein, it is necessary to improve existing traditional technology so that the cake can be utilized in human foods.

Partial Refining of Oil

Groundnut oil obtained by traditional processing has several impurities, and is less stable than refined oil. Refining the oil removes impurities, vitamins, and the typical groundnut flavor. However, the cost of refined oil is almost 1.5 to 2.0 times that of crude oil. Cheaper ultra-filtration treatment is now being commercially used to partially refine crude oil. Partially refined oil has better keeping quality than crude oil, and has a natural flavor. Simple processing to remove suspended particles and impurities could improve the storage stability and the quality of crude oil. Such processing technology needs to be developed for groundnut oil, to improve the availability of good quality oil at lower cost.

Cake Utilization

Groundnut cake containing 45-50% protein is commonly used as an animal feed. A suitable technology needs to be developed to remove pigments, fibers, and residual oil from the cake, which can then be used in the preparation of bakery products, protein concentrates, and isolates. The cake meal can be used along with cereal and other legume flours to prepare composite flours.

Technology Standardization for Roasted and Salted Groundnuts

Roasting is a common processing treatment given to groundnut kernels before these are used in various recipes such as paste, meal, or coarsely ground powder. However, over-roasting results in loss of nutritional quality. Therefore, optimum conditions that avoid nutritional losses need to be worked out for the roasting process. Similarly, the salted peanuts available in India are inferior in quality to those made in some developed countries. The commercial preparation of such a product under optimum processing conditions could improve groundnut utilization.

Use of Groundnut to make Nutritious Foods

Groundnut meal is a good source of protein, lipids, minerals, and vitamins. The use of groundnut meal in cereal-legume based foods can improve the nutritional quality of the products. Several weaning or high-protein foods, containing groundnut meal as one of the ingredients, have been prepared in India and other countries. The use of defatted groundnut meal in developing composite flour based on cereal: legume : groundnut on commercial scale for the preparation of traditional foods such as *roti, chapati,* and *bhakri* would be useful.

Utilization in Unconventional Foods

Several groundnut-based foods, including fermented and non-fermented foods such as *oncom*, *tofu*, and peanut butter, are commonly consumed products (Table 4). The technology for the preparation of these products using local varieties need to be standardized in accordance with consumer preferences.

Table 4. Some popular groundnut products.

Product	Description	Utilization
Oncom	Groundnut kernels are pressed to remove oil. The press cake is soaked in water for 24 h, drained and added with high starch material such as cassava or residue from soybean milk. The material is then steamed, incubated with fungus *Neurospora intermedia* or *Rhizopus oligosporus* and fermented for 1-2 days at 25-30°C after wrapping in banana leaves. It is fried in oil or margarine and consumed.	Indonesia
Tofu (curd)	Groundnut kernels are soaked overnight and ground into an emulsion. The fine mash is boiled or steamed and put through cloth filters. The curd is precipitated from the resulting fluid by adding calcium or magnesium sulfate. The product is left to settle and transferred to boxes lined with cloth filters or spread on trays. Sold as slices or slabs. The curd is served in soup. The wet curd can be deep-fried in oil.	China, Japan
Peanut butter	Peanuts are heated to 160°C for 40-60 min. After roasting, the nuts are cooled, blanched and fine milled to paste. During milling, stabilizers are added alongwith preground dextrose and salt. Other additives include hydrogenated vegetable oil, antioxidants, honey, lecithin, whey etc. The product is packaged in plastic or metal containers, lined fiber drums or boxes for bulk volumes. The butter is used as spread on bread and in the manufacture of candy, cookies, sandwiches, wafers, patties, bars, etc.	USA

Milk-Based Products

Groundnut milk can be used in the preparation of yogurt-like products, ice-cream, and other products. Our preliminary experiments have shown that it is possible to replace 20% of cow's milk by groundnut milk in the preparation of acceptable ice cream (Anonymous 1990). Further efforts are required to improve the quality of other popular products, such as yogurt and *paneer.* Micro-organisms that are most suitable for fermentation of groundnut milk in the preparation of such products need to be identified. This will help to popularize groundnut milk based products with Indian consumers.

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Groundnut Quality Requirement for the Export Market-Present Status, Constraints and Future Needs in India

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Abstract. *As the worlds largest producer of groundnut (estimated output in 1988/89 over 7.5 million t unshelled) India has the undoubted potential to supply medium- and small-seeded varieties of groundnut, in shell and as kernels. Bombay bold, Java, JL 24, and G2 are varieties available in counts varying between 40/50 (57-71 g.100^{-1} kernels) and 70/80 (36-41 g. 100^{-1} kernels) kernels per ounce, well suited to meet the requirements of a sizable section of discerning users around the world.*

Despite supply potential, Indian edible groundnut exports languished for a decade because of unsteady production and lack of government support. Fortunately, through a welcome combination of a pragmatic government attitude and high farm output, Indian groundnut exports have just started to look up. Amongst Indian exporters there is now a rediscovered consciousness that they must meet the demands of exacting quality standards, tailor-made to suit the specific requirements of individual buyers. However, sorting/grading facilities are inadequate, though there is scope for mechanization of various operations.

Production of processed groundnut, such as roasted/salted kernels and roasted in-shell nuts, is low in volume, and exports are almost non-existent. Improvement in the shelf-life of processed groundnut requires attention. There is need to propagate virginia-type large-sized groundnut. Recent liberalisation of seed import for cultivation is reportedly aimed at overcoming the shortage of high-yielding seed varieties. The evolution of varieties resistant to the aflatoxin-producing fungus Aspergillus flavus *will have far-reaching beneficial implications for India. Quality, including aflatoxin control, is another area that needs to be strengthened through education and the adoption of appropriate postharvest practices.*

Introduction

The word "peanut" has somehow come to be associated with insignificance or trivia. When one claims to be in the peanut business, people take one for a small-time trader. Some may

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even betray amusement or worse, sarcasm. I remember, in the office of one of the prominent exporters of Indian groundnut, there is a caricature of a monkey (incidentally, peanuts are also known as monkey nuts) with the caption "We work for peanuts and we are proud of it". How very true, sensible, and well informed! No wonder, he is the largest exporter of hand-picked selected (HPS) groundnuts from India. The groundnut business is indeed a serious one, and can't be treated lightly.

Quality Requirements

Quite contrary to uninformed lay perception, the quality requirements for groundnut in the food market are rather rigid and exacting. Natural Resources Institute of the UK Ministry for Overseas Development lists the following quality requirements for groundnut pods and kernels:

- pod color and type; size; pod texture; cleanliness; freedom from damage, and absence of blindnuts for in-shells; and
- grading for size or count; shape; ease of blanching; skin color and condition; resistance to splitting; moisture content; cleanliness; oil content; and flavor; for kernels.

The over-riding consideration with regard to quality is without doubt freedom from aflatoxins, the toxic metabolites produced by some strains of fungi of the *Aspergillus flavus* group. These are the general quality requirements for edible groundnut. But users may demand certain additional attributes, depending upon the specific end use of the product. To illustrate the rigidity of users' requirements, some of the salient technical specifications under which a large groundnut processing factory makes its purchases are:

Size/Grade: for medium runners - graded between 83 mm and 71 mm slot screens a count size of 155-170 kernels 100 g^{-1}.

Aflatoxin: 5 parts per billion maximum.

Moisture: between 6-8% (determination by air oven drying of ground sample at 130°C for 2h).

Oil Quality: the acid value of cold-pressed oil from kernels shall not exceed 1.5, while the peroxide value shall normally be zero and shall not exceed 1.0 milliequivalents kg^{-1}.

Edibility: groundnut shall be free from pathogenic organisms (e.g., *Salmonella, Escherichia coli)* and also free from insect infestation, live or dead, and viable eggs.

Then there are conditions relating to odor and flavor, splits, damaged kernels and unshelled groundnuts, foreign matter, and discolored/moldy nuts.

A well acknowledged attribute of Indian groundnut is its original natural flavor, nutty taste, and crunchy texture. Indian groundnut also has a relatively longer shelf-life. Therefore, with a growing consumer taste the world over for organic food with natural flavor, Indian groundnut should find better acceptance in the export market, other commerical terms, such as price, remaining equal.

Groundnut Production

In 1988 India regained the distinction of being the largest producer of groundnut in the world. The estimated output during the crop year, November 1988/October 1989 is, over 7.5 million t unshelled pods. At a shelling percentage of 70, groundnut kernel availability was an estimated 5.25 million t, up from a mere 3.5 million t kernels in 1987.

India produces two sizes of groundnut kernels - medium and small. The medium-sized kernels, known as Bombay Bolds, generally count 50/55 kernels per ounce. They can also be graded to 40/50 kernels per ounce, though availability at this size is not unlimited. The small-sized kernel called the Java type, is equivalent to the US Spanish or the South African Red Natal. The generally traded grade of Java is 70/80 kernels per ounce. A couple of other varieties are becoming increasingly popular amongst groundnut cultivators. They are JL 24 and G2. These are spanish-type kernels, larger in size than traditional Javas, and generally count 60/70, or even 50/60, kernels per ounce.

Quantum of Exports

Export of HPS groundnut from India has been rather unsteady during the last few years. Annual exports averaged some 20,000 t, that too to a single destination, the Soviet Union. It was primariliy because of unsteady production and lack of government support that exports languished. Fortunately the attitude of policy makers in the government has become more pragmatic.

There is now a commitment to encourage unrestricted exports. What is more, fiscal assistance (at the rate of 5% of the export value) has been granted to promote HPS groundnut export. The Government of India has projected that by the terminal year of the 7th Five Year Plan (1990), oilseeds production will reach 18 million t, of which groundnut will account for 52%, or 9.3 million t. With such a large production base, a sizable quantity of groundnut will be available for export.

On the farm front, the Technology Mission on Oilseeds (TMO), constituted under the chairmanship of the Prime Minister is providing technological back-up to India's efforts to boost oilseeds production. In the last 2 years, the TMO has done commendable work to increase the output of oilseeds. As a result of past lessons and present efforts, India's groundnut exports have just started to look up. In 1988/89, exports are projected to exceed 50 000 t (8% of world trade), over half of which will reach free-market countries.

Requirement of Export Markets

Indian groundnut exporters are becoming more alive to the international situation. There is now a rediscovered consciousness of the exacting demands of overseas buyers as to quality standards. Each groundnut buyer has his own rigid standards to suit his specific need.

For preparing export grade edible groundnut, hand-picking and selection through hired labor is still practised. Although, in the Indian context, human endeavor is worthy of appreciation and encouragement, the need to instal mechanical graders cannot be overemphasized. Machine grading will not only be faster and more reliable, but hygienic. Optical sorting machines are not used at present, but color sorters have now become almost indispensable for removing aflatoxin-infested kernels. The harvested crop is allowed to dry in the fields and the vagaries of weather affect the quality.

Mechanization

It is only through selective mechanization that India can hope to gain the confidence of international buyers of edible groundnut. It is hoped that the large export potential will provide sufficient motivation for shellers to build the required infrastructure. Adequate storage capacities need to be built up. The use of mechanical dryers for reducing moisture to acceptable levels should be popularized.

Despite the fact that Indian Bolds are ideally suited for processing into roasted/salted nuts because of their excellent flavor, production of processed peanut is very low in volume. The domestic market for processed groundnut has not been actively promoted, and exports are almost non-existent. For export of processed groundnut in consumer packs, attractive packaging and longer shelf-life are important requirements. Packaging costs in India are exorbitant. As for shelf-life, exporters should be able to guarantee at least 26 weeks of stable quality from the time of packing. The integrity of packing becomes crucial if the demand for packaged groundnut in the international market is to be met by Indian exporters.

Varieties for Export

For the groundnut market, big is beautiful. Therefore, special large-sized varieties need to be grown for export. The Bhabha Atomic Research Centre at Bombay has developed a groundnut variety called TG 19-A. The pods are large, with nuts which count 26/30 kernels per ounce. Each kernel weighs approximately one g. The sucrose level in dry kernels is high at 7%, and the oil content is 47.4%. TG 19-A variety has not yet been released for commercial cultivation, but based on available information, there is reason to believe that TG 19-A can be successfully offered for the export market. Breeders need to develop varieties with Virginia type large nuts to suit the different agro-climatic conditions in this country.

