PRELIMINARY INVESTIGATION OF THE POTENTIAL FOR SMALL SCALE PRODUCTION OF QUALITY SOLAR DRIED PRODUCE, KWAZULU-NATAL

January 2004

Omer Ibrahim Mohammed

Submitted in partial fulfillment of
The degree of M Agric (Food Security),
School of Agricultural Science and Agribusiness,
Faculty of Science and Agriculture,
University of KwaZulu-Natal,
Pietermaritzburg

ABSTRACT

This study undertook to carry out a survey of dried fruits and vegetables that could be dried using a solar drier system and determine the efficiency of solar drying in terms of a) the effect of temperature and humidity on the solar drier; b) effect of this drying system on three fruits and three vegetables in terms of quality which was measured by ascertaining the colour, texture, and flavour and moisture levels; and c) the effectiveness of pre-treatment systems on the above parameters.

A small markets survey was conducted to investigate what dried fruit and vegetable products were available in four selected supermarkets in Pietermarizburg. The findings of this survey were compared with small scale production in the region and the prevailing climate. Experimental dried products were produced and the efficiency of the solar drier to produce quality products on a small-scale farmers level was evaluated through three tests. First, the quality of the dried fruits and vegetables were rated by sensory evaluation of terms of colour, flavour, texture, and moisture content by members of a rural community solar project. The fruits (apple and banana) were treated by three methods, namely soaking in 35% sugar syrup and lemon juice (preserved with sulphur dioxide), 25% lemon juice (preserved with sulphur dioxide), 25% lemon juice (preserved with sodium metabisulphite). Half the vegetables (carrot, tomatoes, and pumpkin) acted as controls while the second half of the samples were pre-treated with steam blanching. Forty-seven panellists used a five-point hedonic scale to evaluate the dried products. Second, the moisture content of dried products was measured using the Association of Official Analytical Chemists, Official Method 934.06 and compared to available standards for dried fruit and vegetable products. Third, a data logger was used to measure the difference between temperature and humidity levels inside and outside the solar drier.

The results of the supermarket survey showed that, drying methods used, treatments, packaging, raw material, and processing practical are all appropriate and affordable small-scale farmers. In addition, the climatic conditions of the study area indicated that the drying process especially solar drying could be applied almost all year round. The results of the sensory evaluation showed that the quality characteristics such as colour, flavour, and texture of the sample dried fruits are better when treated with sugar syrup and lemon juice preserved with sulphur dioxide than those pre-treated only with lemon juice preserved with sulphur dioxide and lemon juice preserved with sodium metabisulphite. Dried vegetables had better texture, colour and flavour when treated with steam blanching. The ability of the solar drier to maintain the desired level of temperature and humidity inside the drier also indicated its efficiency. Therefore, small scale farmers by using solar drier and appropriate pre-treatments and packaging could produce good quality of dried products

DECLARATION

I hereby declare that the research in this thesis is my own investigation. Where use is made of the work others, this has been duly acknowledged in the text.

Signed: ________________ Date: 15/03/04

Omer Ibrahim Mohammed

As research supervisor I hereby agree to submission of thesis for examination.

Signed: ________________ Date: 15/3/04.

Dr. SL Hendriks

ACKNOWLEDGEMENTS

My sincere thanks is extended to the following persons for their contribution to this study

The government of Eritrea, Ministry of Agriculture and University of Asmara for granting funding and the opportunity to pursue my studies.

My supervisor, Dr. Sheryl Hendriks, for her patience, guidance, speedy return of draft copies, and invaluable advice.

Mrs. Karen Caister, Mrs., Anusha Maikoo, and Ms. Mimi Ndokweni for help with transportation, purchasing raw materials, and arranging the sensory evaluation sessions.

Dr. D. Jagany' for assistance with explaining chemical reactions.

Quraishia Abdulla for assisting with proof reading.

Mr. More wood, Mr. Hendriks and Mr. Gregory of the Mechanical Instrument workshop for manufacturing the solar drier.

Dr. Dorothea Smith and Mr. Issac Abbib of the University Soil Science Discipline for assisting with the moisture tests.

Staff and students of the Food Security Programme, University of Natal, for their valuable suggestions and friendship.

My friends, Tecle A., Osman K., Abraham A., Mohammad A., Hassan H., Petter, and Ismael T. for their valuable support and friendship.

The Maphaphetheni community members who participate in the sensory evaluation.

My mother, brothers, and sisters for their interest, encouragement and emotional support.

I also thank GOD for the power and courage he bestowed me to finish my thesis.

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLES

Abbreviations

ANOVA	Analysis of variance
CRS	Christian Rural Services
CSIR	Centre for Science and Industrial Research
CTA	Technical Centre for Agricultural and Rural Cooperation
FAO	Food and Agriculture Organization of the United Nations
GTZ-ITFSP	German Technical Cooperation-Integration of Tree Crops into Farming Systems Project
HNSDA	Hoima Nursery Schools' Association
LSD	Least significant difference
ISHS	International Society for Horticultural Sciences
NSTA	National Science Teachers Association
UNIDO	United Nations Industrial Development Organization
UNIFEM	United Nations Development Fund for Women
w.b.	Wet basis

CHAPTER ONE
THE PROBLEM AND ITS SETTING

1.1 Importance of the study

Small scale farmers in KwaZulu-Natal produce a variety of fruits and vegetables including: apples, avocados, bananas, beans, cabbages, carrots, chillies, guavas, mangos, onions oranges, papayas, pineapples, potatoes, pumpkins, sweet potatoes, and tomatoes. Fruits and vegetables are highly perishable commodities and therefore need to be preserved while in season to enable supply throughout the year and ensure good nutrition among communities. The surpluses of many local seasonal crops can be preserved and prolonged by various processing methods requiring simple and inexpensive equipment (such as solar drying) to preserve the qualities of edible produce and reduce storage and handling costs (Droits 1985, FAO 1989). Other benefits of dehydration are that it facilitates transportation of produce as the products are lighter and less susceptible to damage (GTZ-ITFSP undated). Dried food often permits easier and cheaper handling and storing (Whitfield 2000).

This study investigates the potential of solar drying in the KwaZulu-Natal midlands, South Africa. Solar drying uses natural energy to induce water evaporation through air ventilation and solar radiation. Research was undertaken to investigate the efficiency of the solar drier to produce quality product on a small-scale farmers level by evaluating the quality characteristics (such as colour, flavour, texture, and moisture content) of the dried products and by comparing the conditions in the drier to available standards for other similar studies. A market survey was also conducted to evaluate the availability of commercial products with opportunity for small-scale production.

1.2 Statement of the problem

To study the efficiency of a solar drier to produce quality products on a small scale farmers' level by evaluating the quality of the dried fruits and vegetables in terms of colour, flavour, texture, and moisture content and comparing the conditions in the drier to available standards for efficient solar drying.

1.3 Sub-problems

Sub-problem one: To compare the availability of commercial products with opportunities for small scale production.

Sub-problem two: To evaluate the quality of the dried fruit and vegetables through sensory evaluation.

Sub-problem three: To evaluate the efficiency of the solar drier.

1.4 Hypothesis

Quality produce can be dried on a small scale using the efficient solar drier manufactured for the study.

1.5 Study limits

The study is limited to experimentation at the Ukalinga research station in Pietermaritzburg, KwaZulu-Natal. Therefore, the results cannot be generalised for South Africa as the climate varies considerably across regions. The microbial and nutritional value of the dried products was not tested due to limited available funds. Only fruits and vegetables available in the region during the study period (April to September) were dried. The study does not investigate the possibility of drying during the more humid months when most crops are harvested and so the evaluation of the capacity for larger scale production is limited.

1.6 Study assumptions

The study was based on six assumptions. First, it was assumed that the weather (temperature and humidity) was typical of the study area. Second, it was assumed that the taste ability of the panellists was not affected by age and physiological aspects. Third, that small scale farmer seeks for appropriate food preservation methods to extend the shelf life of agricultural produce and/or seek additional on-farm income opportunities. Fourth, it was assumed that further deterioration did not occur in storage and that the packaging was appropriate and prevented spoilage. Fifth, it was also assumed that as the study was conducted during winter, that the higher temperatures during the summer months would facilitate faster drying through increased convection and higher internal drier temperatures. However, this cannot be verified from this study. Six, it was assumed that other small-scale farmers, by using solar driers, appropriate packaging and pre-treatments could produce dried products of the same standard and quality as those produced in this study.

1.7 Thesis organisation

This thesis has six chapters. Chapter one presents the importance of the study, research problems, hypothesis, study limits and assumptions. In chapter two, the review of related literature is presented. Chapter three presents a discussion of the analysis of the supermarket survey, discussion of the weather typical for this region and discussion of the possibilities for small scale drying in this region. The research design and methodology is presented in Chapter four. The main findings of the sensory evaluation are discussed in Chapter five. A concluding chapter presents the conclusions, recommendations and implications for further research.

CHAPTER TWO
REVIEW OF RELATED LITERATURE

2.1 Food storage issues in rural South Africa

South Africa is the third largest horticulture-producing country in southern Africa (Trade Partners 2003). Horticultural crops are produced throughout South Africa. More than a third of all South African horticultural produce is exported (Linton and Westell 2001). Fresh fruits and vegetables have relatively high water content (85-95%), that supports both enzyme activity and growth of micro-organisms, leading to rapid post-harvest deterioration (Minnaar undated). Reducing post harvest losses is very important to ensure that sufficient food (both in quantity and quality) is always available. While improved post harvest storage could reduce costs of production, trade and distribution, lowering prices for consumers and increasing farmers' income (Herregods 1998). An adequate crop and food storage system is needed, together with efficient processing and distribution of foods, to ensure equitable and adequate supplies at the national, district and household level food security (FAO 1997 a, Minnaar undated).

Kader *et al* 1992, p. 15 reported that the magnitude of post harvest losses in fresh fruits and vegetables is 5 to 25 percent in developed countries and 25 to 50 percent in developing countries. Studies of post harvest losses in Ghana (Droits 1985) have shown that annual losses estimate 30 to 40% for starchy crops, vegetables, and fruits. Most losses are attributed to lack of storage and preservation facilities. Reduction of losses through appropriate preservation methods could increase domestic shortfalls in Ghana by 20% - 30% (Droits 1985). The highly perishable nature and seasonality of fruits and vegetables poses special challenges in marketing, transportation, and storage (Toma *et al* 1990). Raw materials need to be converted into products with longer shelf lives or distributed quickly to domestic and international markets to avoid spoilage (FAO 1989, Minnaar undated).

Table 2.1: Storage requirements and shelf life for fruits and vegetables (Gast undated, p. 3-5).