In order to regularly service export markets, by far the most important need is for the propagation of Virginia type, large-sized groundnuts. The size of Indian groundnut is medium to small, but most consumers abroad are increasingly taking a fancy to large jumbo-sized nuts. These large nuts are used as table nuts along with other edible nuts like cashew, almond, and walnut. Jumbo groundnut is generally processed into roasted/salted nuts, or coated with honey, masala or chocolate. Therefore, a combination of the large size of the Virginia type, and the natural nutty flavor of the Indian Bolds will be irresistible, and should find ready consumer acceptance.

There is a special demand for roasted groundnut in-shell, particularly in the markets of Japan and Singapore. Here too preference is for large-sized in-shells with 12/14 pods per ounce, that is a kernel equivalent of 38/42 counts.

Import Liberalisation

Recently, the Indian Government liberalized its import policy for high-yielding seed varieties, including those of oilseeds. This was purportedly to overcome persistent shortage of quality seeds for cultivation. The extent to which this policy will succeed and continue remains to be seen. I feel, however, in the long run, there is no alternative to strengthening indigenous efforts.

Promotion

The Indian Oil and Produce Exporters Association (IOPEA), the Government of India designated export promotion agency for Indian HPS groundnuts, would only be too willing to assess the suitability of new groundnut varieties for the export markets.

In a small way, the IOPEA has started its endeavor to educate farmers about sound postharvest practices in Gujarat, which is the largest groundnut-producing state in the country. Over 2 000 copies of literature printed in vernacular (Gujarati) language highlighting proper methods of handling, storage, and transportation were distributed in Saurashtra, prior to the rainy season harvest during November 1988. Andhra Pradesh is another large producer of groundnut but the farmers here do not seem to be as conscious as their counterparts in Gujarat about proper drying, storage, and moisture levels. More organizations can join the campaign to promote suitable postharvest practices, and as a consequence , increase the returns to the farmers.

Research Areas

An area of research that will benefit groundnut export is the development of aflatoxin-resistant varieties. The evolution of such groundnut varieties will have far-reaching beneficial implications for the promotion of HPS groundnut export from India. The lingering doubt about aflatoxin affliction in India groundnuts can be dispelled once for all. There is a need to start a groundnut quality enhancement program right from the farm level onwards. As a short-term measure, appropriate postharvest practices intended to preserve, and possibly enhance groundnut quality have to be propagated. Farmers and shelters have to be educated in proper storing, handling, and transportation methods.

A quote I read almost a decade ago is probably as much relevant even today.

Food technologists and nutritionists on six continents are discovering that an agricultural commodity which has been relished by practically all forms of fowl and domestic animals, and which abundantly supplied proteins, vitamins, minerals, and scarce nutrients to pigs, cattle, poultry, turkey, horses and dogs is a valuable source of food for humans.

Hardly a month passes without the announcement of a new discovery for the use of groundnut as a food item. These range from confections, bakery products, snack items, peanut flour, peanut milk, peanut icecream, peanut-flavored milk snacks, defatted peanuts, and peanut in breakfast cereals, to peanut protein, peanut lipoprotein, peanut protein isolates, polyunsaturated peanut fats, and dietetic and special foods. Possibly no crop in the world has the potential of being processed in as many ways and uses, in as many products, as does peanut. The number of groundnut products has increased from a dozen to more than 400.

Cereal-based Foods Using Groundnut and Other Legumes

Bharat Singh[1]

Abstract. *A review of studies conducted on application of flours or concentrates from groundnut, cowpea, and soybean to improve nutritional characteristics of wheat-based bread and cookies, sorghum-based* uji, *and sorghum-based* kisra *are presented. Acceptable cookies were made from composites containing 50% wheat, 35% groundnut, and 15% cowpea flours. At this level of fortification, the protein content was 151% higher than the wheat protein content. Acceptable breads using 70% wheat, 20% groundnut, and 10% cowpea flour had 70% more protein than breads prepared from wheat alone. The composite flours had significantly higher amounts of protein, fat, fiber, and almost all minerals, and lower amounts of tannins than wheat flour. Cowpea flour and soybean concentrate were used to improve the protein content of sorghum-based* uji, *a common food in Tanzania.*

There was an increase of 40% protein content in the sorghum-cowpea combination (80% sorghum and 20% cowpea), and a 74% increase in sorghum-soybean concentrate combination (80% sorghum and 20% soybean concentrate). Kisra *is a sorghum-based product, commonly used in the Sudan. Acceptable and nutritionally superior quality* kisra *was prepared from sorghum flour fortified with defatted groundnut flour. The addition of defatted groundnut flour resulted in improvement of baking ease, color, and texture of the final product. The percentage increase in protein content at the 30% level of fortification varied from 53% to 122%. There were significant increases in all essential amino acids. Fortification with groundnut and subsequent fermentation improved the in vitro digestibility of the sorghum flour.*

Introduction

Grain legumes flours have been used since ancient times. They have been utilized in indigenous foods to (a) extend available wheat grain supplies (supplementation); (b) enhance the nutrient values of food products; or (c) to counteract the effects of inherent

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nutritional inhibitors present in the cereal or legume. Rapid urbanization in developing countries and wheat grain surpluses in developed nations have significantly affected the optimum utilization of grain legumes in indigenous foods. However, in recent years efforts have been made to develop new processing methods to increase utilization of grain legumes in indigenous foods, especially to reduce the amount of wheat imports, and at the same time to increase the nutritional values of cereal-based diets.

This paper is a review of research completed at A & M University in Alabama, on the utilization of grain-legume flours or protein in cereal-based products. The paper includes data on three different food systems: (1) wheat-based bread/cookies using groundnut, or groundnut and cowpea; (2) sorghum-based *uji* using soybean and cowpea; and (3) sorghum-based *kisra* using groundnut.

Effect of Groundnut Flour on Baking Characteristics of Wheat Flour

The importation of wheat places a severe strain on the limited financial resources of several developing countries in Africa. In these countries, groundnut cake (after oil extraction) is available in abundance, notably in the Sudan and other Sahelian countries. It is possible that the cake could be converted to flour to supplement or fortify other flours. The advantages of developing such a technology are two-fold. It could enhance the protein level in the diet, and reduce food imports. Since cowpea is a commonly available legume, composites were made using wheat and cowpea flours.

Twelve different composites were prepared using wheat flour (cv Coker-747), partially (PD), and fully (DF) defatted groundnut flour (cv Florunner), and cowpea flour (Table 1).

Table 1. Proportion of wheat, groundnut, and cowpea flour in composite flours.

Treatment	Wheat (%)	Groundnut[1] PD (%)	Groundnut[2] DF (%)	Cowpea (%)
1	100	0	0	0
2	0	100	0	0
3	0	0	100	0
4	0	0	0	100
5	85	10	0	5
6	85	0	10	5
7	80	10	0	10
8	80	0	10	10
9	70	20	0	10
10	70	0	20	10
11	60	30	0	10
12	60	0	30	10
13	60	25	0	15
14	50	0	25	15
15	50	35	0	15
16	50	0	35	15

1. PD = partially defatted groundnut with 30% fat level.
2. DF = defatted groundnut with 18% fat level.

Farinographic studies and proximate analyses were carried out using standard methods (AACC 1962). Minerals and phytic acid contents were determined (Singh and Reddy 1977). Tannin concentration was determined by the vanillin-hydrochloric acid method (Burns 1971). Trypsin inhibitor activity (TIA) and aflatoxins were determined according to the AOAC methods (AOAC 1975). Taste panel studies were conducted on the bread and cookies, with the composites being compared with wheat flour preparations, which were used as controls.

Bread-baking parameters, such as absorption, optimum mixing time, and loaf volume decreased with increased amounts of groundnut and cowpea flours in the formulations (Table 2). Specific volumes of the bread decreased when groundnut and cowpea flours replaced wheat in the blends. The trend indicated that the higher the groundnut content in the blend, the lower was the volume. The most acceptable bread-making blend, in terms of loaf volume, was 85% wheat, 10% PD or DF groundnut, and 5% cowpea (Table 2). Taste-panel evaluations were conducted. Panelists graded the bread out of a possible score of 100. The blends used in this evaluation were those containing levels up to 30% of groundnut and 10% of cowpea flours, as substitutes for wheat flour. Higher substitution levels of groundnut and cowpea flours produced doughs that could not be baked into satisfactory breads. At the 10% of cowpea flour substitution level, a beany flavor was detected.

The blends were more suitable for baking cookies than bread. There was little difference between the diameters of the cookies made from wheat and the PD groundnut blends. As DF groundnut flour was increased in the blends, the diameters of the cookies decreased. PD groundnut blends produced cookies with a higher diameter than the corresponding DF blends. Results however showed that the DF groundnut blends had

Table 2. Characteristics of most acceptable blends of wheat, groundnut, and cowpea flours for bread and cookie manufacture[1].

Flours (%)				Loaf volume (cc)	Specific loaf volume (cc g^{-1})	Cookie volume (cc)	Bread score	Cookie score	Protein (%)
W:	PD:	DF:	B(2)						
100	-	-	-	448a3	3.10a	69.6a	76.2d[4]	8.3a*	9.7f
85	10	-	5	371b	2.49b	62.5c	78.3a	8.0b	12.3e
85		10	5	339c	2.37bc	68.2a	75.1e	7.7c	13.7d
80	10	-	10	320d	2.25c	61.6c	77.9b	7.5c	14.1d
70	20	-	10	310e	2.17d	58.5d	77.0c	7.1d	16.6c
50	35	-	15	-	-	64.1b	-	8.1b	20.8b
50	-	35	15	-	-	64.7b	-	8.1b	24.4a

1. Mean of three replications.
2. W = wheat; PD = partially defatted groundnut; DP = defatted groundnut; B = cowpea.
3. Means noted with different letters following are significantly different (P < 0.05) based on Duncan's Multiple Range Test
4. A subjective score was given based on nine panel members : Breaks and shred-6; crust color-7; symmetry-7; crumb color-10; volume-15; flavor-15; grain-20; and texture-20. Total 100.
5. Ratings for cookie evaluation were based on nine panel members : 04 poor, 5-below average; 6-average; 7-above average; 8-good; 9-very good; and 10-excellent.

significantly higher values for volume than the PD blends. Wheat flour cookies were rated the best followed by cookies made of flours with 35% groundnut and 15% cowpea. Characteristics of most blends for baking cookies and baking bread are presented in Table 2.

Proximate compositions of individual flours and of the blends used to prepare the most acceptable bread and cookies showed that the protein levels in them ranged from 12.28% to 24.40%. As the amount of groundnut flour increased in the composites, the fiber and ash levels also increased.

Among the flours under study, DF groundnut flour had higher concentrations of all the minerals except potassium and sodium. Cowpea flour had the highest potassium content. As the quantity of groundnut and cowpea flours were increased in the composites, the levels of all minerals except sodium increased over those obtained in wheat products. None of the flours had detectable levels of aflatoxin. Phytic acid levels were highest in the DF groundnut flour, followed by PD groundnut, cowpea, and wheat flour. The composites with DF groundnut and cowpea flour had significantly higher phytic acid levels than corresponding composites with PD groundnut and cowpea flour. Wheat had the highest tannin content followed by cowpea, DF, and PD groundnut flours. There were no significant differences between the tannin levels of the composite flours. However, tannin levels were significantly lower in composite flours than in wheat and cowpea flours. The trypsin inhibitor activity (TIA) in PD and DF groundnut flours was lower than in wheat and cowpea flours. Levels of TIA in the composites were lower than in the individual flours.