Commodity	Recommended Storage Temperature (° C)	Relative Humidity (%) of fresh product	Average Storage Life of fresh produce
		Fruits	
Fruits			
Apple	-1.1-4.4	90	3-8 months
Apricot	-0.55-0	90	1-2 weeks
Avocado	10-12.7	90-95	3-10 days
Blackberry	-0.55-0	90-95	2-3 days
Blueberry	-0.55-0	90-95	2 weeks
Grapefruit	4.4-10	85-90	4-6 weeks
Grape	-0.55-0	85	2-8 weeks
Orange	0-4.4	85-90	3-10 weeks
Peach	0.55-0	90	2-4 weeks
Pear	-1.6-(-0.55)	90-95	2-4 months
Strawberry	0	90-95	5-7 days
Raspberry	0.55-0	90-95	2-4 days
		Vegetables	
Bean, green or snap	4.4-7.2	90-95	7-10 days
Broccoli	0	90-95	10-14 days
Cabbage, late	0	90-95	3-4 months
Carrot	0	90-95	4-5 months
Cauliflower	0	90-95	2-4 weeks
Eggplant	7.2-12.7	90-95	1 week
Potato, late	4.2-7.2	90	2-9 months
Pumpkin	10-12.7	70-75	2-3 months
Spinach	0	90-95	10-14 days
Sweet Potato	12.7	85-90	4-6 months
Tomato, mature green	12.7-21.1	85-90	1-6 weeks
Onion, dry	0	65-70	1-8 months
Garlic, dry	0	65-70	6-7 months
Okra	7.2-10	90-95	7-10 days
Pepper, dry	0-10	60-70	6 months
Pepper, sweet	7.2-10	90-95	2-3 weeks
Mushroom	0	90	3-4 days

Most fresh fruits and vegetables have a storage life of only a few days under even the best environmental conditions because of their fast respiration rate, that causes depletion of moisture (FAO 1989, Gast undated) (Table 2.1). Many crop surpluses can be preserved by various processing methods using simple and inexpensive equipment (such as solar drying) to preserve the qualities of edible produce and to reduce storage and handling costs through drying, canning, and freezing (Droits 1985, Minnaar undated, FAO 1997 a, FAO 1989).

2.2 Fruit and vegetable preservation

Food processing techniques involve the application of scientific principles to slow down or stop the natural processes of food decay caused by micro-organisms and enzymes (Azam-Ali *et al* 2003, p. 1, Fellows 1997 b, p. 1, Fellows and Hampton 1992, p. viii, Green and Schwarz 2001, Smith *et al* 1997, p.3). Preserving basic foods such as fruits and vegetables against periods of shortage increases the food security of populations by reducing food losses, increasing food availability and ensuring continual availability of foods (Azam-Ali *et al* 2003, p.1, Fellows and Hampton 1992, p. viii, FAO 1997 a, FAO 1992). There are several methods of food preservation, including: canning, freezing, pickling, drying, and curing (smoking and salting) (Green and Schwarz 2001, Minnaar undated, Smith *et al* 1997, p.3). Freezing is quick, easy, and ensures good quality products but freezers are too expensive for many rural households in developing countries and require electricity, which many households in developing countries do not have (Smith undated). Canning needs more work than freezing and requires energy (electricity, wood or gas). Drying foods requires less energy than what is needed to freeze or can (Herringshaw 1994). Moreover, dried products are lightweight and easy to transport and store (Herringshaw 1994, Smith undated).

2.2.1 Food drying

Globally, drying is the most widely used preservation method for home production or small scale income generation. Drying preserves fruits and vegetables by lowering the moisture content of food to between 5 and 25 percent to prevent microbial growth (such as bacteria, yeast, moulds) and occurrence of chemical reactions such as enzymes, that can only occur when enough water is present (Minnaar undated, University of California 1998, Whitfield 2000). Drying provides shelf-stable products for up to six to twelve months (Barbosa-Canovas *et al* 2003, University of Illinois 1995, Whitfield 2000) (Table

2.2). In many developing countries, open air drying (sun drying) has largely been replaced by commercial fire wood driers, driers with boilers to heat incoming air, electrical driers that create heat by electricity, and simple solar driers that create heat by radiation (Arfaoui undated a). Firewood or fuel driers (heat for drying is created by fuel source) and electrical driers are faster than open sun drying, use less space and often render better quality products (Arfaoui undated a). However, the equipment required for drying fruits and vegetables by small-scale farmers is expensive and requires substantial quantities of wood, fuel or electricity to operate (Arfaoui undated a). Therefore driers that require heat sources to operate, are not suitable for small scale producers.

Table 2.2: Recommended self-life for dried foods (Andress and Harrison 1999, p. 1)

Food product	**Maximum storage life (months)**	**Recommended storage temperature (°C)**
Dried fruits	12	15.5
Dried vegetables	6	15.5
Vegetables dehydrated flakes	6	15.5

2.2.2 Pre-treatments fruits and vegetables before drying

Pre-treatment are techniques used to ensure quality products (Herringshaw 1994). The major reasons for treating foods before drying are: to preserve colour and flavour, minimize nutrient loss, stop decomposition (enzyme action), ensure more even drying, and to extend storage life (University of Idaho 1995). Drying foods alone does not stop the enzymatic action that causes fruit to mature and decay; it only slows it down (Schmutz and Hoyle undated). Most fruits and vegetables need some form of pre-treatment prior to drying or dehydration in order to prevent enzymatic activity, which causes them to change colour, flavour and lose nutritional quality (Barbosa-Canovas *et al* 2003, Fellows and Hampton 1992, p. 9, Kenawi 2000, Schmutz and Hoyle undated). Pre-treatment means blanching or dipping the foods in preservatives, which include items such as sulphur dioxide, ascorbic acid, citric acid, salt, sugar and blanching (Dauthy 1995). Some foods keep well without pre-treatment, but the majority deteriorate in colour, flavour, texture, and nutrients occur after drying unless treated (Reynolds 1998 a).

2.2.2.1. Pre-treating fruits

Pre-treating fruits prevents darkening (Reynolds 1998 a). Many light-coloured fruits such as apples, apricots, pears, and peaches darken rapidly when cut and exposed to air (Brady 2003 a, Brett *et al* 1996 b, Reynolds 1998 a). If not pre-treated, these fruits will continue to darken even after drying. Therefore, Pre-treating those fruits can decrease browning during processing, storage and lower losses of flavour and vitamins A and C (Harrison 1993). Browning process, which called oxidation, robs the fruit of flavour, colour and vitamins A and C (Harrison 1993). Some of the most commonly pre-treatment procedures used to treat fruits, include sulphuring fumes, sulphiting dip, ascorbic acid, fruit juice, syrup blanching, and blanching.

Sulphuring is an old method of pre-treating fruits (Brennand 1994). Sulphites are used primarily as antioxidants to prevent or reduce discolouration of light-coloured fruits and vegetables by blocking both enzymatic browning and non-enzymatic browning reactions (Reynolds 1998 a, University of Idaho 1995). Sulphuring also inhibits growth of bacteria, yeasts, and moulds (Kendall and Allen1998). However, sulphites pose hazards to people who are sensitive to the substance (University of Idaho 1995). There are two methods of applying sulphur dioxide treatments: sulphiting and sulphuring (Azam-Ali *et al* 2003, p. 47, University of Idaho 1995).

Sublimed sulphur is ignited and burned in an enclosed box with the fruit so that the sulphur fumes penetrate the fruit and act as a pre-treatment by retarding spoilage and darkening. The sulphur fumes also maintain colour, flavour and vitamins A and C (Brennand 1994, Reynolds 1998 a). Fruits must be sulphured out-of-doors where there is adequate air circulation. Sulphuring fumes are achieved by exposing pieces of cut fruits to burning in a sulphuring cabinet (Brennand 1994). For most fruits, 350-400 g sulphur dioxide is used per 100-kilogram of fruits, and burning for 1-3 hours before drying (Fellows 1997 b, p.32, Fellows and Hampton 1992, p. 9).

Sulphite dips can achieve the same long-term anti-darkening effect as sulphuring but quickly and easily to apply (Harrison 1993). Sulphite dipping is achieved by soaking pieces of cut vegetables in a sulphiting solution (Azam-Ali *et al* 2003, p. 47, Brennand 1994). Either sodium bisulphite, sodium sulphite or sodium meta-bisulphite can be used for preparing the solution (Azam-Ali *et al* 2003, p. 21, Fellows 1997 b, p. 32, Fellows and Hampton 1992, p. 9). A sulphiting solution is prepared by mixed four tablespoons (40 millilitres) sodium metabisulphite per 3.785 litre of water, two tablespoon (20 millilitres) sodium sulphite per 3.785 litre of water, or one tablespoon (10 millilitres) sodium bisulphite per 3.785 litre of water (Brennand 1994, Michigan State University Extension 1999).

Ascorbic acid (vitamin C) is an antioxidant that keeps fruit from darkening (Kendall and Allen 1998). Ascorbic acid mixed with water is a safe way to prevent fruit browning (Georgia University undated, Harrison 1993). However, its protection does not last as long as sulphuring or sulphiting (University of Georgia undated). Ascorbic acid is available in powder or tablet form from drugstores or grocery stores. One teaspoon (5 ml) of powdered ascorbic acid is equal to 3000 mg of ascorbic acid in tablet form (Reynolds 1998 a, Wolf *et al* 1990). To prepare an ascorbic acid solution, 0.5 teaspoon of ascorbic acid crystals should be combined with 0.946 litre of water and the cut fruit be placed in the solution for 5 minutes, and 0.946 litre of solution will treat 8 cups of dried fruits (University of Minnesota Extension Service, Wolf *et al* 1990).

A fruit juice that is high in vitamin C can also be used as a pre-treatment, though it is not as effective as pure ascorbic acid (Wolf *et al* 1990). Juices high in vitamin C include orange, lemon, pineapple, grape and cranberry (Harrison 1993, Scholl undated, Wolf *et al* 1990). Vitamin C in fruit juice slows down the reaction between the chemicals in the fruit and oxygen in the air (Scholl undated). Browning or oxidation is the result of a reaction between oxygen and a pigment in the fruit (Scholl undated). Each juice could add own colour and flavour to the fruit. To prepare the solution, add one part of lemon juice to 20 parts of boiled water (GTZ-ITFSP undated). The fruit slices should be soaked in the solution for 3 to 5 minutes, and then the slices should be placed on dryer trays. This solution may be used twice, before being replaced (Wolf *et al* 1990).

Blanching fruits in syrup helps to retain colour fairly well during drying and storage, and will produce softer textured and sweeter flavoured fruit than other methods (Harrison 1993, Michigan State University 1999, Reynolds 1998 a). The resulting product is similar to candied fruit. Fruits that can be syrup-blanched include: apples, apricots, figs, nectarines, peaches, pears, plums and prunes (University of Idaho 1995). Sugar syrup is prepared by mixing one part of sugar with two parts of boiled water. The fruit slices are added to the boiled syrup, simmered for 5 minutes, and then drained on paper towels before drying (University of Idaho 1995).

2.2.2.2 Pre-treating vegetables

Enzymes in vegetables are responsible for colour and flavour changes during drying and storage (Reynolds 1998 b). These changes will continue during drying and storage unless the produce is pre-treated to slow down enzyme activity (Reynolds 1998 b). Blanching is a necessary step in preparing vegetables for drying (Brady 2003 b). However, onions, green peppers, okra, and mushrooms can be dried without blanching (Brady 2003 b, Reynolds 1998 b, Schmutz and Hoyle undated). Blanching is the process of heating vegetables to a temperature high enough to destroy enzymes present in the tissue that cause loss of colour, flavour, and texture during drying and storage (Barbosa-Canovas *et al* 2003, Fellows 1997 b, p. 32, Fellows and Hampton 1992, p. 9, Kenawi 2000, Reynolds 1998 b, Schmutz and Hoyle undated). It also sets the colour and shortens the drying and rehydration time by relaxing the tissue walls so moisture can escape or re-enter more rapidly (Azam-Ali *et al* 2003, p. 57, Schmutz and Hoyle undated). Blanching may also prevent undesirable flavour changes during storage and improve reconstitution during cooking (Brady 2003 b, University of Idaho 1995). Moreover, blanching helps clean the material and reduce the amount of micro-organisms present on the surface (Anon 1998, Brennand 1994, Dauthy 1995, Fellows and Hampton 1992, p. 9).

Blanching may be done with either water or steam (Fellows and Hampton 1992, p. 9, Schmutz and Hoyle undated, University of Idaho 1995). In water blanching, vegetables are submerged in boiling water for a set amount of time (Table 2.3). In steam blanching, the vegetables are suspended above the boiling water and covered with a lid to prevent the steam escaping for a certain length of time (Fellows 1997 b, p. 32) (Table 2.3).

Steaming allows the vegetables to retain more water-soluble nutrients, but takes a little longer than immersing (Azam-Ali *et al* 2003, p. 57, Fellows 1997 b, p.32, Fellows and Hampton 1992, p. 9). Water blanching usually results in a greater loss of nutrients, but takes less time than steam blanching (Dauthy 1995, Reynolds 1998 b, Schmutz and Hoyle undated). The blanched vegetables will usually have better colour and flavour quality than unblanched products (Anon 1998, University of California 1998, Wolf *et al* 1990).

Table 2.3: Required duration for steam and water blanching of vegetables (Brady 2003 b, p. 3-4)

Vegetables	**Blanching time (minutes)**	
	Steam	**Water**
Carrots	3:00-3:30	3:30
Cabbages	2:00-3:00	1:30-2:00
Broccoli	3-3:30	2:00
Garlic	NA	NA
Okra	NA	NA
Onions	NA	NA
Peas, green	3:00	2:00
Pumpkin	2:30-3:00	1:00
Beans, green	2:00-2:30	2:00

2.3 Solar drying for improved storage

Drying provides a shelf-stable product for up to six to twelve months by lowering the amount of water or the moisture content of foods (Table 2.2) (Whitfield 2000, University of Illinois 1995). The most common method of drying (sun drying) involves simply laying products in the sun on the ground, roofs or drying floors (Pryor 2001, UNIFEM 1993, p. 10). The advantages and disadvantages of sun drying are shown in Table (2.4).

Table 2.4: Solar dryers compared to open-air, fuel driers and electrical driers (Arfaoui undated a, p. 5-6)

Drying technology	Advantage	Disadvantage
Open air drier	No investment is required. No fuel is required.	The product is exposed to various risks, such as dust, animals, ants, rain, etc. The products take time to dry. Requires labour to survey the crops. Quality of the drying is not good (exposed to dust).
Fire wood/fuel drier	Quicker than the open air type.	Requires investment in fuel. Requires investment in building or dryer box. Pollution and forest degradation. The quality of the dried product, can be affected by the smoke. Not easy to control the drying. Requires labour for operation and maintenance.
Electrical drier	The drying is quicker, than both the above mentioned The drying of the crops is well controlled. The quality of the dried product is excellent, depending on the type of the dryer.	The dryer is costly. It is expensive to run and operate the dryer. The dryers require energy, which is not often available in rural areas. It is not affordable for small farmer and co-operatives. The dryer has to be installed in a building that requires further investment. The drying is not environmentally friendly – if powered by a generator. Requires labour for operation and maintenance. Requires introduction to technology.
Solar drier	Very easy to maintain and operate. Does not require a specialised manpower. Well controlled dying. Quicker drying. The crops are well protected during the drying process. Can be produced locally, and from local available materials. Affordable to every body. Environmentally friendly. Does not require fuel.	The dryer should be operated properly to reach the good quality of the dried products. Requires a small investment. Requires introduction to the technology.

Sun drying is slow, usually taking several days even in good conditions, and often exposes foods to a number of hazards. Natural decay takes place when the food is exposed for a long time to warm and moist conditions, which are also ideal for the growth of destructive, and sometimes toxic, moulds (Fellows and Hampton 1992, p. viii). Exposing food in this manner provides exposure to insects, rodents, birds, and other animals and contamination with dust and dirt (Goldman and Elliott 1984, Droits 1985, Minnaar undated). Foods dried in this manner do not keep well in storage.

Solar drying overcomes many of these disadvantages as prepared produce is arranged on trays made of non-metal material, and the trays are placed in a sealed structure covered with glass or plastic. Solar drying is like sun drying, only more effective and cheaper than mechanised drying (Table 2.4). Solar drying facilities combine the advantages of direct sun drying and mechanised dryer methods, namely low investment costs and high product quality (Arfaoui undated a).

Compared with direct sun drying, solar driers concentrate the sun's energy as much as possible to heat the food and the air surrounding it, shortening the drying time (Hughes and Willenberg 1994, Intermediate Technology Development Group 2002 a). The shorter drying time for solar drying gives micro-organisms less chance to cause spoilage during drying and storage (Fellows 1997 b, p.114, Mulokozi *et al* 2000). Solar dried products also have lower moisture contents than products dried in the open, reducing microorganism activity (Arfaoui undated a, Sekiku 2003, Whitfield 2000, FAO 1993).

2.3.1 Principles of solar drying

Solar drying is suitable for use in remote areas as this method of drying relies on the sun for energy (University of Georgia undated) and so is well suited for use in small-scale farm production in developing countries (Whitfield 2000). Solar drying uses a specially designed drying container to increase the internal chamber temperature and create a through air current to speed up drying (FAO 1993, Hughes Willenberg 1994, Somogyi *et al* 1996, p. 205). The sun's rays typically radiate a box-like wooden chamber with a vented bottom raised about one metre above the ground. The chamber is usually covered by a plastic sheet or glass for protecting the dried material from direct sunlight, and to increase the heat of the sun inside the dryer, therefore enhancing the drying process (Fellows 1997 b, p. 114, Green and Schwarz 2001). The internal chamber temperature is raised by 20^0Cto 30^0C above room temperature, which shortens the drying time and lowers the moisture content of the produce by removing moisture evaporated from the produce in the drier (Fellows 1997 b, p.114, Hughes and Willenberg 1994, Intermediate Technology Development Group 2002 a, Sekiku 2003). Solar drying also affords protection against dust, animals and insects (FAO 1997 a, Intermediate Technology Development Group 2002 a, Troftgruben and Keith 1984).

Solar drying success is affected by many variables, especially the amount of sunlight, relative humidity, and air circulation or ventilation (Azam-Ali *et al* 2003, p.14, Roberts 1999, Whitfield 2000). The relationship between these three variables is important if drying is to be successful. Warm temperatures cause moisture to evaporate, low humidity allows moisture to move quickly from the food to the air, and air current speeds up drying by moving the surrounding moist air away from the food (University of Georgia undated). For optimum drying, food needs to be exposed to a minimum temperature of 28°C (higher temperatures being better) and relative humidity below 60 percent (Brett *et al* 1996 b, Georgia University undated, Jackson and Tingha 2003). The solar dryer must be designed to maximise air flow through holes in the base of the dryer and an exit at the top (Vanderhulst *et al* 1990, Minnaar undated). Ventilation ensures that moisture saturated air is replaced with less saturated air drying the products faster (Troftgruben and Keith 1984). Good ventilation leads to a lower average temperatures but reduces the relative humidity, improving drying (Vanderhulst *et al* 1990). Ventilation can be achieved by forced air (electric fans) or by non-forced air (Green and Schwarz 2001).

2.3.2 Control of fruit and vegetable spoilage through solar drying

The deterioration of fruits and vegetables is caused by enzyme activity or one or more of three major organisms, namely moulds, yeasts, and bacteria found in great numbers in air, soil, and water (Dauthy 1995, FAO 1993, Minnaar undated). Yeasts, moulds, and bacteria cause foods spoilage and can cause food poisoning with severe health implications (Minnaar undated). Enzymes, the other major causes of food spoilage, are complex chemical substances present in cell tissues, including the skins and flesh of fresh fruits and vegetables that can change the colour, flavour or texture of foods and cause food spoilage (Brennad 1994, Dauthy 1995, Fellows 1997 a, Minnaar undated). Food preservation methods attempt to prevent these four agents from spoiling food.

Improved adaptable solar drying technologies provide high air temperatures and lower relative humidity, improving drying rates and lowering the moisture content of dried products (Sekiku 2003). Consequently, the risk of spoilage during the drying process and in storage is reduced (Intermediate Technology Development Group 2002 a). All these factors contribute to an improved and more consistent product quality with increased market value (Sekiku 2003). The most important factors that affect the rate at which micro-organisms and enzymes cause foods to spoil will discussed in the following sub sections.

2.3.2.1 Moisture content of foods

Fresh foods such as fruits, vegetables, and meat have water contents (85-95%) sufficiently high to support both enzyme activity and growth of micro-organisms (Azam-Ali *et al* 2003, p. 13, Barbasa-Canovas *et al* 2003, FAO 1989). Micro-organisms and enzymes are only active if water is present in sufficient quantities for optimum growth of the organisms (Barbosa-Canovas *et al* 2003, Minnaar undated, Stapleton 2000). If water is not available, these organisms are not active. To prevent microbial growth (such as bacteria, yeast, and moulds), and detrimental chemical reactions by enzymes, several processing methods can be applied (Fellows and Hampton 1992, p. 4). The simplest method to prevent the natural decay of food is to reduce the amount of moisture (Arthey 1991, p.154, Brennad 1994, Smith *et al* 1997, p.5). Solar driers can produce products with low moisture contents and longer shelf-life (Droits 1985). Therefore, the shelf-life of foods can be increased by drying, while simultaneously increasing their convenience and value (Fellows 1997 b).

2.3.2.2 Temperature

Temperature is the most important environment factor that influences the deterioration of harvested commodities (Kader *et al* 1992, p. 80-81). The rate of water loss from fruits and vegetables depends upon the vapour pressure deficit between the commodity and the surrounding ambient air, which is influenced by temperature and relative humidity (Kader *et al* 1992, p. 18). First, micro-organisms and enzymes act best when the environmental temperatures are approximately 37°C, but micro-organisms can still grow rapidly at temperatures between 20°C and 50°C (Figure 2.1).