Conclusion

Groundnut flour after partial or full removal of fat can be utilized to increase the protein content of cereal-based food products. It can be bleached to improve acceptability. The addition of groundnut flour resulted in an increase of protein, a reduction of tannins, and the enhancement of some desirable minerals. A possible extension of this study will be the fortification of sorghum-based foods with groundnut flour in the Sudan and other Sahelian countries.

Effects of Soybean Protein Concentrates and Cowpea Flours on Acceptability and Nutrient Compositions of Sorghum-based *Uji*

Uji is a food product commonly prepared from maize or sorghum in Tanzania. The most limiting amino acids in sorghum protein are lysine, threonine, and methionine (Paul and Fields 1981). In addition to its poor quality and low protein content, sorghum contains tannins, which decrease the availability of proteins (Chavan et al. 1979). In areas where sorghum is a staple diet, there is a need to have a nutritional improvement program on sorghum. In this study, soybean concentrate and cowpea flour were used to improve the protein quality of sorghum flour.

Nine different composite flours were prepared using sorghum flour, soybean concentrate, and cowpea flour (Table 3). Soybean concentrate and cowpea constituted up to 20%

Table 3. Time taken to cook *uji* with different flour blends.

Treatment	Sorghum (%)	Maize	Soybean[1] (%)	Cowpea (%)	Time (min)
1	100	0	0	0	45
2	75	25	0	0	45
3	50	50	0	0	45
4	80	0	20	0	75
5	85	0	15	0	65
6	90	0	10	0	60
7	80	0	0	20	60
8	85	0	0	15	55
9	90	0	0	10	50

1. Soybean protein concentrate.

of the total composite flour, maize did not constitute more than 50% of the composition. Proximate composition, minerals, phytic acid, and tannins were determined as described earlier. Amino acid determinations were made using standard procedures. Gelatinization characteristics were determined by using a Brabender amylograph (AACC 1962).

Uji was prepared by adding 200 g flour to 1200 mL of warm water while stirring. The mixture of water and flour was allowed to boil for 45-75 min depending on the composition of the flour. The cooking time for each composite flour was established after running several trials. While cooking, two tablespoons of lemon juice and three table spoons of sugar were added to each *uji* formulation. A panel of tasters consisting of nine students from eastern Africa evaluated the products for their flavor, degree of cooking, after-taste, mouth feel, and consistency.

Sorghum-maize blends of *uji* (50:50 and 75:25) were both rated as highly acceptable (Table 4). One of the reasons for the low rating of cowpea was its strong beany flavor.

Table 4. Taste panel results of *uji* prepared using various blends[1,2].

Treatment	Mean scores	Rank
Sorghum:cowpea (80:20)	1.88	9
Sorghum:soybean[3] (80:20)	2.44	8
Sorghum:cowpea (85:15)	2.88	7
Sorghum (100%)	3.11	6
Sorghumxowpea (90:10)	3.33	5

Continued.

Table 4. *Continued.*

Treatment	Mean scores	Rank
Sorghum:soybean[3] (90:10)	3.55	4
Sorghum:maize[3] (85:15)	3.77	3
Sorghum:maize (75:25)	4.22	2
Sorghum:maize (50:50)	4.88	1
LSD	0.11	

1. Values reported are the average values of duplicate determination.
2. Treatment with the highest mean score is the most acceptable treatment (formulation) and the treatment (formulation) with least mean score is the least acceptable formulation or treatment
3. Soybean protein concentrate.

The starch gelatinization properties of the composites were studied. The difference in gelatinization temperatures is due to the size of the starch granules. A lower gelatinization temperature in any starch grain would be desirable to reduce cooking time. In this study, maize and cowpea were found to have lower gelatinization temperatures, followed by sorghum and soybean protein concentrate.

The soybean concentrate significantly increased the protein content of sorghum flour and lowered tannin levels. However, phytate and mineral levels increased significantly. Limiting essential amino acids, including lysine, were significantly increased, and the increase in lysine ranged from 21% to 35%. The cowpea flour also increased the levels of essential amino acids and mineral contents, but the levels of tannins and phytate were not reduced. The iron content increased more than 30% in all the composites developed from sorghum and cowpea flours.

Utilization of Defatted Groundnut Flour in Preparation of Sorghum-based *Kisra*

Kisra is a thin pancake-like leavened bread made from whole sorghum flour. It is the predominant staple diet of people in the Sudan. In the Sudan, groundnut cake (after oil extraction) is exported. It is possible to convert the cake into flour for local consumption. The objectives of this study were to determine the effect of the addition of defatted groundnut flour on the *kisra*-making quality and nutrient composition of sorghum flour.

Sorghum flour was prepared from the cultivar Dabar obtained from the Sudan. Defatted groundnut flour was obtained from a flavored-nuts company (Seabrook Blanching Corporation, North Carolina, USA). The starter for fermentation was obtained from the Sudan in a powdered (sun-dried) form and was typical of the local product used to make *kisra.* It is derived from wild yeasts that occur naturally in fermented sorghum flour.

Fermented dough and *kisra* were prepared in the traditional way employed by the typical Sudanese housewife. Sorghum flour (90 g) was mixed with water (120 mL) and the starter (30 g) in a stainless steel beaker. After thorough mixing the mash was incubated in a fermentation cabinet at *2TC* for 18-20 h. At the end of the fermentation process the pH had reached 3.9-4.0. Just before baking, another 60 mL of water was added. The batter was baked for 1.5-2.0 min on a hot plate at 150-160°C to a thin-sheet consistency. Baking ease was determined by weighing the residues collected on the surface of the hot plate after the removal of the product. Acceptability, color, texture, and keeping quality were determined by a panel of eight members, composed of Sudanese and Ethiopians familiar with *kisra.* Proximate composition and amino acids were determined as described earlier, and in vitro digestibility was determined according to Osilaja (1986).

The effect of various levels of fortification on baking ease, color, taste, and acceptability are presented in Table 5. The addition of defatted groundnut flour appeared to decrease the residue and improve baking ease, and hence increase the yield of the final product. Acceptable *kisra* was obtained with fortification up to the 30% level with defatted groundnut flour. Taste, color, and texture were not significantly influenced, and this may probably be due to the use of colorless groundnut flour. The keeping quality was reduced after 24 h at room temperature. However, *kisra* is generally used within 24 h after baking. Amylograph curves for the composites showed that the defatted groundnut flour decreased the heights of peak viscosity.

There was a significant increase (73%) in the amount of protein added by fortification. The amino acid compositions in the fermented blends and in *kisra* showed that fortification increased the amounts of all amino acids. The increase in the lysine content was 102% when fortification was at the 30% level. Fortification and subsequent fermentation improved in vitro digestibility and reduced the leucine/isoleucine and the leucine/lysine

Table 5. Baking-ease and sensory evaluation of *kisra* from 'Dabar' flour fortified with defatted groundnut flour.

Fortification level (% defatted groundnut flour)	Residues on the hotplate (g)	Color[1]	Texture[1]	Taste[1]	Overall acceptability after[1] 24 h at room temperature
0	4.10a[2]	4.22e	3.62b	3.58a	3.20a
10	4.08a	4.26d	3.68b	3.52a	3.18a
15	3.88b	4.28c,d	3.69b	3.57a	3.03b
20	3.80b	4.31b,c	3.75a,b	3.53a	2.78c
25	3.68c	4.33a,b	3.76a	3.56a	2.70c,d
30	3.60c	4.35a	34.03a	3.55a	2.63c

1. Means of 8 individual observations as rated on a hedonic scale of 1-5, where 5 = excellent and 1 = very poor.
2. Means of any parameter with the same letter are not significantly different *(P* = 0.05) using Duncan's Multiple Range Test.

Table 6. Ratios of amino acids as quality indices and in vitro digestibility of sorghum flour from cultivar 'Dabar' with indicated levels of defatted groundnut flours.

Sample	Leucine/ isoleucine	Leucine/ lysine	E/T[1]	Pepsin-pancreatin digest (%)
Sorghum flour	4.91	6.13	2.65	66.2
Fermented dough	4.78	5.98	2.62	67.4
Kisra	5.71	6.23	2.65	66.7
10% blend				
Fermented dough	4.75	6.16	2.61	67.0
Kisra	5.10	6.55	2.57	66.7
15% blend				
Fermented dough	3.96	4.11	2.55	68.9
Kisra	4.28	3.88	2.49	67.5
20% blend				
Fermented dough	3.26	2.84	2.45	69.5
Kisra	3.14	3.25	2.43	68.9
25% blend				
Fermented dough	3.36	2.43	2.42	70.3
Kisra	3.12	2.84	2.24	68.9
30% blend				
Fermented dough	2.74	2.18	2.40	72.5
Kisra	2.69	2.72	2.18	69.7
FAO/WHO(1973)			2.25	

1. The proportion of total amino acids (T) that must be supplied as essential amino acids (E).

ratios for composite flours (Table 6). It has been suggested that a leucine/isoleucine ratio higher than 3.0 should be regarded as deleterious. Apparently, fortification resulted in the reduction of the ratio. The proportion of total amino acids (T) that must be supplied as essential amino acids (E), the E/T ratio is considered as a quality index in the FAO Provisional Pattern (FAO/WHO Adhoc Expert Committee 1973). Sorghum flour by itself seemed to have an acceptable E/T ratio due to its higher leucine and phenylalanine contents. The 30% level of fortification showed a lower E/T ratio. In vitro digestibility was improved by the addition of defatted groundnut flour.

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Traditional and Potential Alternative Uses of Chickpea, Pigeonpea, and Groundnut in Myanmar

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Abstract. *Chickpea, pigeonpea, and groundnut have been grown in Myanmar since the beginning of the 19th Century. Together, the three crops cover 196 000 ha. Chickpea is a readily available source of protein for daily food, and is usually served as a soup. It is also used in snacks and desserts. Pigeonpea is appreciated for its nutritional qualities and is eaten as soup, but its mildly unpleasant aroma, and slight bitterness prevent its wider use. Groundnut is a popular source of cooking oil in urban areas. Groundnut is cooked in many ways in the home, and is an ingredient of snack foods.*

Introduction

Chickpea, pigeonpea, and groundnut constitute the major legume food crops in Myanmar. They occupy 34% of the area under noncereal food crops, and account for 47% of noncereal food crop production. Chickpea and pigeonpea contribute to Myanmar's foreign exchange earnings, as the country exported 7428 t of chickpea and 7912 t of pigeonpea in 1984/85 (Table 1). Groundnut is grown exclusively for national consumption.

Table 1. Chickpea and pigeonpea exports from Myanmar, 1981-85.

Year	Chickpea (t)	Pigeonpea (t)
1981/82	3479	6272
1982/83	5005	31119
1983/84	4217	2142
1984/85	7428	7912

Source : Export Division, Agriculture Corporation, Rangoon, Burma.

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Cultivation

Chickpea

About 200 000 ha are sown with chickpea annually. The production for 1985/86 was 234 000 t (Table 2). Chickpea is mainly grown as a relay or sequential crop, with rice. If it is grown sequentially, minimum tillage is usually applied. There are some upland areas where chickpea follows sesamum and maize, while recently chickpea has been mix-cropped with wheat and sunflower. Sowing of chickpea on upland farms begins between late September and early October, while on rice land it starts 2 weeks before harvest in a relay-cropping system and by middle-November to early December in a sequential-cropping system. Wilt disease and pod borer attack are major problems faced by chickpea farmers. A yearly decline of chickpea yield on rice land is a major agronomic problem.

Pigeonpea

Pigeonpea is mainly a dry-zone crop, and is grown mostly in Magwe, Mandalay, and Sagaing Divisions. The cropping system in some townships in these Divisions is mostly pigeonpea based. Local long-duration varieties compare well with exotic, short-duration varieties, both in seed size and adaptability. The crop is commonly sown either as a mixed crop or as an intercrop with groundnut, sesamum, and local short-duration cotton. Recently sesamum, mung bean, and groundnut intercropped with pigeonpea are being demonstrated and advocated for further extension.

Pigeonpea varieties of 90-120-day duration have been introduced during this decade, but their adoption by farmers has not been widespread.