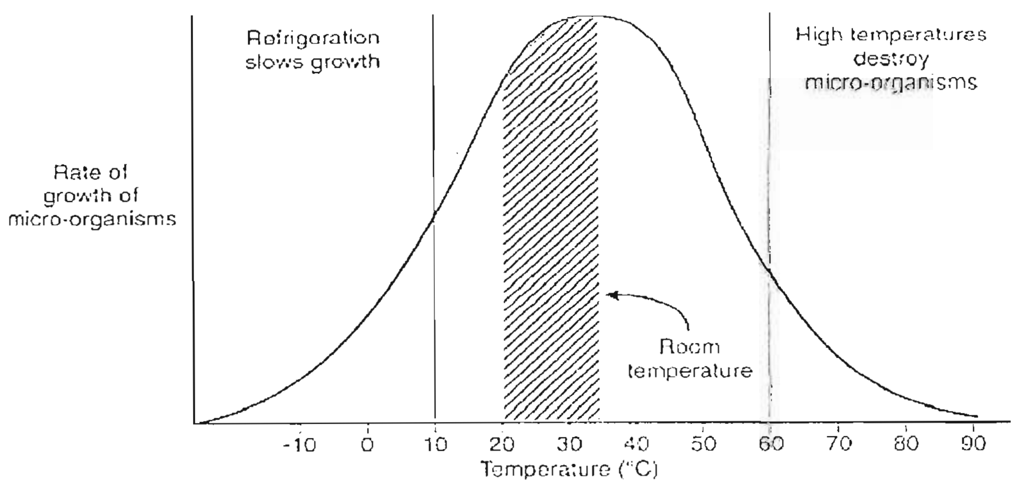


Figure 2.1: The effect of temperature on micro-organism growth (Fellows 1997 a, p.5)

When foods are heated above 60°C, many enzymes and micro-organisms are destroyed. Therefore, in storing food above 50°C or below 20°C temperatures, micro-organisms will not flourish and rapidly multiply (Fellows 1997 a). Second, the respiration and metabolic rates of fruits and vegetables depend on temperature conditions (Gast undated). When respiration rates are high, produce deteriorates faster. Lower temperatures slow respiration rates, ripening, and senescence processes that prolong the storage life of fruits and vegetables (Gast undated, FAO 1989).

2.3.2.3 Acidity of foods

Many of the micro-organisms that bring about food spoilage are very sensitive to acidity levels and cannot live in highly acidic environments (Intermediate Technology Development Group 2002 c, Minnaar undated). Increasing food acidity can control the activity of such spoiling agents. Most fruits and some vegetables (e.g. beans, corn, mushrooms, pumpkin, and potatoes) are naturally acidic (Anon 2000, Fellows 1997 a). Foods with pH's below 4.5 are regarded as strongly acidic (e.g. lemons, grapefruits, oranges, tomatoes, and pineapples) and cannot sustain the growth of moulds and yeasts (Anon 2000, Anon 1996, Holdsworth 1983).

2.3.3 Benefits of solar drying for nutrition

In 1999 the South African National Food Consumption Survey of children 1- 9 years old showed that more than 24% of the sample children were stunted (short for age), 9% were underweight (low weight for age ratio), 5% showed signs of wasting, and 6% were overweight (Blum 2000, Labadarios 2000). Half the sampled children had energy intakes less than two-thirds of the requirements for their ages and the nutrient density of the foods consumed was poor (lacked calcium, iron, zinc, and vitamins A, D, E, B6, and C). Malnutrition was most prevalent in the Eastern Cape, Northern Province and KwaZulu-Natal. The food items commonly consumed in the study were maize, sugar, tea, whole milk, brown bread, and few vegetable were consumed and very little fruit (Blum 2000, Labadarios 2000).

Fruits and vegetables are the most important plant foods that supply humans with many nutritive requirements (Fellows and Hampton 1992, p. 1). Fruits and vegetables contain essential minerals such as calcium, phosphorus, and iron, not present in many other foods in sufficient quantities for body needs (Dauthy 1995, FAO 1981). Fruits and vegetables also supply vitamins C, A, B1, B2, B6, B12, and vitamin D (Arthey 1975, p. 36-37). In addition fruits and vegetables supply carbohydrates, fibre, and energy (Herregods 1998). Fresh fruits and vegetables supply the best vitamins compared to dried one (FAO 1981, Fellows 1997 b, p. 8), but the seasonality of fruits and vegetables make them plentiful for a few months only (Minnaar undate). Increased availability and/or reduction of fruit and vegetable losses are essential to improve dietary intakes (Toma *et al* 1990). By drying fruits and vegetables, they can be preserved and made available out of season, providing vitamins year round (FAO 1997 b, GAIA-Movement undated, Goldman and Elliott 1984).

Drying fruits and vegetables using direct sun drying decreases the nutritional value of the dried products, especially vitamin A and C (FAO 1997 b, FAO 1989, Minnaar undated, Rodriguez-Amaya 2003). Solar dried food is nutritious and as tasty as the fresh products (Goldman and Elliott 1984). The use of solar driers can help maintain and improve health for households by providing nutrients that might not be available during off-seasons, when certain foods are either scarce or expensive (Goldman and Elliott 1984, FAO 1997 b, Mulokozi *et al* 2000).

The Tanzanian Food and Nutrition Centre (Mulokozi *et al* 2000) introduced an improved solar drier for drying fruits and vegetables among rural women living in the semi-arid region in central Tanzania to assess the impact of solar drying on availability, micronutrient intake and nutritional quality of dried foodstuffs and the impact on economic status of households (Mulokozi *et al* 2000). The study indicated that vegetables dried by enclosed solar drier retained more of their beta-carotene (20-30% more) than those dried using traditional open sun driers (Mulokozi *et al* 2000).

2.3.4 Benefits of solar drying for food security and sustainable rural livelihoods

In general, food security refers to that situation in which there is access for all people at all times to enough food for an active, healthy life (Welch *et al* 2000). Food self-sufficiency and food security can be improved through processing technologies (FAO 1992, Fellows 1997 b, p. 8). Introducing adoptable processing solar drying technologies for home preservation of fruits and vegetables could reduce wastage, ensure better utilisation of fresh produce, and contribute towards solving nutritional problems by reducing post-harvest crops losses, and increasing food availability (Droits 1985, FAO 1989, Mulokozi *et al* 2000). In many African countries such as Tanzania, Niger, and Kenya solar drying technology has improved food security and increased incomes of small-scale farmers through producing good quality for export markets, and providing excellent nutritive value foods all year round (Mulokozi *et al* 2000, Droits 1985).

Through applying solar drying to dry fruits and vegetables in Tanzania and Senegal, women have reduced the time available for managing their household, raising children, and/or seeking other income generation activities (UNIDO undated, Mulokozi *et al* 2000). Senegal village women have been able to attain food self-sufficiency through an environmentally sound energy use (solar driers), and sell surplus produce in local markets (Mulokozi *et al* 2000, UNIDO undated).

2.4 Review of international studies of solar drying of fruit and vegetables

A number of commercially successful solar drying initiatives have been implemented in east Africa. In Uganda, farmers were producing an abundance of fruits and vegetables, but they were rotting and going to waste due to limiting distances to markets, lack of good roads, and lack of appropriate processing methods (Agona *et al* 2002). Researchers from the United Kingdom and Uganda investigated alternative methods of processing and an appropriate solar drying system to dry surplus produce (Arfaoui undated b, Tropical Wholefoods undated). The solar driers are very simple, resistant to sun damage, and dry the fruits quickly, and hygienically (Arfaoui undated b).

The Ugandan company "Fruits of the Nile" has been involved in assisting and supporting selected individuals and women's groups to produce solar dried fruits and vegetables for export to the United Kingdom (Brett *et al* 1996 b). By introducing solar driers, the project participants have been helped to reduce post-harvest losses and increase their families' standards of living. In Niger, members of local women's groups were successfully trained to perform drying tasks for home consumption and to market the dried products to generate income (FAO 1993). This project has lead to improvements in food consumption and prevented micro-nutrient deficiencies.

In Tanzania there is an abundant supply of vegetables during the rainy season and scarcity in the dry season (Mulokozi *et al* 2000). Several traditional methods (commonly sun drying) are used to preserve produce but the products are often of poor quality as little control can be exercised over the drying process; contamination of the product by dirt, rodents, animals, infestation by insects or moulds occurs frequently; and exposure of the produce to rain and wind causes repeated wetting and redrying (Droits 1985). To provide year round sources of vitamin A, the Tanzanian government and other agencies focus on improving preservation techniques for vitamin A-rich foods and introduced improved two types of solar driers (solar drier made from wood and mud brick solar drier) (Mulokozi *et al* 2000). The produce produced in these driers was superior to that dried by traditional methods (trays and mats) (Droits 1985). This because of the long direct exposure to the sun which leads, to nutrient losses and other undesirable physiological and biochemical changes on the quality of dried products produced by direct sun drying (Mulokozi *et al* 2000).

The Food Research Institute and the Danish Institute of Agricultural Sciences (Frank and Kristensen 1999) has established that there is a need for drying foods (vegetable, fruits, spices, and tubers) in Ghana. To increase the value of agricultural produce, the Food Research Institute of the Council for Scientific and Industrial Research and the Ghana Atomic Energy Commission recommend the use of improved sun drying cabinet solar drier which consists of a rack with trays, polythene or polythene bags for better packaging of products, and appropriate pre-treating such as blanching the products before drying (Droits 1985).

A cause study in Uganda, in the Nebbi district, showed the potential of mango fruit production. A large quantity of mango fruits is not consumed for food, or sold for income generation, but instead was left to rot (Arfaoui undated b). To reduce these losses, the Danish Non-government organisation (Mellemfolkeligt Samvirke) and the Christian

Rural Services (CRS) introduced drying technologies to preserve the glut of mangoes by converting them into shelf-stable products (Arfaoui undated b). The introduced technology applied traditional way, by exposing to the sun in free air, and spreading the mango on a carpet or sheet. The food is not protected at all, and exposed to various risks such as; animals, dust, rain, and the food takes long time to dry (Arfaoui undated b). To solve this problem the CRS together with Hoima Nursery Schools' Association (HNSDA) introduced the locally made Nebbi solar dryers to their members and to small scale farmers in three districts for testing. When the dried products were of good quality, other marketing channels was investigated. However, the dried mango fruits did not meet the increased demand of the United Kingdom based importer since the quality with the final products did not qualify the United Kingdom standards (Arfaoui undated b).

2.4.1 Comparison of drier designs

There are three different solar driers suitable for drying agricultural produce (Intermediate Technology Development Group 2002 b). The choice of solar drier depends on: availability of locally available construction materials, purchase price, maintenance costs, drying capacity, adaptability of the drier to different products, drying times, and the quality of the end products (Vanderhulst *et al* 1990). This comparison of the solar drying technologies will be limited to: low cost solar driers such as (Nebbi, Kawanda, Tent, and Brace solar drier) and an electrical solar drier such as (AC and DC powered electrical solar drier). Low cost solar dries are more suitable for small farmers, who have limited disposable incomes. The low cost solar driers are best produced from locally available materials by local carpenters. AC and DC powered driers are quite different from low cost driers as they require heat sources (fuel or electricity). Also, the AC and DC powered electrical solar driers are bigger and supplied with fans to circulate hot air inside the dryer (Arfaoui undated a). The AC and DC driers are usually made for drying tobacco, timber or coffee.

Low cost solar driers can be constructed from locally available materials. There are different types of low cost solar dryer such as cabinet drier Nebbi type, which was presented in the case study of Nebbi district in Uganda, tent solar driers, Brace solar driers, and the Kawanda solar drier (Arfaoui undated b, Brett *et al* 1996 a, Intermediate Technology Development Group 2002 b).

2.4.1.1 Nebbi Solar Drier

The Nebbi dryer is medium sized (approximate 2.5 to 3 metres long and 1.25 metres wide) and easily moved and rotated. The drier has two upper and two lower trays. The drier frame is covered with polyethylene plastic of similar quality to that used to cover greenhouses. Nylon netting is used for the trays (Arfaoui undated b) (Figure 2.2).

Figure 2.2: Nebbi Solar Drier (Arfaoui undated b, Annex.1A)

2.4.1.2 Kawanda solar Cabinet drier

The Kawanda solar dryer cabinet was designed by the Kawanda Agricultural Research Institute in Uganda (Figure 2.3). The structure is very simple can be built locally. The dryer consists of a main frame, with eight supporting legs (Brett *et al* 1996 a). The drying chamber measures 4.4 meters long, 1.5 meters deep, and 0.8 meters high, with twelve trays to provide a total drying area of 10m^2. The drier is capable of drying between 20-35kg of fresh fruits and vegetables. The front of the chamber has three hinged doors to provide access for loading and unloading the trays (Brett *et al* 1996 a).

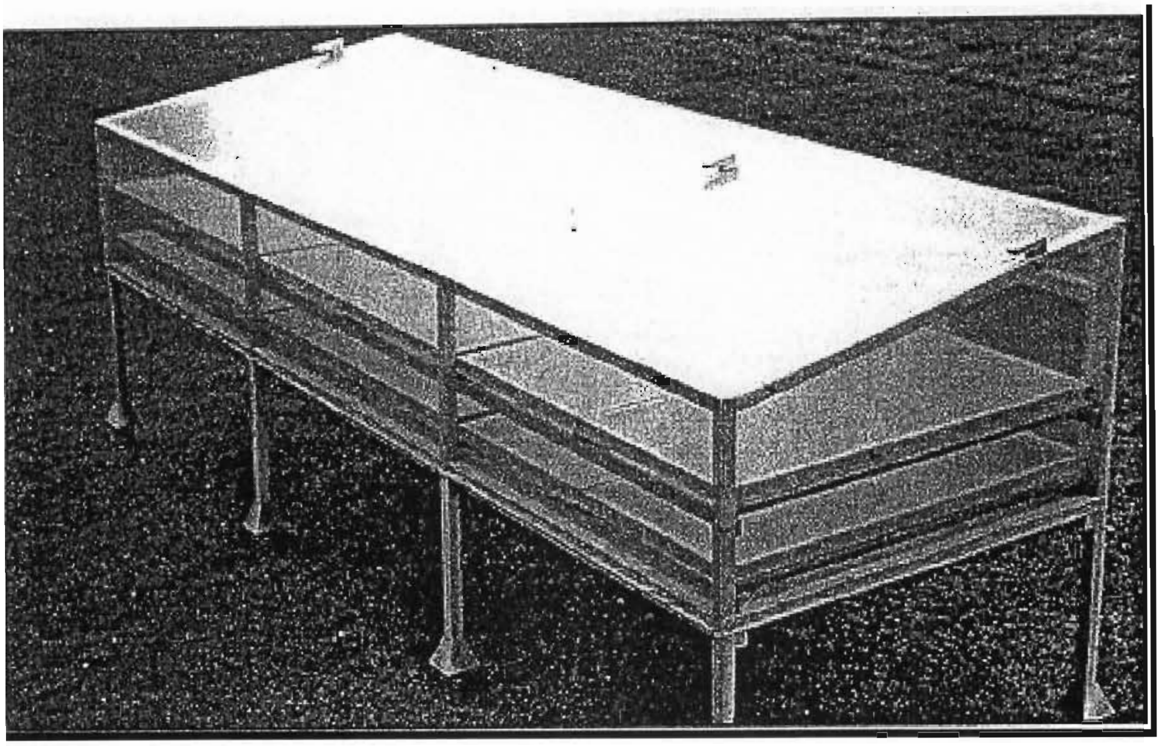


Figure 2.3: Kawanda Solar Drier (Brett A *et al* 1996, p.12).

The Kwanda drier has two tiers of trays. Each tier can accommodate six trays. The trays consist of hardwood frames across which plastic mosquito mesh is stapled. The drying chamber base consists of a papyrus (mat) covered with mosquito mesh to allow air to enter the chamber from underneath, while keeping insects out (Brett *et al* 1996 a).

2.4.1.3 Solar Tent Drier

The tent drier is a simple, natural convection drier consisting of a rigid tent framework, covered by clear plastic on the ends and the side facing the sun, and black plastic on the base and the side in shade to act as a solar collector (Intermediate Technology Development Group 2002 a). The drying rack is made from wood or bamboo and placed along the full length of the tent. The bottom edge of the clear plastic is rolled around a pole, which can be raised or lowered to control the flow of air into the drier. The moist air leaves from the drier through holes in the top corner of the tent (Figure 2.4).

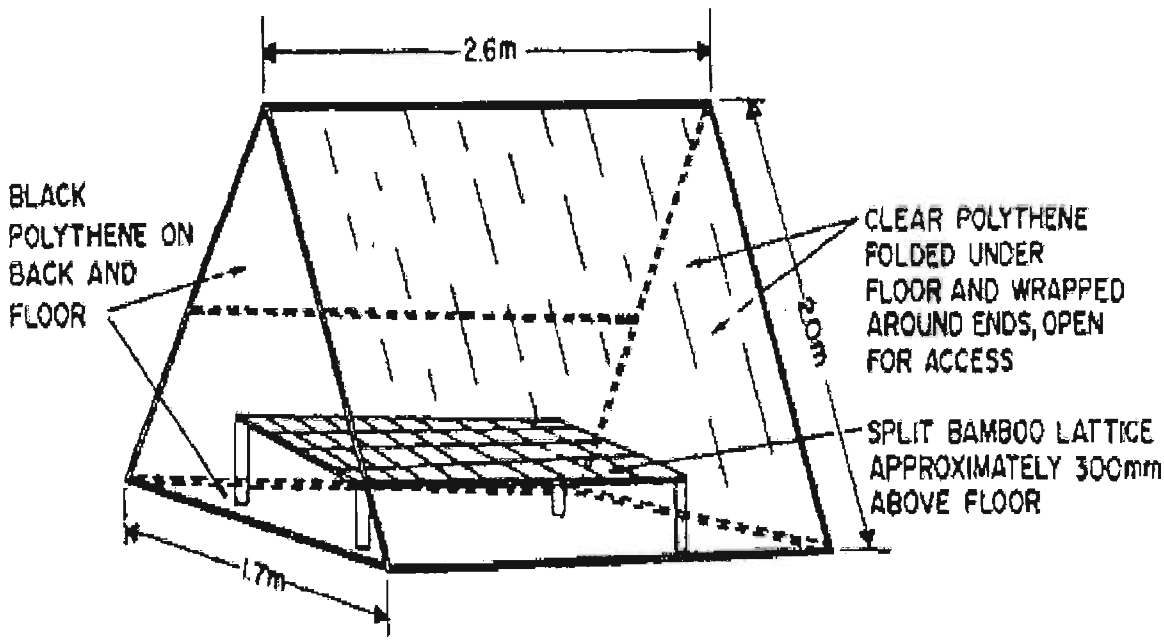


Figure 2.4: Tent Solar Drier (Intermediate Technology Development Group 2002 a, p. 6).

2.4.1.4 Brace Solar Drier

This sample natural convection drier has been widely used by small scale farmers (Intermediate Technology Development Group 2002 a). The drier consists of a wooden box, covered with clear glass or plastic. There are holes in the base and upper parts of the box to allow fresh air to enter and moist air to leave. The air holes are covered with mosquito netting to keep insects out. The inside of the drier is painted black to act as a solar collector (Intermediate Technology Development Group 2002 a). The length of the cabinet must be three times the width to prevent shading by the sidewalls. Food is placed on trays within the cabinet and should be made from basketwork or plastic mesh (Figure 2.5).

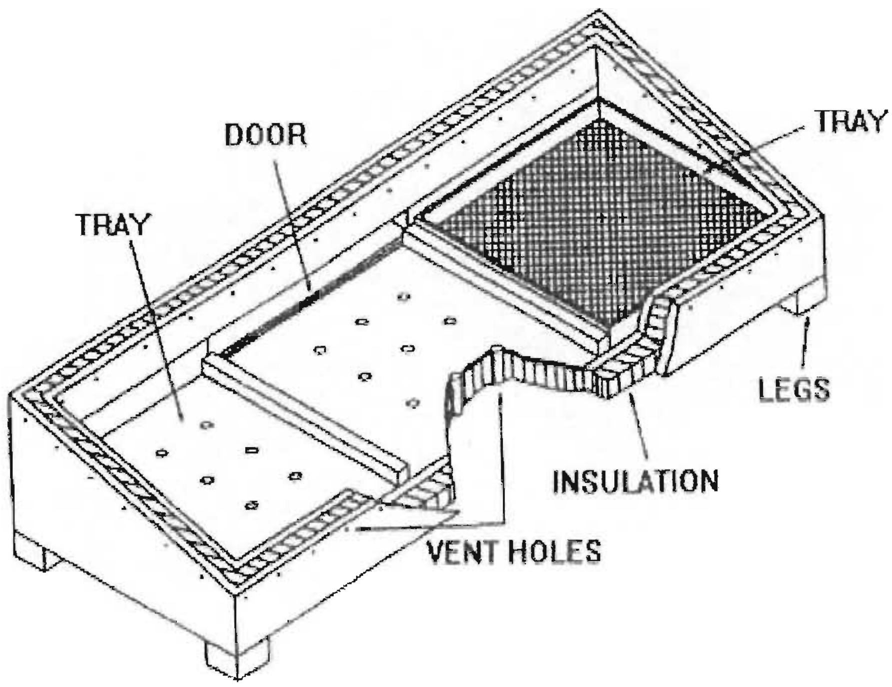


Figure 2.5: Brace Solar Drier (Intermediate Technology Development Group 2002 a, p. 7).