Groundnut

Groundnut has two cropping seasons in Myanmar. With the onset of the monsoon, the long-duration variety (bunch type), and the short-duration variety (erect type) are grown in

Table 2. Annual sown area and production of chickpea, pigeonpea, and groundnut in Myanmar, 1979-86.

	Sown area COO ha)			Production ('000 t)		
Year	Chickpea	Pigeonpea	Groundnut	Chickpea	Pigeonpea	Groundnut
1979/80	117	55	486	39	20	141
1980/81	165	69	515	103	26	113
1981/82	215	76	598	155	41	122
1982/83	162	70	572	126	34	130
1983/84	220	64	561	173	38	153
1984/85	199	81	649	138	49	143
1985/86	276	83	646	234	53	146

Source : Report to Pyithu Hluttaw 1986/87.

the upland areas of central and upper Myanmar. Monsoon-sown erect groundnut is usually harvested in September, and sometimes in early October. The long-duration variety is harvested in November and December. The erect type is sometimes cultivated as a mixed crop with pigeonpea and sesamum, and followed by sesamum or fodder sorghum.

Erect groundnut is widely grown as a winter crop in Myanmar, after most of the fertile areas of the Irrawaddy and Sittaung valleys are inundated during the monsoon. Sowing is spread over late October to early December, depending on the receding of the flood waters. Winter groundnut is also grown as a second crop after the rice is harvested. Most of the groundnut produced in Myanmar is from the monsoon crop in central and upper Myanmar.

Utilization

Chickpea

Main dishes. Chickpea has two major culinary uses. *Dhal* is boiled in water until soft enough to be squeezed easily between two fingers. Salt, cooking oil, and spices are added and the mixture is cooked over a low fire. When the cooking oil begins to smell, the soup is cooked. The second use is as *dhal* meal. In this preparation, *dhal* is first soaked in water for 6-8 h. Ginger, onion, and tomatoes are fried in oil; the soaked *dhal* is then added; and the cooking continued until all the residual water in the *dhal* evaporates. Just before serving, spices e.g., cinnamon or caraway seeds are added.

Snacks. *Ba-ya-gyaw:* Chickpea *dhal* is cleaned and soaked overnight in water. It is then mixed with wheat or rice flour with a little water, made into small balls, and fried in a shallow vessel.

Ka-lapai-gyan-gyaw: Chickpea *dhal* is cleaned and soaked overnight in water. It is dried in the shade, and then deep fried. This product is very important, as it is one of the major ingredients in a commercial Burmese dessert, *La-phet-thoke.*

Moke-hin-ga: Vermicelli soup is usually made with chickpea dhal flour. It is cooked with fish, fish vinegar, and monosodium glutamate. Onion, ginger, and other ingredients are also included. This soup with Burmese vermicelli or rice noodles is served at food stalls all over Myanmar. Most Burmese people consider it their favorite snack.

Pa-la-ta or *Htat-ta-ya:* This breakfast snack is made out of wheat and chickpea flours fried with onions in a shallow pan.

Ka-la-pai-chaung: Chickpea flour is mixed with wheat flour and shaped into long, thick sticks, and coated with sugar syrup. The product has become a popular snack in Mandalay.

To-phu: Jelly-like *To-phu* is made with chickpea flour or chickpea *dhal*. If *dhal* is used it must first be soaked in water and then ground. Ground *dhal* or chickpea flour is mixed with a small amount of water till it becomes a paste. Additional water is added, and the mixture is stirred well and filtered through a loosely woven cloth. The filtrate is allowed to settle down for 15 min, and the supernatent liquid is cooked in another pan, over a low fire. Salt and other required seasoning are added before the material turns into a jelly.

Hard *To-phu* is also prepared as mentioned above, but with less water.

Pea Noodle. Pea noodles are mainly made from chickpea. Well-cleaned chickpea *dhal* is first soaked in water for 24 h, and stirred occasionally. In winter, warm water is added.

After draining, the *dhal* is ground with a sour starter solution obtained from a previous batch. The meal is allowed to settle in a small tank and the supernatent liquid is removed. The residual meal is transferred into a wooden tub. After setting for 8 h, the meal is transferred into a cloth bag, which is hung up to drain out the water for about 15 h. Then the material is put into tanks in an air-tight room for sulfur fumigation, after which the product is allowed to dry for 2 days, and then sulfur-fumigated a second time. After the second fumigation, the product is mixed with a sago solution and extruded into boiling water. The noodles are taken out of the hot water after 5 min when they are soft and put into cold water. The noodles are then dried on poles or drying racks for 1 or 2 days.

As chickpea is very expensive in Burma, noodle manufacturers mix it with cowpea and pigeonpea in the ratio of 15:15:70 cowpea, pigeonpea, and chickpea.

Pigeonpea

Pigeonpea is consumed as soup for lunch and dinner in rural areas. Pea soup is also consumed, but it is not usually served for dinner. Rural people and Burmese physicians value pigeonpea for its medicinal properties.

Pigeonpea can be used to replace some of the chickpea in composite flours which are consumed as a meal, or used to make noodles or soup. Pigeonpea's drawback is its unpleasant smell and a perceptible bitterness. Pigeonpea is agronomically valuable in the semi-arid areas as pigeonpea stubble is used as a fuel. The roots left in the soil after harvesting serve as an organic reserve and passages for the infiltration of rain water.

Groundnut

Groundnut is principally used to produce cooking oil, and only about 25-30% of seed produced annually is consumed directly or used as an ingredient in other foodstuffs.

Fried groundnut. Whole seed is fried and stored for sale as an ingredient for *La-Phet-Thoke.* Red-seeded groundnut is preferred.

Roasted groundnut. Whole seed is boiled with garlic and ginger, air dried, and then roasted in an open pan. The product is then sealed in small plastic packages and sold.

Groundnut cake (sweet). Is made from pounded groundnut, and cane sugar or palm sugar. Sometimes flour is added. Split groundnut and cane molasses are also used to make sweet groundnut cake.

Culinary and salad uses. Groundnut seed is pounded and cooked with onion and tomatoes for lunch.

Groundnut powder or ground seed. Is usually added to dressing in pickles and salads in the Burmese dish, *Hin-Ywet-Thoke.*

Groundnut oil-cake meal. Fermented groundnut oil cake is mixed with rice, onions, and spices.

Acknowledgement

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Traditional and Potential Alternative Uses of Chickpea, Pigeonpea, and Groundnut in Nepal

T. Karki[1]

Abstract. *Legumes are a source of protein supply to the majority of the people in Nepal. Emphasis has been placed on increasing production of legumes, notably chickpea and pigeonpea, and oilseeds such as groundnut, for their contribution to Nepalese diets. Most of these legumes are consumed in the form of* dhal, *and as soup or soup-like products; the green leaves, pods, and tender seeds are eaten as a vegetable. Chickpea and groundnut are roasted, deep-fat fried, and salted, and consumed as a snack. Groundnut is also roasted in-shell, and eaten after shelling. Chickpea and pigeonpea are sprouted and eaten in vegetable soups. A mixture based on legumes and cereals has been developed as a weaning food. Recently, these legumes have been combined with wheat flour and developed into a noodle-like product with attractive color and taste.*

In South Asian Association for Regional Cooperation (SAARC) countries, the use of legumes, cultured with microorganisms, has been limited to a few products (such as idli, *and* dosa *in India). There is tremendous scope for utilization of these leguminous crops by enhancing their flavor and taste, and increasing B-vitamins by selected biotechnological processes that are already available in other South Asian countries. These processes help not only to eliminate antinutritional factors inherent in the leguminous crops, but also to increase the nutritional level of the products. Products like* tempeh *from Indonesia, and* kinema *from Nepal, India, and Bhutan must be carefully studied, and future collaborative research activities should be initiated in the region to develop products and recipes suited to local tastes. Other viable collaborative research actitivies should be initiated to develop highly nutritious extruded products from these legumes to suit local tastes.*

Introduction

Legumes are a major source of nutrients, especially protein, to a majority of the people in Nepal. Due to the varied topography of the country, several traditional varieties of legumes are cultivated in a wide range of agro-climatic zones.

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	Production (x10^{-3} t)			Annual growth rate (%)	
	Actual[2]	Actual[3]	Target (1990/2000)	Actual (1975-85)	Target (1985-2000)
Cereals					
Rice	3796	4312	8651	1.3	4.8
Wheat	2491	2757	5096	1	4.2
Maize	796	818	1750	5.6	.7
Millet	142	126	145	-1.2	0.9
Barley	25	23	35	-0.8	2.8
Legumes	70[4]	955	247	3.1	6.6
Potatoes	308	387	869	2.3	5.5

Table 1. Production targets of cereals, legumes, and potatoes in Nepal by the year 2000[1].

1. HMG, National Planning Commission (1987) Program for Fulfillment of Basic Needs (1985-2000).
2. Average of 1973/74, 1974/75, and 1975/76.
3. Average of 1983/84, 1984/85, and 1985/86.
4. Production 1974/75.
5. Production 1984/85.

A basic needs program has been drawn up with a target of meeting the daily nutritional requirement of 9.43 megajoules caput^{-1} day^{-1} by the year 2000. In the year 2000, the contribution of cereals, legumes and potatoes to energy intake is projected at 87.3% with milk, meat, poultry, and fruits and vegetables contributing 12.7%. To achieve this goal, the production of cereals will have to be increased by 4.8%, legumes by 6.6%, and potatoes by 5.5% (Table 1). These projections are made primarily on the assumption of increasing productivity by improved technology rather than by increasing the crop area under legumes.

Legumes are grown over an area of 213 700 ha. Lentil, grass pea, chickpea, horse gram, soybean, black gram, and pigeonpea are important legumes and are also cash crops in Nepal (K.O. Rachie and M.D. Bharati 1987). Of the total production of legumes in the country, chickpea accounts for 17.1%, pigeonpea 6.0% and groundnut 1.9%. The *terai* and inner *terai* are the major legume-producing areas followed by some hills and valleys located at elevations up to about 2000 m.

Utilization of Grain Legumes

Processing of Legumes

In Nepal, grain legumes are largely consumed in the form of *dhal*. Techniques for dehusking and splitting of grain legumes are similar to those that are practiced in India. On a home scale, grain legumes are dehusked and split using the traditional technique that involves using dry, moist or wet heat followed by milling in a stone mill (quern or *chakki*). Losses during milling by this system ranges 10-15%. There are a few processing units established in Nepal using the improved technology developed by the Central Food Technological Research Institute, Mysore, India. However, the processing methods that are used in Nepal are mostly traditional and very little scientific assessment has been made to monitor the quantity and quality of legumes recovered.

Cereal and Grain Legume Mixtures

Several cereal and legume mixtures have been formulated to improve the nutritive value of the product, particularly its essential amino acid concentration.

A traditional food product called *astamandap* (a mixture of eight different ingredients) mainly consisting of two parts cereals to one part legumes with such other taste-enhancing components as spices, salt, or sugar is very popular amongst children and convalescing old people. It is an easily digestible product because grains are roasted, ground, and fried to make into a gruel or broth. Rice and green gram are usually used to make this product. However, it is also made with chickpea or pigeonpea.

Sprouted Legumes

Quanty is the local name for a dish whose main ingredients are cooked sprouted legumes. A mixture of legumes in equal proportions are soaked in water for 2-3 days, and germinated. The mixture is cooked to soft texture like a vegetable soup after adding several spices for taste. The vitamin C content is enhanced, and phosphorus availability increased by processing. There is also an overall improvement in the flavor of the product.

Masayura

A high protein traditional Nepali curry, made from various ingredients depending on the raw materials available in different regions. A combination of *gundruk* (a fermented product made from leafy vegetables and sun-dried) and *masayura* curry is a popular item in Nepalese diets (L.T. Karki 1986). *Gundruk* is a fermented product obtained particularly from leafy vegetables *(Brassica* sp. e.g. Cabbage, Brussels sprouts). It is also dried in sun. Thus the dried *gundruk* and *masayura* are cooked as a curry which also contains spices, salt, and oil as used in curry preparation. This is a typical Nepalese curry. *Masayura* is prepared during the winter season, dried in sun, and stored for future use.

Processing of *masayura.* To one part of soaked (overnight) and ground black gram, chickpea, or pigeonpea, four parts of washed and minced colocasia roots are added. The mixture is ground, made into balls and kept at room temperature for 24 h. This spongy-textured product is sun-dried for 3 or 4 days preferably on bamboo trays, so that *masayura* balls can be easily removed when dry. In the hills, colocasia roots or tender stems and black gram are used for *masayura* preparation, whereas in the *terai,* green gram and ash gourd are commonly used.

Fuloura is a product similar to *masayura,* but of a slightly different composition. It contains various spices and salt as important ingredients. Fermentation helps to develop the typical spongy texture of *fuloura.* It is deep-fried in oil and eaten, but is not dried or stored like *masayura.*

Noodles

Recently, noodles and noodle-like products have been developed at the Central Food Research Laboratory, Nepal, using wheat flour as the base and various legumes, minor cereals like millets, and potatoes as other ingredients. The main objective of this work is to identify desirable substitutes in the traditional recipes and also to make the product acceptable to consumers.

Chickpea, pigeonpea, and green gram are the major legumes used in noodle development. The noodles are composed of flour (66%), legumes (30%), salt (2%), gluten (2%). The ingredients are kneaded thoroughly and then extruded using a noodle maker (adjustable to various sizes). The extruded product is then evenly dried in the shade.

Other Legume Products

In Nepal, legumes are consumed puffed, deep-fat fried, fermented like *kinema,* and as soups. However, there is scope for developing extruded products based on traditional snack foods.

Fermented Products

Fermented products like *tempeh* and *natto* have been recognized as valuable and nutritious foods. The fermentation process enhances the availability of B-vitamins in these products. Starch is digested by the release of enzymes during fermentation. *Kinema,* a product like *natto,* is produced in eastern Nepal, parts of Sikkim and Bhutan. Soybean is the predominant substrate for the fermentation. However, other legumes like chickpea or pigeonpea could also be used.

Groundnut

Groundnut is an important oilseed crop in Nepal. However, the present level of utilization is limited to deep-fat fried snack nuts, roasted in-shell nuts, and oil. The utilization of cake should be explored as this is an important source of protein. Various mixes of cereals, legumes, and groundnut could be used to develop infant foods.

The Future

Research and development in the following areas deserve serious consideration.

- Evaluation and improvement of the existing milling systems.
- Investigation of antinutritional factors of legumes to enhance the uses of traditional and newly developed recipes.
- Nutritional evaluation of weaning foods based on legumes-and- cereal mixtures.
- Assessment of the nutritional advantages of germination to increase utilization.
- Exploration of biotechnological processes to improve the nutrient quality of legumes to enhance their use in such popular products as *idli, tempeh* and *kinema.*

- Development of convenient and nutritious snack foods from legume-and-cereal combinations, using extrusion technology.
- Improving the quality of noodle-like products prepared from legumes.

Collaborative Research

- Initiate collaborative projects to improve the nutritional and food quality of legumes notably chickpea, involving institutions in Africa, southeast Asia, and **ICRISAT.**

Training

- Initiate training programs to facilitate adoption of appropriate milling technology.
- Provide training facilities on evaluation of grain quality, antinutritional factors, and food products.

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Asian Grain Legumes Network Activities

D.G. Faris and C.L.L. Gowda[1]

Abstract. *The Asian Grain Legumes Network (AGLN) is a research network whose members are scientists and research administrators in Asia, interested in coordinating their activities on groundnut, chickpea, and pigeonpea. Its major goal is to strengthen the capability of national programs in Asia to conduct research on these legumes, with an ultimate aim of increasing their production and consumption in Asia. Its members are drawn from national agricultural research systems (NARSs), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), other international and regional research institutes, and donor groups. The network activities include coordinated yield trials and nurseries, collaborative research, meetings, monitoring tours and workshops, training, exchange of ideas, information, technology and material, and distribution of literature.*

The network has a coordination unit that is supported by ICRISAT and is part of the ICRISAT Legumes Program. The coordination unit has developed strong links between ICRISAT and the national programs of II countries through formal Memoranda of Understanding and bilateral work plans. The coordination unit facilitates direct contact between national and ICRISAT scientists, who carry out collaborative research and activities identified in the work plan. Contact among national program network members, in AGLN countries and in other regional institutes associated with the AGLN, comes from joint meetings, tours, and workshops sponsored by the AGLN.

The AGLN is interested in studying alternative uses of its crops, particularly pigeonpea in Indonesia and Thailand. The lead role in this work has been taken by the Australian Centre for International Agricultural Research (ACIAR), and the scientists and economists in these two countries, with input from Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT) and ICRISAT.

ICRISAT's future plans include giving more emphasis to the uses of its mandate crops. For this reason, there should be increased activity within the AGLN on developing new uses of groundnut, chickpea, and pigeonpea in Asian countries. The recommendations of this meeting will influence the nature of these activities, and contacts made here can form the basis for starting new initiatives.

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Introduction

The Asian Grain Legumes Network (AGLN) is a network that was formed in response to a need, identified by legume scientists from national agricultural research systems (NARSs) in Asia, to coordinate their research activities on groundnut, chickpea, and pigeonpea. This paper outlines the structure, states the philosophy, and indicates the types of activities associated with this network. It includes a brief listing of the network's activities on research on uses of the three legume crops, as a background for possible future activities.

Start up

Two meetings at ICRISAT in 1983 (ICRISAT 1984) and 1985 (ICRISAT 1987a) of NARS administrators and scientists, representatives from regional and international institutions and from donors in Asia, and ICRISAT staff identified the need for more research in Asia on groundnut, chickpea, and pigeonpea. This included listing the major constraints that needed to be overcome by research to ensure high, stable yields of these crops. In response to the recommendation of these meetings that a network be organized to coordinate the research on these problems, ICRISAT, on 1 January 1986, appointed a network coordinator and provided funds to support his activities.

Objectives

The network's aim is to strengthen the NARSs in Asia to do research on groundnut, chickpea, and pigeonpea by facilitating collaborative research, and the interchange of ideas, information, and material between NARS legume scientists in Asia and those at ICRISAT. The ultimate goals are to help farmers in the region increase their legume production, and to expand the use of legumes in the region.

The specific objectives of the network are to:

- produce a directory of AGLN cooperators;
- operate an information bank for the cooperators;
- support identification of adapted grain legume lines and the appropriate agronomy for their cultivation in each AGLN country;
- promote training of legume scientists from AGLN countries; and
- foster special research support projects.

These objectives are presently under review as the result of a recommendation by network coordinators, who met at ICRISAT Center, 15- 17 December 1988 (ICRISAT 1989).

The core countries of the AGLN are Bangladesh, Myanmar, India, Nepal, Pakistan, and Sri Lanka in South Asia, and the People's Republic of China, Indonesia, the Philippines, Thailand, and Vietnam in East and Southeast Asia. Other countries in Asia are also informally associated with the AGLN as needs arise.

Network Structure and Operation

The network structure is built on strong links between the core NARS and ICRISAT, based on a formal Memorandum of Understanding (MOU) between each country and ICRISAT. These MOUs are backed up by formal work plans which outline the specific annual commitments to network activities by each party (ICRISAT 1987b). These work plans are developed or reviewed at network meetings held in each country every year or two. These meetings also review research progress and identify the need to change initiatives.

The links between the NARSs and ICRISAT are facilitated by the AGLN coordination unit, which is part of the ICRISAT Legumes Program. This linkage is also aided by country-AGLN coordinators, who act as the administrative link between the ICRISAT-AGLN coordinator and the NARS. Each country-AGLN coordinator keeps track of, and helps to coordinate AGLN activities in the country where he or she is located.

The main function of this structure is to bring into contact the scientists who are AGLN cooperators in NARS and at ICRISAT so that they can work directly with each other. This can take the form of exchange of ideas and information, of material and trials, or of collaborative research projects.

Another part of the AGLN structure is formed by the regional and international institutes and donors involved in the activities of the AGLN. The list is very long, but includes ACIAR, ADB, IDRC, IRRI, FAO, CGPRT, ODNRI, AIDAB, and Peanut CRSP (see acronym list at end of paper). These groups have played an important role in supporting the activities of the network. For example, the ADB has provided funding for strengthening the NARS of Bangladesh, Myanmar, Nepal, and Sri Lanka through the activities of the AGLN. The ACIAR/AIDAB and CGPRT have provided assistance and inputs into studies on the utilization of pigeonpea in Indonesia and Thailand. FAO, Peanut CRSP, IDRC, and ACIAR have provided assistance and inputs into several specialized training courses organized by ICRISAT-AGLN.

Contacts between the cooperators in different NARSs are provided by network activities such as tours, meetings, and workshops (similar to the present), which bring scientists together from many countries. These activities provide an opportunity for scientists to share ideas and information, identify priority problems and the resources available among members, and develop plans for collaborative research. The workshops often take the form of a training exercise where scientists come together to share their data so as to learn and test new concepts. An example was the workshop on the Agroclimatology of AGLN countries, held at ICRISAT Center, 5-17 December 1989 (Virmani et al. 1990). At this workshop participants shared climate and crop data from their countries; they drew maps showing the distribution of AGLN crops in their own country and areas that could potentially grow these crops. Consultant geographers, cartographers, and agroclimatologists helped the participants produce these maps. At the same time the participants learned mapping techniques.

Use of AGLN Crops

Although the research and activities in the AGLN have emphasized research to improve crop production, it has been understood that farmers may not be interested in producing these legumes if they do not have an assured market for the crops. Thus there have been several activities associated with the network aimed at determining the potential market for these crops, and identifying uses of the crops that would cater to consumer demands. The best example is pigeonpea in Indonesia and Thailand.

Research on pigeonpea carried out by NARS scientists in Indonesia and Thailand, with support mainly from ACIAR but also from ICRISAT, demonstrated that this crop can produce high yields in both countries. Adapted genotypes and an agronomic package for successfully growing them have been developed. However, pigeonpea was not an important crop in either country. Therefore, before this package was given to farmers, surveys were conducted by ACIAR scientists with support from CGPRT and ICRISAT (Wallis et al. 1988) to determine potential markets for pigeonpea. Research was carried out, again with support from ACIAR, to develop new uses for this crop, particularly as a substitute for soybean, which is being imported in large amounts into both countries. In Indonesia, research determined that pigeonpea could be successfully used as a partial replacement for soybean in making *tempeh;* in Thailand, research showed that pigeonpea could be used economically to replace 30% of soybean by mass in broiler chicken feed rations. Trials are presently underway to test these findings and their economics at an operational level, and ICRISAT-AGLN is becoming more involved in the new studies.

The concepts of these initiatives and greater involvement of ICRISAT-AGLN was supported in an ODNRI consultant's report (N. Poulter, ODNRI, personal communication 1988).

Other initiatives that ICRISAT-AGLN have been interested in through the Biochemistry Unit at ICRISAT, include an In-service Training Course on Analytical Techniques for Evaluation of Nutritional Quality of Food Legumes, held at ICRISAT Center, 1-14 August 1988, with financial support from the FAO through RAS/82/002. This training involved participants from eight AGLN countries. Another activity was the demonstration by a Thai scientist working in the ICRISAT Biochemistry laboratory that noodles could be made from pigeonpea *dhal* that were of better quality than those made from mung bean.

The Future

For the future, food scientists in Bangladesh, Myanmar, Nepal, and Pakistan have identified the need to standardize analytical methods for determining quality factors of chickpea as a first step to doing collaborative research. Scientists in Indonesia and Thailand see a need to extend the collaborative research already started to develop alternative uses for pigeonpea, for such products as *tempeh,* flour, starch, and starch products.