2.5 Overview of agricultural production by farmers in rural areas of KwaZulu-Natal

South Africa is one of the three main horticulture-producing countries in Southern Africa, along with Zimbabwe and Kenya (Trade Partners 2003). The climate in South Africa is hot in summer, with many cloudless days, but few areas are frost-free in winter. Together with soil factors, temperature plays an important part in the natural demarcation of areas suitable for the cultivation of different horticultural crops (ISHS undated). South Africa is self-sufficient with regard to vegetable production and exports both fresh and processed vegetables (ISHS undated).

Subtropical fruit varieties require warmer conditions and are sensitive to large fluctuations in temperatures and to frost hence KwaZulu-Natal is one of the main production areas of subtropical fruit in South Africa (National Department of Agriculture 2000 b). Different varieties of fruits such as granadillas, guavas, avocados, bananas, mangoes, litchis, papayas, pineapples, oranges, grapefruit, lemons, and naartjes are produced in KwaZulu-Natal (Table 2.5) (National Department of Agriculture 2000 a-d). Different varieties of vegetable crops grown in KwaZulu-Natal are: cabbage, tomatoes, pumpkins, beans, chillies, potatoes, sweet potatoes, carrots, and onions (Table 2.5) (Trade Partners 2003).

The seasonality of production results in large quantities of fruits and vegetables being brought to respective markets at the peak of the growing season, followed by scarcity. Processing fruits and vegetables during plentiful periods into shelf stable products farmers could avoid wastage of the food and loss of incomes (Minnaar undated).

Table 2.5: Seasonality chart for fruits and vegetables in KwaZulu-Natal (Bower J.P 2003, Modi A.T 2003).

Crop	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Banana	X	X	X	X	X	X	X	X	X	X	X	X
Pineapple				X	X	X	X	X				
Avocado					X	X	X	X				
Mango	X	X	X	X								X
Papaya	X	X									X	X
Oranges				X	X	X	X	X	X			
Grapefruit				X	X	X	X					
Guava	X				X	X	X					X
Cabbage	X	X	X	X	X	X	X	X	X	X	X	X
Carrot	X	X	X	X	X	X	X	X	X	X	X	X
Tomato	X	X							X	X	X	X
Pumpkins	X	X							X	X	X	X
Beans	X	X							X	X	X	X
Chilli					X	X						
Sweet potato	X	X										X
Potatoes	X	X								X	X	X
Onion	X	X	X									

X =Represents the peak of produce

2.6 Potential benefits of solar drying for rural households and economic development in rural KwaZulu-Natal

Malnutrition is a direct result of inadequate dietary intake and disease. Malnutrition leads to: household food insecurity, inadequate maternal and childcare, and poor health (Blum 2000). Without food security, good nutrition cannot be achieved; and without good nutrition, individuals have more difficulty being economically productive (Welch *et al* 2000). Drying of surplus fruits and vegetables using solar driers could help maintain and improve household health by providing nutrients that might not be available during off-season, when certain foods are either scarce or expensive, so individuals will be more economically productive (Goldman and Elliott 1984). Moreover, the use of solar driers could improve food security and provide small-scale farmers with sources of income generation while reducing post harvest losses (Droits 1985).

CHAPTER THREE

COMPARISON OF SUPERMARKET SURVEY FINDINGS WITH LOCAL PRODUCTION POTENTIAL OF SOLAR DRIED FRUIT AND VEGETABLES

3.1 Introduction

South African dried fruits provide local markets, while surpluses are exported to Australia, Africa, Canada, Europe, New Zealand, the Middle East, Spain, and the United States (Trade Partners 2003, National Department of Agriculture 2000 a). Dried fruits are mainly sourced from the western, south-west and northern Cape, Little Karoo, Olifants River area and lower and upper Orange River areas (National Department of Agriculture 2000 a). The most important dried fruit products produced in South Africa are: raisins, sultanas, prunes, peaches, and apricots (National Department of Agriculture 2000 a). South Africa also imports dried fruits and vegetables (primarily for use as product ingredients) to satisfy local market demands.

To explore the potential for small scale production of dried fruits and vegetables in KwaZulu-Natal, a brief survey of dried fruit and vegetable products available in local supermarkets was conducted to establish what product markets exist. The objectives of the market survey overview were to:

- understand the current availability of dried fruits and vegetables in KwaZulu-Natal,
- identify the treatments used in preparation of the products, drying methods used, character and shape and form of the dried products, and the packaging used, and
- identify possible market opportunities for small-scale producers in KwaZulu-Natal.

3.2 Survey methodology

Four supermarkets in Pietermaritzburg were purposively selected, namely: Hayfields Pick 'n Pay, Cascades Shoprite, Woolworth's, and Park Lane Spar. These supermarkets represent the key chain stores supported by a range of socio-economic consumer groups and stock products available in most other supermarkets. Surveying additional branches of these four main supermarket chains would most likely not have identified additional products. The aim of the survey was to count the number of different dried fruits and vegetable products available, rather than to count the frequency of occurrence of each item. Therefore, as stores were visited, products were sequentially added to the list rather than counting whether or how many the products appeared in each store.

The selected stores were visited by the researcher in April 2003 and the stores' shelves were inspected. A list of all dried fruits and vegetables products was prepared and the following information was recorded for each sample product:

- drying method used,
- pre-treatment,
- type of packaging,
- price of the dried products,
- character (shape and size) of the dried product, and
- ingredients

The data collected were entered into a spreadsheet and analysed using SPSS (version 11.00, 2002).

3.3 Supermarket survey findings

Fifty items were identified from the sampled supermarkets including: dried fruits, dried vegetables, and products made from dried fruits and vegetables. Figure 3.1 illustrates the range of products founded in the sample of Pietermaritzburg supermarkets. The result of the survey indicated that of the 50 dried products found, (26 percent of products) were dried fruits (whole, half, slices, and diced fruit), followed by (28 percent) were dried fruits with sugar, (28 percent) were vegetable stock powder, stuffing mixes and soups, and (18 percent) were sauces, pastes, and chutneys (Figure 3.1).

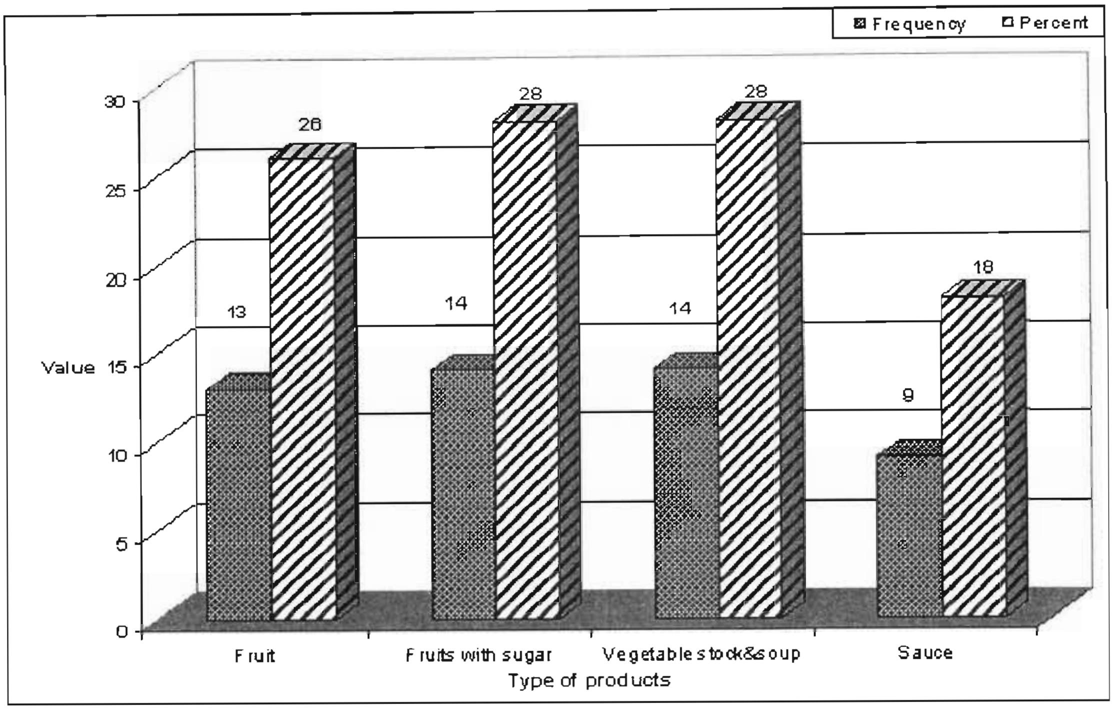


Figure 3.1: Type of dried products available in surveyed Pietermaritzburg supermarkets, April 2003 (n = 50)

Many dried fruits and vegetable were found as ingredients in other products (Tables 3.1 and 3.2). Of the 50 dried products identified, 10 (20 percent of the total number of items) products were apricots or contained apricots as an ingredient (Appendix A). Apricot was found whole, halved, and sliced; in mixed fruits; and in processed products including fruit dainties, fruit rolls, and chutneys (Table 3.1). Dried peaches, apples, and prunes (12 per cent each of all products), pears (10 percent), and dried mangos (8 percent) were also used as ingredients in many processed products such as tropical dried fruit mix and fruit dainties (Table 3.1). Dried mango, banana, and apple were found as ingredients in chutneys (Table 3.1 and Appendix A). Nuts were not included in the survey but mixed dried fruit products were found with mixtures of nuts and dried fruit (2 percent of the products found) and these were included in the survey.

Apart from instant mashed potato and dried tomato (although essentially a fruit), no other dried vegetables were found. Dried vegetables were commonly found as ingredients in sauces, pastes, soups, and chutneys. Most dried vegetables were used in powder form as ingredients in a range of products including instant soups, stock powders, and poultry stuffing mixes (Table 3.2).

Table 3.1: Dried fruits and vegetable products and ingredients found in selected supermarkets, Pietermaritzburg, April 2003 (n = 50)

Dried fruits as ingredients	Products
Apricot	Halves, fruit dainties, mixed dried fruits, apricot roll, and chutney.
Peach	Fruit dainties, peach halves, and peach roll.
Apple	Fruit dainties, mixed dried fruits, chutney, and apple rings.
Pear	Fruit dainties, mixed dried fruit, and pear halves.
Prune	Pitted prunes, whole prunes, prune roll, mixed dried fruit, and fruit bars.
Figs	Fruit dainties, and fig roll.
Mango	Tropical dried fruits mix, mango roll, mango slices, and fruit dainties.
Raisins	Seeds in and seedless raisins.
Banana	Banana chips and tropical dried fruit mix.
Sultanas	Cake mix and sultanas.
Nuts	Mixed dried fruits.

Tomato was the most commonly dried vegetable found in the selected stores (Appendix A). Dried tomato was an ingredient in 17 products (Appendix A). Dried onion (18 percent), chillies (14 percent), carrot (12 percent), spinach (4 percent), and potato (4 percent) were also used as ingredients in products (Table 3.2 and Appendix A). Potato was also found as instant mashed potato.