We expect that the increasing research emphasis within the AGLN will continue to identify more uses of groundnut, chickpea, and pigeonpea. We look forward to your suggestions and ideas for future research, and plans for research collaboration among food scientists. Where these suggestions involve collaborators in the AGLN, the AGLN coordination unit will be glad to consider and implement appropriate action to help facilitate these suggestions and try to help identify necessary sources of funding.

Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AGLN	Asian Grain Legumes Network
AIDAB	Australian International Development Assistance Bureau
CGPRT	Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Root and Tuber Crops in the Humid Tropics of Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IRRI	International Rice Research Institute
MOU	Memorandum of Understanding
NARS	National agricultural research system
ODNRI	Overseas Development Natural Resources Institute
Peanut CRSP	Peanut Collaborative Research Support Program
RAS/82/002	Technical Cooperation among Developing Countries for the Research and Development of Food Legumes and Coarse Grains in the Tropics and Subtropics of Asia (FAO-UNDP project)

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Discussions

- The crop's environment, including growing conditions and its management, significantly influences the flavor and composition of groundnut. Some of these environmental factors can override groundnut cultivar differences. There are reports indicating that larger groundnut seeds have better flavor, but this needs further investigation and verification, as does the association between sugars and flavors in groundnut.
- The use of typical to atypical amino acid ratio as an indirect measure for flavor compounds in groundnut needs further confirmation. The use of gas chromatography and mass spectroscopy for flavor compounds identification was suggested.
- Since over 70% of groundnut produced in India is used for oil extraction, groundnuts could potentially be partially defatted and then roasted as the taste and texture quality of these nuts are quite acceptable and comparable to that of whole fat roasted nuts. The economics of the process are yet to be determined.
- Oil that is ultra filtered has better storage quality and appearance. In addition to fatty acid composition, the other factors that contribute to better storage quality of oil, need to be investigated.
- The unusable oil (slurry) obtained during refining of groundnut oil can be used for soap manufacture.
- Although India is one of the largest producers of groundnut, the quality aspect is not being investigated in detail in many of the institutions concerned with the crop. The Indian Oil and Produce Exporters Association is keen to collaborate in research to improve groundnut quality.
- The need to introduce mechanization for selecting better quality groundnut of the hand-picked selection (HPS) type for the export market was emphasized.
- By exporting 1 t of premium priced HPS groundnut containing 450 kg oil, India can earn $ 650 in foreign exchange which could be used to import 2 t of cheaper substitutes like palm oil, or palmolein oil. Therefore, economics favor export of HPS groundnut, and jumbo kernels of 40/50 counts and 38/42 counts per ounce are in demand. It was explained that counts per ounce (oz^{-1}) is followed in the trade though mass per seed or 100 seeds is used by the breeders.
- Edible grade defatted groundnut flour is available in India but consumer awareness of this high protein flour needs to be increased to promote its utilization.
- Partially defatted soybean meal can be used to make milk products with 30% supplementation. A similar attempt needs to be made for groundnut defatted flour.
- There was a suggestion that basic and applied research should be carried out to improve utilization of groundnut, and the presence and quantity of goitoregens should be investigated in groundnut.
- The shelf-life of composite (wheat and groundnut) flour is about 3 months. Loaf volume and specific volume are important criteria for the acceptance of bread made from composite flour. Supplementation of groundnut flour with wheat makes acceptable bread with no changes in crust color or texture up to the recommended level of fortification.
- Storage of groundnut needs further evaluation, and the effect of storage on viability and dormancy needs to be further investigated.

- Resistance to *Aspergillus flavus* seems to be related to three factors; seed coat resistance to preharvest infection, resistance to seed colonization, and resistance to aflatoxin production. Progress has been made using these three traits but resistance to *Aspergillus flavus* still poses a difficult problem.
- Regarding the limits to aflatoxin tolerance, it was noted that this was a matter of national policy to be decided by individual nations. Similar to quarantine, the restriction of imports from another country is regulated through the aflatoxin limit empowered by the concerned nation, and the level varies from 5 ppb in Japan to 30 ppb in the UK, and 20 ppb in the USA.

Recommendations

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Participants

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The group discussed:

- areas of research,
- novel and alternative uses, and
- collaborative research

Area of Research

There were general discussions on various areas of research, however, few areas were delineated.

Postharvest quality requirements. It was recognized that in determining quality after harvest, there is a need to define quality parameters which could be easily determined. It is desirable to work cooperatively with plant breeders and agronomists to determine the quality of groundnut under two categories:

- In *in-shell* whole kernels and corresponding quality requirements including pod size (large i.e., 12-14 pods oz^{-1}, ease of dehulling, aflatoxin contamination, and sensory quality; uses of hulls and derived products.
- Quality for consumption of kernel as roasted, boiled, or salted peanuts.

Quality requirements: Kernel size (>1 g $kernel^{-1}$)
Uniform size and shape
Resistance to splitting
Ease of testa removal
Flavor (Location specific preference to be determined by a taste panel through sensory evaluation)
Color (Location-specific preference to be determined through national program).
Sugar contents need to be determined as it affects flavor.
There were discussions on consumer preferences, and market demands; these should always be considered.

Processing quality. The requirements for oil extraction are:

- improvement of available technologies for efficient extraction,

- introduction of blanching (skin-removal) step in oil pressing, especially for India,
- making groundnut cake utilizable by manually removing molded or undesirable contaminants or foreign matter,
- utilization research on supplementing weaning foods, biscuits, and other local foods with groundnut cake flour, food technologists need to consult the Protein-Calorie Advisory Group Guideline for maintaining quality,
- oleic: linoleic fatty acid ratio to be maintained at 1.6 or above, and
- processed products, the general requirements for peanut paste/peanut butter:
- testa separation through maintaining harvesting requirements (maturity is important),
- improvement of peanut butter quality by using the existing knowledge of peanut butter processing such as the use of emulsifiers, stabilizers, and maintenance of required temperature during processing, and
- national programs need to collect data on consumer preferences relating to taste, color, and texture.

There were discussions on postharvest handling and storage. It was recognized that this aspect is crucial to groundnut utilization and should be given high priority.

Recommended Activities for Future Research

- Development of specifications and grades for marketing.
- Investigations on quality factors controlling resistance to storage pests and molds.
- Documentation of available methods including traditional storage methods to provide a data base within the network systems.
- Identify centers which conduct activity in storage research e.g., Food Research Center (in Sudan), Peanut-CRSP activities in SAT Africa and Southeast Asia, and IDRC.
- Include considerations on marketing channels, and consumer demands, and acceptance.

Research Collaboration

- Participants agreed that food technologists should develop a network to exchange information, avoid duplication and define the method of research for national programs.
- Other institutions such as Central Food Technological Research Institute, Mysore, National Research Center for Groundnut, Junagadh, need to be identified and invited as partners/collaborators with ICRISAT.
- Other countries where groundnuts are grown and utilized, such as Mali, Burkina Faso, Senegal, Cameroon, Nigeria, and Niger, need to be contacted by ICRISAT.

General

General Discussion and Conclusions

- The consensus was that production has to be stabilized and adequate production assured for finding alternative uses for legumes. Since a variety of uses have been discussed, it is essential to conduct location-specific studies to assess consumers' requirements and expectations. It was also perceived that there were certain commonalities in consumption patterns which would indicate broad directions for quality improvement.
- The involvement of and contribution from food technologists, nutritionists, and economists is a prerequisite to finding avenues for crop utilization. In a developing country, one has to be cautious in commercializing food products and involving private industry, because of associated constraints. Also, the commercially processed product will cost more than if it were home made, and consumers may not be able to afford it. Government legislation has to come early in the development and marketing of new products in developing countries, because it takes a long time for institutional development, brand name rights, and related legalities to be finalized.
- The need to differentiate between levels of utilization was emphasized, i.e., the rural/domestic/traditional level of use and commercial/industrial uses which require different approaches in terms of quality and technological improvement. It was suggested that the traditional sector could be served through existing extension services of NARSs.
- The deficiencies in the NARSs in food technology facilities and capabilities was seen as a constraint in a national program even though some countries, particularly those in Asia, have well-established food research centers, and many Universities in the region have good food technology departments. It was suggested that international research centers could support NARSs through project funding to meet operational and research costs, where NARSs funding is limited.
- The extent of involvement of international agricultural research centers in market research depends on the commodity, and how well it is already established in a market. Where markets and consumers are not well understood, it is essential to find out what they want and what their potentials are, before putting resources into production and functional research. It is difficult to make an ad hoc judgement in resource allocation as that is really a part of the strategic studies and consideration.
- There is a need to develop market standards while developing any new product, and the involvement of private industry/sector is as essential as the regulatory requirements. Market analysis should consider input and output parameters of the commodity as these are part of the food system. However, to what extent they are included, and which ones are important depends on the purpose and focus of analyses. Packaging and legal aspects also need to be investigated while examining market requirements.
- Multipurpose pilot plants to develop new processing technologies would be useful, and need to be established.
- It is also important to perceive consumer desires and their reaction, before introducing any new product. A questionnaire-based survey needs to be conducted to understand both the consumers' response and the potential market. The involvement of the private sector in conducting such a survey was stressed. The response from rural areas needs to be carefully assessed because of biases and other overriding considerations.

- An example of how crop research can respond to consumer preferences was cited. In Canada, there is systematic evaluation of wheat varieties, at 27 locations, spread over a period of 3 years. A joint meeting involving various disciplines is held every year. These meetings are also attended by representatives of flour millers and companies involved in crop research. Mexican wheat varieties gained acceptance in India only after crop scientists were able to improve their yield and quality by local adaptation.
- Soybean has been used as a casein supplement in the diary industry. Soybean proteins are different but complimentary to those of milk. Butter and margarine have similar flavors and quality. Legume and diary proteins could be similarly combined. Therefore the functional properties and qualities of pigeonpea and chickpea have to be studied in relation to those of other legumes so that these legumes can supplement or compliment existing food products. It was also pointed out that soybean research is much more advanced than other legumes and lot of money has been spent on research on this crop. For the mandate legumes of ICRISAT, universities could take up some research projects to develop more basic information.
- Animal feeds and by-products of food processing need to be considered an important aspect of utilization.
- There are six centers' including two in Andhra Pradesh, that have projects funded by ICAR on nutrition and identifying consumer preference characteristics of food crops in India, and ICRISAT could benefit by interacting with these centers.
- The interaction between breeders, the quality improvement team, and other disciplines such as food technology through a networking mechanism was considered a vital component of the utilization strategy. The objectives of such a network have to be clearly identified, and the benefits derived have to be clearly spelled out. Country centers or coordinators should identify the components of intra-country networks, and encompass the efforts of private industry. Peanut-CRSP activities in SAT-Africa and Southeast Asia could be taken up on a collaborative basis between crop research institutions, funding agencies, and NARSs. The existence of the Asian Grain Legume Network and its interaction was mentioned. ICRISAT publishes international Newsletters for all these crops, and information on crop utlization could be communicated/shared via these newsletters.

Concluding Remarks

In his concluding remarks, Dr Nene observed that the absence of representatives from Africa was because of ICRISAT's inability to identify participants in time. He assured the participants that where feasible, appropriate actions would be taken on their recommendations. Since ICRISAT alone cannot carry out the recommendations, he suggested a joint meeting between ICRISAT and ICARDA to identify common areas that could be addressed, and projects on which the two institutions could collaborate. He thanked the participants on behalf of ICRISAT for contributing to the success of the meeting.

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Appendix 1

Food products mentioned in this proceedings, with description.