Table 3.2: Type of products including dried vegetables as ingredient, Pietermaritzburg, April 2003, (n = 50)

Dried vegetables as ingredients	Products
Tomato	Instant soups, dried sliced tomato, quartered tomato, sun dried, pesto and pasta sauce.
Onion	Instant stocks, and poultry stuffing powder.
Chill	Instant soups, and chutney.
Carrot	Instant stocks and soups
Spinach	Poultry stock.
Potato	Stock powders and instant soups, and "Smash" or instant mashed potato.

Of the 50 dried products found in the selected supermarkets, 41 products (82 percent of the total number of products found) were sun dried and 9 products (18 percent) were dried using a dehydrator (Figure 3.2).

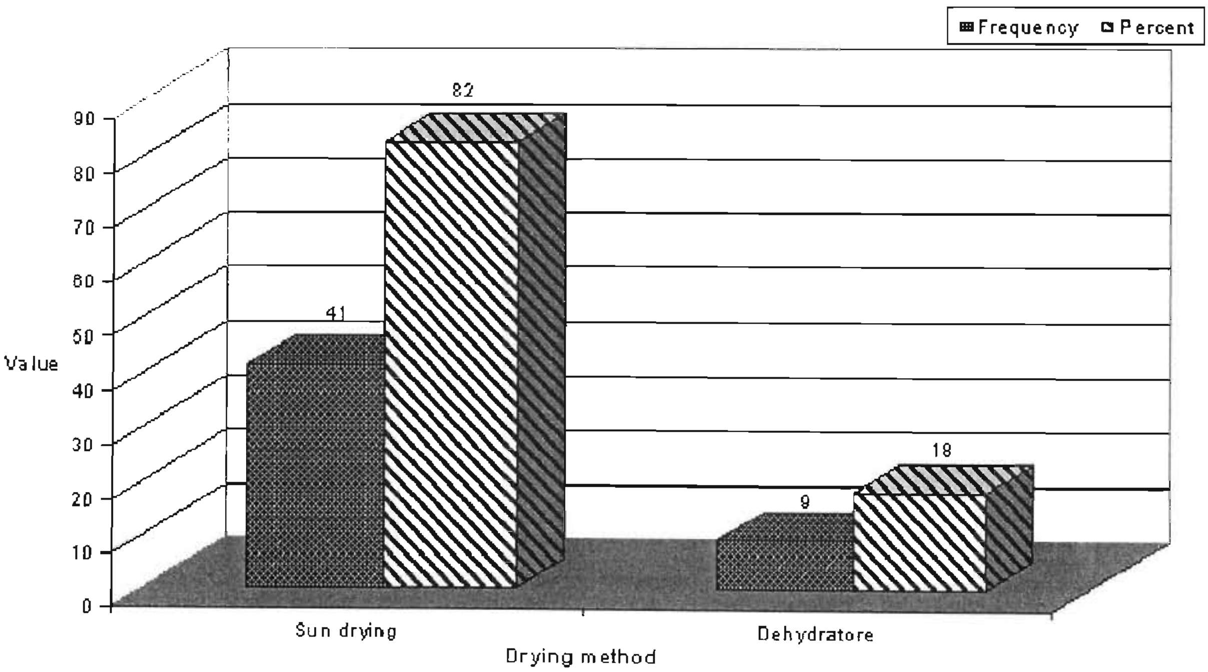


Figure 3.2: Drying methods used for drying the products found in selected Pietermaritzburg supermarkets, April 2003, (n = 50)

Packaging has a dramatic effect on the quality of dried products. Appropriate packaging reduces losses, extends the shelf life of the products, ensures that products reach customers in the best possible condition, makes food more attractive to increase sales, and conveys information to customers abut the foods (NSTA 2001). Dried foods must be protected from moisture absorption and insect infestation. Dried foods will reabsorb moisture and spoil if they are not packaged well (Brennand 1994). There are many types of packaging materials suitable for dried products. Glass bottles with tight-fitting lids, tin cans, plastic bags, and cartons are used to package and store dried foods (Brennand 1994, Dauthy 1995). Most dried fruit products found in surveyed stores were packaged in polyethylene plastic (68 percent of all products) followed by cartons (cardboard) boxes (12 per cent), glass (10 percent), and cans (10 percent) (Figure 3.3).

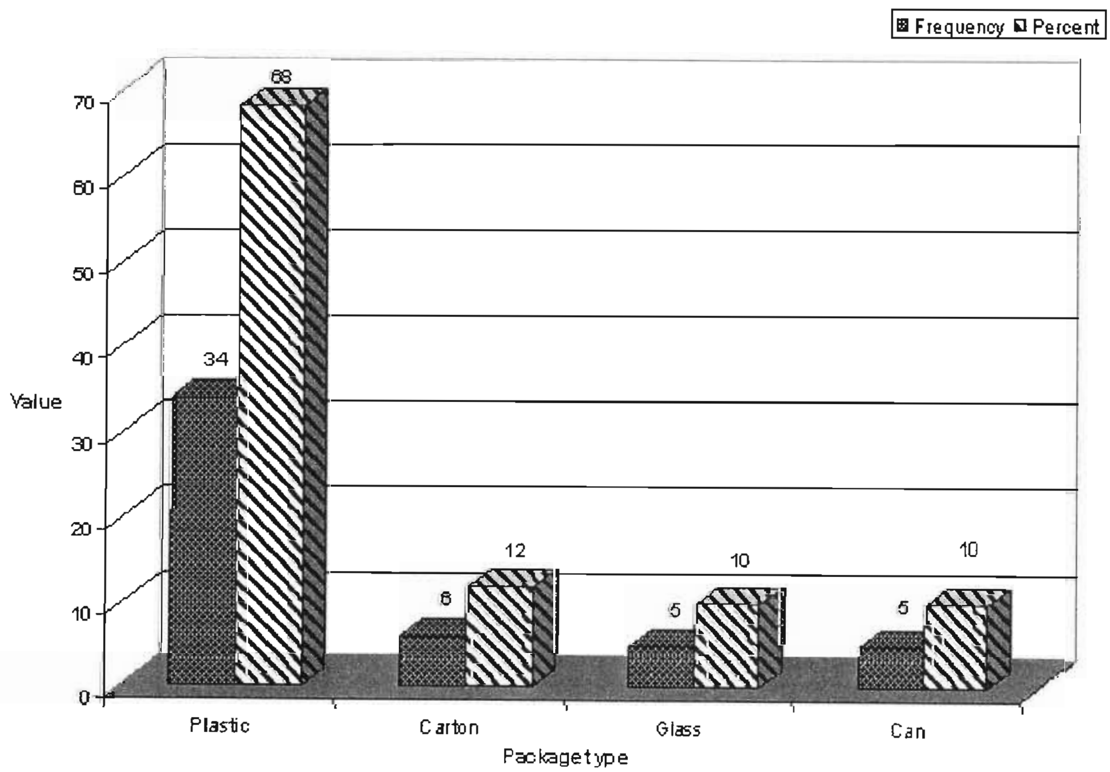


Figure 3.3: Type of packaging used for the dried products in selected Pietermaritzburg supermarkets, April 2003, (n = 50)

Dried fruits and vegetables were whole, halved, sliced, powdered, rounds or strips. Ten products (20 percent of all products) were found in powder form (Figure 3.4). Nine products (18 percent of all products) were found in paste form (Figure 3.4). Followed by dried products in whole, slices, and roll (14 percent) each, mixed characters (8 percent), pulp and half were (4 percent) each, and dried products in (2 percent) were found as rings (Figure 3.4).

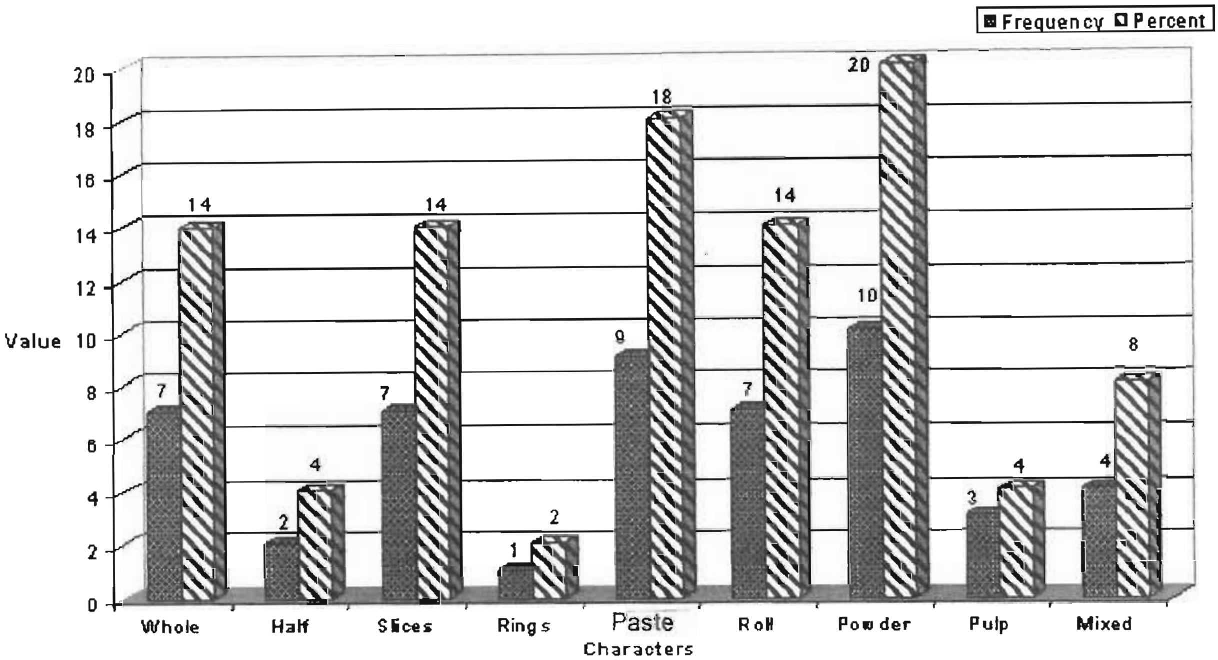


Figure 3.4: The character of dried products investigated in Pietermaritzburg supermarkets, April 2003 (n = 50)

Pre-treatments generally improve product quality, particularly for dried fruits and vegetables. Five major reasons for treating foods before drying are to: preserve colour and flavour, minimise nutrient loss, stop decomposition (enzyme action), extend storage life, and ensure more even drying (Owner 1998). Twenty-nine dried products (58 percent of all the products) found in the selected supermarkets used sulphur-dioxide as a pre-treatment (Figure 3.5). Fifteen products (30 percent) were dried without pre-treating, while five products (10 percent) were pre-treated with ascorbic acid, and one product (2 percent) was per-treated with citric acid.