Local name	Description
Adai	India: pigeonpea combined with cereals and fermented before cooking.
Ashuk	Ethiopia: Roasted and boiled faba beans.
Astamandap	Nepal: A traditional food product, this is a mixture of eight different ingredients mainly consisting of two parts cereals to one part legumes, with other taste-enhancing components as spices, salt, or sugar. This is very popular amongst children and convalescing old people.
Asure	Turkey: A dessert flavored with chickpea.
Azifa	Ethiopia: A popular dish for fasting days made from lentils. Whole lentil seed is soft boiled and mashed; it is seasoned with chopped raw onion, garlic, green pepper, lemon, oil, and salt, and served.
Baladi	The Sudan: Medium, white flat-seeded variety of bean grown in the northern part of the Sudan.
Balila	West Asia and North Africa: In *balila,* kabuli chickpea is boiled and mixed with salt and cumin seed. A wide range of snack foods, sweets, and savory dishes are also prepared, marketed, and consumed on a small scale.
Balilah	The Sudan: This is an important chickpea dish prepared by boiling chickpea in water with salt and sesame oil. It is a very popular, energy-giving food, eaten especially during the fasting period of Ramadan.
Bassaru	India: A pigeonpea-based curry eaten with rice and chapathis.
Ba-ya-gyaw	Myanmar: Chickpea *dhal* is cleaned and soaked overnight in water. It is then mixed with wheat or rice flour with a little water, made into small balls, and fried in a shallow vessel.
Beguni	Bangladesh: Prepared by applying *besan* paste to sliced eggplant, and frying it in oil.

Beleila dhurah Egypt: Maize kernels are washed and cooked in boiling water until they become soft. Sugar, dry raisins, and milk powder are added, together with a flavoring substance, such as vanillin. The ingredients are stirred and poured into special serving dishes.

Besan India, Pakistan: Whole chickpea, or *dhal*, is ground dry to a flour.

Bessara Faba beans are decorticated, boiled in water, squeezed, and prepared as puree.

Bisi-bele-bhath India: This is a hot, spicy, south Indian dish that combines pigeonpea with rice and vegetables (2:1:0.5 ratio).

Biteheneh West Asia and North Africa: Kabuli chickpea consumed in the form of puree.

Bongko Indonesia: If *brubus* (see below) is wrapped in banana leaf and steamed for about 30 min, it is called *bongko.*

Boot birani Bangladesh: Whole chickpea seeds are soaked in water overnight, boiled, and fried with oil, using salt, onions and chilies.

Brubus Indonesia: Made from green pigeonpea seeds mixed with grated coconut, and ground spices consisting of coriander, coconut sugar, salt, chili, garlic and onion. The mixture is then cooked for about 30 min.

Bundia *Besan* is mixed with wheat flour, formed into small balls, fried in oil, and then soaked in a thick sugar solution.

Burghul bihomos West Asia and North Africa: Kabuli chickpea soaked and boiled and served with steamed *burghul* (broken parboiled durum wheat).

Chanachur Bangladesh: *Besan* paste is fried in oil as flakes, and mixed with roasted groundnut, mung bean, and lentil seed.

Chapathis India: Pancake-like product made of unleavened wheat and other flours, usually eaten with curry.

Chikki India: Very popular product in western India. It is prepared by mixing roasted and decorticated groundnut kernels with a hot slurry of sugar or jaggery. The mixture is spread on a tray and after cooling, is cut into small pieces and packed.

Cocido Spain: The traditional procedure of cooking *cocido* (boiled chickpea) is to soak seeds overnight, and drain off excess water. Additional ingredients, such as pork, beef, and potato, are boiled, and added to the previously soaked seeds. *Cocido* is modified according to regional preferences.

Couscous	North Africa: Consists variously of cracked wheat steamed and eaten as a cereal or with meat and vegetables as a main dish or with fruits and nuts as a dessert.
Da'a	West Asia and North Africa: *Qadami safra* seed (see below) are ground to a flour and mixed with lemon juice and salt to make *da'a.*
Dabo	Ethiopia: Kind of bread, using split chickpea flour, salt, and coriander.
Dhal	India: Decorticated dry split cotyledons.
Dhal chutney	India: Made of roasted pigeonpeas, red chillies, garlic, and ground with grated coconut, tamarind, curry leaves and salt, using a little water.
Dhokla	India: Fermented, steamed product made of ground rice and chickpea.
Difin misir wot	Ethiopia: See *wot.* This is *wot* made from whole lentil.
Dosa	India: Pancake-like dish made with *dhal* in combination with cereals, fermented and fried.
Eksili corba	Turkey: A chickpea-flavored soup.
Elbet	Ethiopia: Salt, fenugreek, and water are added to a mix of equal proportions of roasted and dehulled lentil flour and faba bean flour. A batter of good consistency is made, which is poured into boiling water and cooked until it becomes thick. The paste is allowed to cool, and then beaten with a spoon till it becomes fluffy. It is served as a side dish with *injera* together with other sauces.
Endushdush	Ethiopia: Soaked and roasted faba beans.
Fafa	Ethiopia: A commercial weaning food.
Falafel	West Asia and North Africa: Prepared by soaking and boiling chickpea, mashed with hot pepper and herbs, formed into small cakes and fried.
Falafel	Faba beans decorticated, soaked in water, ground, mixed with onions and parsley, and fried in oil.

Fattir	Egypt: Prepared from wheat flour mixed with water, fennel seeds, anise seeds, hydrogenated oil, and baker's yeast made into a dough. The dough is fermented for 2 h, divided into small pieces, and a piece of semi-dry date added to each piece. The dough is then baked in a preheated oven (250°C) for about 20 min.
Foul medamis	Faba beans boiled in a minimum of water over a gentle fire.
Fufu	The Sudan: Peanut butter.
Ful	The Sudan: Faba bean prepared as a stewed dish.
Ful masri	The Sudan: Broad bean or faba bean.
Ful Sudani	The Sudan: Groundnut soup.
Fuloura	Nepal: A product similar to *masayura* (see below), but of a slightly different composition. It contains various spices and salt as important ingredients. Fermentation helps to develop the typical spongy texture of *fuloura.* It is deep-fried in oil and eaten, but is not dried or stored like *masayura.*
Gandasturi	Indonesia: *Gandasturi* is made by mixing soaked green pigeonpea seeds with coconut sugar and salt. The mixture is cooked, made into small balls covered with cassava or wheat flour and then fried.
Gundruk	Nepal: A fermented product made from leafy vegetables and sun-dried.
Gunkul	Ethiopia: Boiled or roasted sprouted faba beans.
Hadji halvahl Halvah	Turkey: A popular dish made of roasted chickpea flour.
Halva	Bangladesh: Prepared from dehulled chickpea seeds, which are soaked overnight, boiled, and then made into paste. The paste is cooked with sugar, butter or oil, and aromatic spices.
Halwa	India: Sweet made of malted and germinated flour.
Holige or obbattu	India: A well known sweet dish in South India. This is a sweet pancake prepared with cooked split pigeonpeas, jaggery (gur), grated coconut, and cardamom powder.
Homos	Jordan, Iraq, Lebanon, Turkey: In these places, *homos* is a traditional favorite. Chickpeas are soaked overnight, cooked, crushed, and mixed with sesame seed oil, garlic, and lemon juice. The creamy paste is eaten as a dip with Arab bread.

Homos-biteheneh	Jordan, Iraq, Lebanon: This is prepared by soaking chickpeas, boiling, cooling, and then blending with *tiheneh* (mashed sesame seed), garlic, lemon juice, and olive oil. The resultant puree is garnished with black pepper, paprika, and olives, and served cold. It is eaten as a *mezze* (starter) dish, or used as a sauce with other dishes.
Idli	India: A steamed fermented mixture of ground rice and *dhal.*
Injera	Ethiopia: A leavened bread made from cereals.
Kadabu	India: Dish where pigeonpea is combined with cereals and fermented.
Kai nok kata	Northeastern Thailand: Fried cowpea paste.
Ka-la-pai-chaung	Myanmar: Chickpea flour is mixed with wheat flour and shaped into long, thick sticks, and coated with sugar syrup. The product is a popular snack in Mandalay.
Ka-lapai-gyan-gyaw	Myanmar: Chickpea *dhal* is cleaned and soaked overnight in water. It is dried in the shade, and then deep fried.
Kanom kloke	Northeastern Thailand: Charcoal-baked cowpea flour with sweet batter.
Kanom saree	Northeastern Thailand: Cowpea sponge cake.
Kao kreb	Northeastern Thailand: Puffed snack made from cowpea flour.
Kavut	Turkey: Roasted chickpeas, ground and mixed with sugar.
Kichri	India, Pakistan: *Dhal-based* rice preparation.
Kichuri	Bangladesh: *Dhal* is mixed with rice and cooked, and is eaten as a main dish with egg or meat curry.
Kik wot	Ethiopia: See *wot.* This is *wot* made from split seed.
Kinako	Japan: Parched soybean coarse ground, dehusked, and finely ground. Used mainly for flavoring cakes or snacks, with sugar and other flour.
Kinema	Nepal: Puffed, deep-fat fried, and fermented legumes.

Kisra	The Sudan: A thin pancake-like leavened bread made from whole sorghum flour. It is the predominant staple diet of people in the Sudan.
Kitta	Ethiopia: Kind of bread using split pea flour with wheat flour. It is baked on a hot griddle.
Klong kang klob	Northeastern Thailand: Boiled cowpea dough in coconut milk.
Kloy tod	Northeastern Thailand: Fried banana coated with cowpea flour batter.
Kollo	Ethiopia: Prepared from roasted chickpea, lentil, and faba bean. Before roasting, cooking or soaking is involved. In case of chick-pea and lentil, the grain is commonly mixed with roasted barley or wheat.
Koorma/Kootu	India: Stew cooked with coconut paste/cream and spices and sea-soned while boiling.
Krob kem	Northeastern Thailand: Fried crust.
Laddu	India: Groundnut kernels are roasted and deskinned, the separated cotyledons are mixed with thick, hot, jaggery syrup. Small por-tions of the mixture are pressed by hand to obtain balls.
La-phet-thoke	Myanmar: Commercial dessert using chickpea *dhal.*
Lokmet el-kadi	Egypt: This popular breakfast dish eaten with milk is prepared by mixing wheat flour and baker's yeast to form a soft dough and fermented for 2 h. The fermented dough is divided into small pieces, then fried in an open pot in very hot oil. The fried product is usually mixed with sugar before consumption.
Masayura	Nepal: A high protein traditional Nepali curry, made from various ingredients depending on the raw materials available in different regions.
Massoppu	India: Pigeonpea based curry eaten with rice and chapathis.
Mezze	Jordan, Iraq, Lebanon: See *Homos-biteheneh.*
Fermented Miso	Japan: Paste, made from steamed soybean, salt and *koji* (rice or barley or soybean grain processed and incubated with *Aspergillus oryzae* and *Zygosaccharomyces rouxii),* and fermented with *Can-dida* sp., *Pediococcus* sp. and other microorganisms. Used widely for soup, seasoning, and pickles.

Miso natto	The Orient: Fermented soybean food.
Missi roti	India: A preparation of wheat and chickpea flour, popular in rural areas. Pakistan: Chickpea flour is blended with wheat flour to bake *missi roti,* a bread commonly consumed by diabetic patients.
Moke-hin-ga	Myanmar: Vermicelli soup usually made with chickpea *dhal* flour. It is cooked with fish, fish vinegar, and monosodium glutamate. Onion, ginger, and other ingredients are also included. This soup with Burmese vermicelli or rice noodles is served at food stalls all over Myanmar. Most Burmese people consider it their favorite snack.
Muruku	India: An extruded deep-fried product. It is prepared by roasting chickpea flour, mixing it with sorghum flour, adding chili powder, salt, cumin and caraway seeds, and making the mixture into a dough with water. The dough is then divided into balls, that are formed in a mould and extruded using a special device into heated oil where they are deep fried until golden brown.
Natto	Japan: Fermented whole or split soybean grain, boiled and inoculated with *Bacillus natto.* Generally mixed with boiled rice and eaten with *shoyu.*
Nifro	Ethiopia: Made from chickpea, lentil, or faba bean, the grain is either cooked and served by itself, or boiled and mixed with cereals, commonly wheat. The cooked product is salted and served hot as a meal or a snack.
Nohutlu kabak	Turkey: A sweet squash flavored with chickpea.
Nohutlu pilav	Turkey: A kind of pulao, flavored with chickpea.
Oncom	Indonesia: Fermented groundnut press cake. It is fried in oil or margarine and consumed.
Pakoras	Pakistan: Snack using chickpea flour.
Pa-la-ta or *Htat-ta-ya*	Myanmar: This breakfast snack is made out of wheat and chickpea flours, fried with onions in a shallow pan.
Paneer	India: Cheese made from soured milk.
Papadam	India: A crunchy side dish made from dhal pastes; eaten usually with rice.

Peanut butter	USA: Peanuts are heated to 160°C for 40-60 min. They are then cooled, blanched and fine milled to paste. Stabilizers and other additives are added. The butter is used as spread on bread and in the manufacture of candy, cookies, sandwiches, etc.
Pencok hiris	Indonesia: A popular vegetable dish from West Java. Raw young pods and fresh seeds of pigeonpea are mixed with ground spices - chili, coconut, sugar, garlic, salt, fried groundnut and kencur (*Kamferia galanga*).
Pianjoo	Bangladesh: Prepared by mixing *besan* paste with sliced onion, salt, and other spices, and deep frying in oil.
Pilau	India, Pakistan: Spicy rice preparation, often with vegetables and/ or meat.
Qadami bisukar	West Asia and North Africa: Large *qadami safra* seed are coated with sugar of various colors, and marketed as *qadami bisukar*
Qadami safra	West Asia and North Africa: Yellow roasted chickpea, prepared by a more complicated method than *Qadami stamboulieh* or *Qadami stamboulieh bimeleh.* The seed is sieved and separated into two sizes. It is then roasted, placed in wooden boxes and stored for 1 week, followed by a further week of standing in the open in a shaded area. These steps are repeated three more times. After the fourth cycle, the seed is sprinkled with water, allowed to stand in closed containers for 24 h, then stored in the open for 4 days. Finally the seed is roasted again and dehulled. The final traces of husk are removed by manually rubbing over a sieve with a cloth.
Qadami stamboulieh	West Asia and North Africa: Chickpea seed is wetted with some water, blended well, and allowed to stand for 24 h. It is then heated for 5-7 min in a rotating kiln, and then cooled for 2 h, and reheated for 3-5 min in the kiln. The seed is cooled, and graded into two sizes for marketing. At the same time, broken seed is separated out.
Qadami stamboulieh bimeleh	Prepared the same way as *Quadami stamboulieh,* but during the second heating a saline solution is added. During heating and rotation, the seed becomes coated with a thin layer of salt.
Quanty	Nepal: A dish whose main ingredients are cooked sprouted legumes. A mixture of legumes in equal proportions are soaked in water for 2-3 days, and germinated. The mixture is cooked to soft texture like a vegetable soup after adding several spices for taste.

Rempeyek — Indonesia: Rempeyek is made from mature pigeonpea seeds mixed with a concentrated solution of rice flour, egg and coconut milk. Ground spices — coriander, candlenut, salt and garlic are added and then deep fried.

Riz bihomos — West Asia and North Africa: Soaked boiled chickpea served with steamed rice.

Roti — India: Pancake-like product made from unleavened wheat and other flours, usually eaten with curry.

Sambar — India: A kind of soup using pigeonpea, eaten with *idli* and rice.

Samosa — India: Partially refined wheat flour made into a dough, rolled, and stuffed with vegetable or meat curry, shaped like a triangle, and deep fried.

Serundeng — Indonesia: *Serundeng* is made by mixing mature pigeonpea seed with grated young coconut, coriander, onion, garlic, coconut sugar, salt, bay leaf, *greater galingale,* tamarind and the mixture is fried.

Shimbra asa wot — Ethiopia: This is a popular and unique dish for fasting days. It is prepared from dehulled chickpea flour. Unleavened small breads of different shapes are baked on a clay griddle. The basic sauce (see *wot)* is prepared and the bread is dropped into the boiling sauce and allowed to simmer.

Shiro wot — Ethiopia: See *wot.* With the same basic sauce, flour from roasted, dehulled, and spiced chickpea or faba bean is used as a thickener, and the mixture is allowed to simmer. This is called *shiro wot.*

Shoyu — Japan: Soybean sauce, made by compressing *moromi* (steamed soybean, parched wheat grain, and salt, and fermented mostly with *Aspergillus oryzae* or *A. sojae,* and *Zygosaccharomyces rouxii, Candida* sp, *Pediococcus* sp. An indispensable flavor base used for many Japanese dishes.

Siljo — Ethiopia: Split faba bean flour is made into a paste with an extract of cooked and pounded sunflower seeds. The paste is mixed with mustard, fresh garlic, and rue, and allowed to ferment for 3 - 6 days. It is served as a side dish with *injera,* especially during the fasting period.

Soybean milk — Japan: Soaked soybean ground, boiled, and filtered through a cloth. Recently used for health drinks. Soybean milk is sweetened and flavored before it is packed and sold.

Stifled parathas	India: Pancakes made from whole wheat flour dough, rolled and stuffed with cooked dhal, salt and spices, rolled again and griddle cooked.
Sundal	India: Germinated and boiled pigeonpeas.
Taameya	Egypt: Faba beans decorticated, soaked in water, ground, mixed with onions and parsley, and fried in oil.
Tako	Northeastern Thailand: Steamed cowpea gel with coconut cream.
Tamia	The Sudan: *Tamia* is made by soaking decorticated dried seeds. The seeds are ground to a paste, spices and onion added, and deep fried.
Tempeh	India: Made with pigeonpea, with or without soybean. Both fresh and dried *tempeh* can be used to make nutritious snacks and curried dishes.
Tempeh	Indonesia: traditional Indonesian food that is commonly prepared from soybeans by fermenting soaked, dehulled, and cooked seeds, with *Rhizopus oligosporus*, a mold that grows not only on the surface but throughout the seeds converting them into a compact cake.
Tempeh benguk	*Tempeh* product prepared from velvet bean.
Tempe gude	Indonesia: *Tempeh* made out of pigeonpea.
Tempeh kecipir	*Tempeh* product prepared from winged bean.
Tempeh kedele	*Tempeh* product prepared from soybean.
Thovve	India: Pigeonpea-based mashed *dhal* eaten with rice and chapathis.
Tisqieh	Syria: Prepared from soaked whole chickpea which is boiled and then mixed with soaked Arabic flat bread, yoghurt, and olive oil, and served hot.
Tofu	Indonesia: Soybean product.
Nonfermented *Tofu*	Japan: Soybean curd. Soaked and ground soybean steamed, filtered through a cloth, and the extracted soybean milk coagulated with $CaSO_4$ (and/or deltaglucono lactone, $CaCl_2$). Various food products, fresh, baked, fried, or frozen are traditionally made with it.

Tofu (curd)	China, Japan: Groudnut kernels are soaked overnight and ground into an emulsion. The fine mash is boiled or steamed and put through cloth filters. The curd is precipitated from the resulting fluid by adding calcium or magnecium sulfate. The curd is served in soup. The wet curd can be deep fried in oil.
To-phu	Myanmar: This is jelly-like and is made with chickpea flour or chickpea *dhal.*
Uji	Tanzania: Food product commonly prepared from maize or sorghum.
Vanaspati	India: Hydrogenated vegetable oil.
Wot	Ethiopia: The basic seasoning ingredients are onion, garlic, oil, red pepper, spices, and salt. These are made into a sauce. Whole lentil seed, or split lentil or faba bean seed is cooked in a separate pan, mixed with the sauce, and allowed to simmer till the mix becomes homogeneous. Different versions of this dish can be prepared.
Yuba	Japan: Soybean milk slowly heated in a flat dish/pan, and the solidifying surface film (*yuba*) repeatedly skimmed. Fresh and dried *yuba* is used to make snacks, soups, and other dishes.

Appendix 2

Only the common names of crops are used in this report. They are listed here along with their Latin binomials.

Crops

Common names	Latin binomials
Bengal gram, chana, chickpea	*Cicer arietinum* L.
Black gram, urd bean	*Vigna mungo* (L.) Hepper
Candlenut	*Aleurites triloba* L.
Common bean, phaseolus bean, navy bean, haricot bean	*Phaseolus vulgaris* L.
Cowpea	*Vigna unguiculata* (L.) Walp
Faba bean, broad bean	*Vicia faba* L.
Field bean, hakubenzu bean, lablab bean	*Dolichos lablab* L.
Groundnut	*Arachis hypogaea* L.
Horse gram	*Macrotyloma uniflorum* (Lam.) Verdc.
Hyacinth bean	*Lablab purpureus* (L.) Sweet
Lathyrus, grasspea, khesari	*Lathyrus sativus* L.
Lentil	*Lens culinaris* (L.) Medic.
Lima bean	*Phaseolus lunatus* L.
Maize	*Zea mays* L.
Mung bean, green gram	*Vigna radiata* (L.) Wilczek
Pea, field pea	*Pisum sativum* L.
Pigeonpea, redgram, tur	*Cajanus cajan* (L.) Millsp.

Soybean	*Glycine max* (L.) Merr.
Velvet bean	*Mucuna pruriens* (L.) DC. *var. utilis* (Wall ex Wt.) Baker ex Burck.
Wheat	*Triticum aestivum* L.
Winged bean	*Psophocarpus tetragonolobus* L.

Appendix 3

Diseases and Pests

Chickpea diseases

Common names	Latin binomials
Ascochyta blight (Anthracnose)	*Ascochyta rabiei* (Pass.) Labr. *(Mycosphaerella rabiei* Kovachevski)
Black root rot	*Fusarium solani* (Mart.) Sacc.
Botrytis gray mold	*Botrytis cinerea* Pers. ex Fr.
Collar rot	*Sclerotium rolfsii* Sacc.
Dry root rot	*Rhizoctonia bataticola* (Taub.) Butler *(Macrophomina phaseolina* [Tassi] Goid.)
Fusarium wilt	*Fusarium oxysporum* Schlecht. emend Snyd. & Hans.f.sp.ciceri (Padwick) Snyd. & Hans.
Stunt (CpSV)	Luteo viruses (BLRV, other luteo viruses)

Pigeonpea diseases

Alternaria blight	*Alternaria alternata* (Fr.) Keissler
Collar rot	*Sclerotium rolfsii* Sacc.
Fusarium wilt	*Fusarium udum* Butler *(F. oxysporum* f.sp. udum)
Phytophthora blight	*Phytophthora drechsleri* Tucker f. sp. *cajani* (Pal et al.) Kannaiyan et al.

Rhizoctonia root rot	*Rhizoctonia bataticola* (Taub.) Butler *(Macrophomina phaseolina* [Tassi] Goid.)
Sterility mosiac (SM)	Casual agent not known
Witches broom	*Mycoplasma*

Groundnut diseases

Bud necrosis	Tomato spotted wilt virus
Peanut mottle	Peanut mottle virus

Chickpea pests

Aphids	*Aphis craccivora* (Koch)
Bruchids	*Callosobruchus maculatus* (Fabricius) *C. chinensis* (L.)
Leaf miner	*Liriomyza cicerina* (Rondani)
Pod borer	*Helicoverpa armigera* (Hiibner)
Termites	*Microtermes spp* and *Odontotermis spp*

Pigeonpea pests

Blister beetle	*Mylabris pustulata* Thunberg
Bruchids	*Callosobruchus maculatus* (Fabricius) *C. chinensis* (L.)
Leaf webber	*Grapholita critica* Meyr.
Pod borers	*Helicoverpa armigera* (Hiibner) *Exelastis atomosa* (Walsingham) *Maruca testulalis* (Geyer)
Pod bug	*Clavigralla gibbosa* Spinola

Pod fly	*Melanagromyza obtusa* Malloch
Termites	*Microtermes* spp and *Odontotermes* spp

Groundnut pests

Jassids	*Empoasca kerri* Pruthi
Leaf miner	*Aproaerema modicella* D.
Thrips	*Scirtothrips dorsalis* Hood *Frankliniella schultzei* (Trybom)
Tobacco caterpillar	*Spodoptera litura* (Fab.)

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