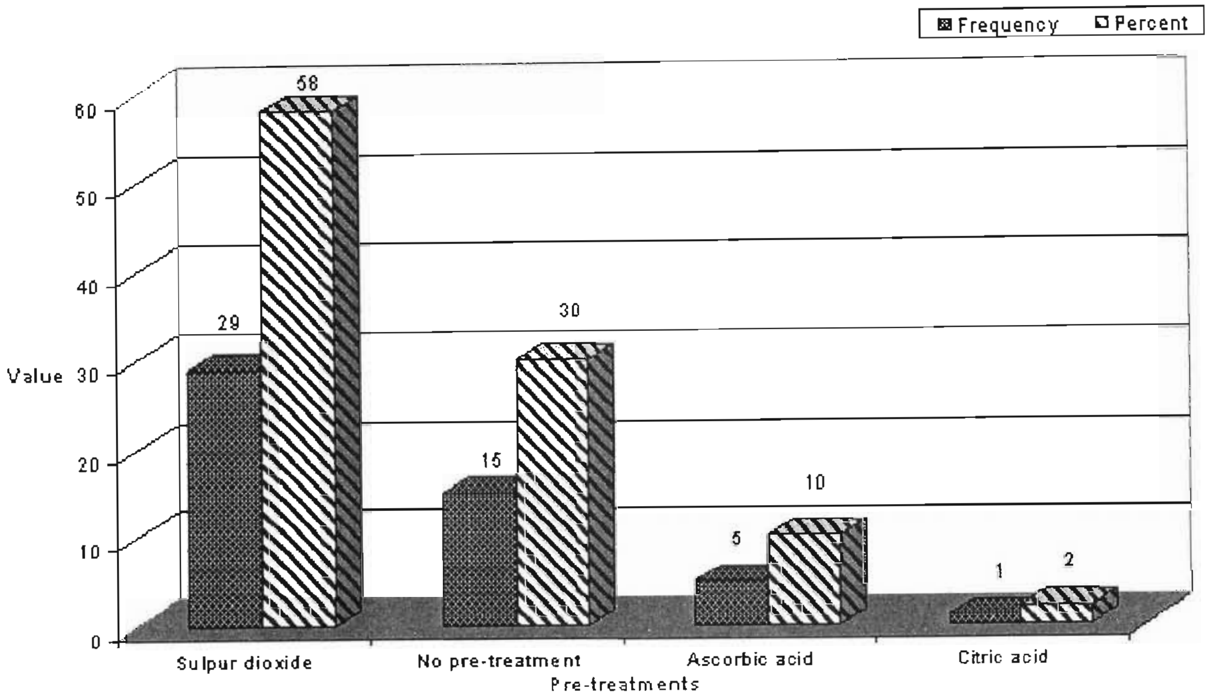


Figure 3.5: Pre-treatment used for the products in selected Pietermaritzburg supermarkets, April 2003 (n = 50)

Dried fruits and vegetables were packed in various size packages ranging from 50 grams to one kilogram. The price of products ranged form R12 to R350 per kilogram (Figure 3.6). The dried vegetable prices ranged from R 24 to R336 per kilogram. The highest price per a kilogram for dried fruits was for dried peaches (R93.00 per kg), while dried raisins were the cheapest fruit, sold at R12.00 per kilogram.

3.4 Fruits and vegetable production in KwaZulu-Natal

Subtropical fruit grown in KwaZulu-Natal includes: avocados, bananas, granadillas, guavas, litchis, mangoes, papayas, and pineapples (Bower 2003, National Department of Agriculture 2000 b). Citrus (grapefruit, lemons, and oranges) and deciduous fruits (eg. peach, apricot, and apple) are also produced in this province (National Department of Agriculture 2000 c). A variety of vegetables are grown in KwaZulu-Natal including: beans, cabbage, carrots, chillies, onions, potatoes, pumpkins, sweet potatoes, and tomatoes (Bower 2003, Trade Partners 2002). Small scale farmers in KwaZulu-Natal carry out little on or off-farm value adding (drying and processing) to farm produce, even for home consumption (CTA 2000). However, small scale farmers in KwaZulu-Natal could produce dried products for sale if there was a sure market for dried produce.

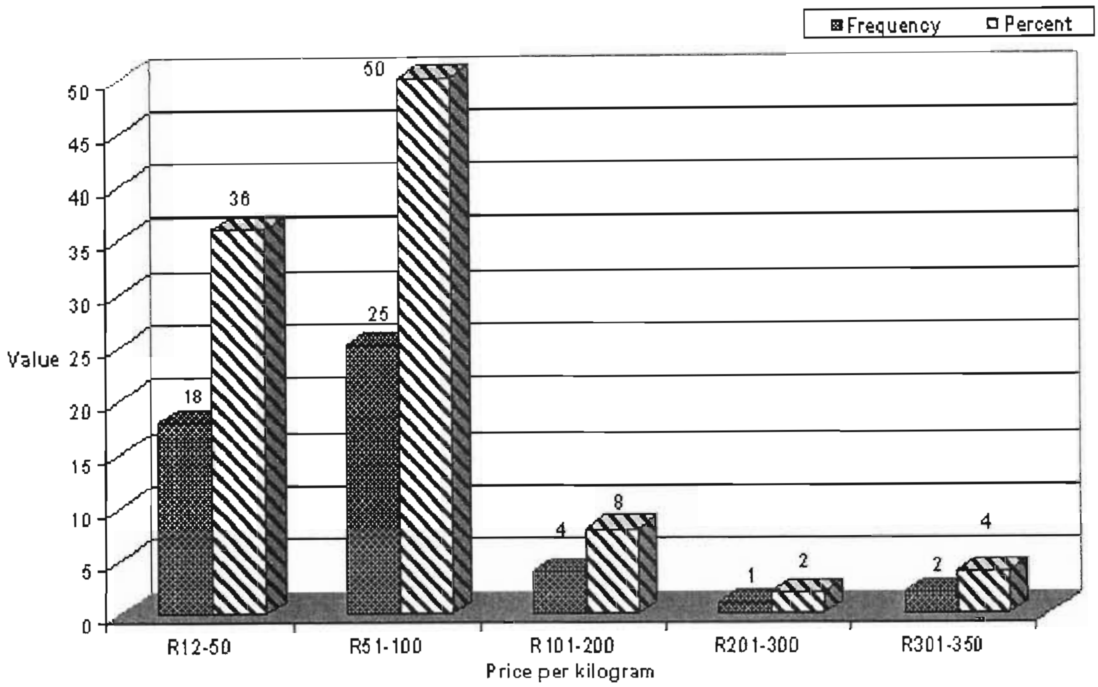


Figure 3.6: Price of the dried products in selected Pietermaritzburg supermarkets, April 2003 (n = 50)

3.5 Identification of potential fruit and vegetable types and products appropriate for solar drying by small scale farmers in KwaZulu-Natal

Many fruits and vegetables produced by small scale farmer in KwaZulu-Natal are suitable for drying. Table 3.3 indicates which fruits and vegetables available in the province are suitable for drying. Therefore, small scale farmers in KwaZulu-Natal could produce dried banana, mango, apple, pineapple, tomato, cabbage, pumpkin, bean, chilli, carrot, potato, and onion in various parts of the province.

Table 3.3: Suitability and non-suitability for solar drying of fruits and vegetables typically grown in KwaZulu-Natal (Reynolds 1993 a, p.2).

Fruits	**Suitability and non-suitability for solar drying**
Banana	Good
Avocados	Not recommended
Apples	Excellent
Papayas	Good
Guavas	Not recommended
Mangoes	Good
Pineapples	Excellent
Vegetables	
Cabbage	Fair
Tomatoes	Fair to good
Beans	Fair to good
Chillies	Excellent
Potatoes	Good
Sweet potatoes	Fair
Carrots	Good
Onions	Good to excellent
Pumpkins	Fair to good

3.6 The suitability of weather conditions (temperature, humidity, and rainfall) in KwaZulu-Natal for solar drying.

In order to help determine whether solar drying is feasible in KwaZulu-Natal it was necessary to examine the climatic conditions (temperature, humidity, and rain) of the study area. Secondary raw data on climatic conditions of the study area (1959-1994) were obtained from the University of Natal's Department of Agrometrology. Six years of available data (1983, 1985, 1987, 1988, 1989, 1994) were used. Data for the missing years were incomplete. Monthly and annual averages of temperature, humidity, and total rainfall were calculated to identify the most appropriate drying periods during the year for the study area (Figure 3.7).

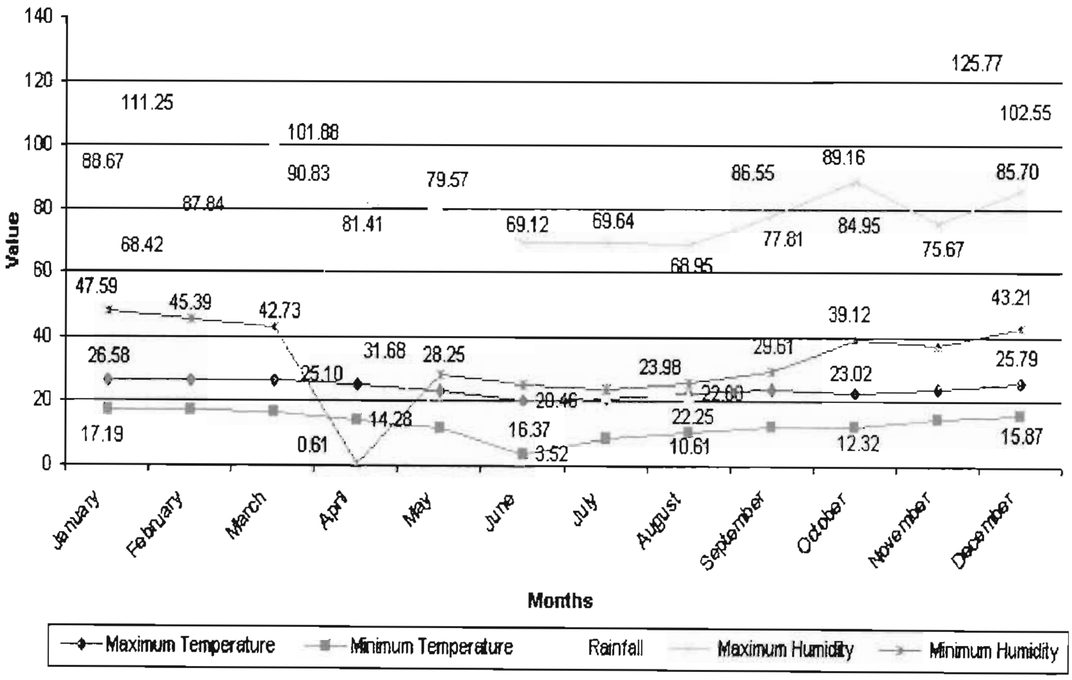


Figure 3.7: Monthly average of temperature, humidity, and rainfall of 1983, 85, 87, 88, 89, 1994 (Ukalinga Research Farm).

Figure 3.7 shows what the weather of the study area for each month during the year. The wetter months were typically: January, February, March, April, October, November and December. Moreover, the temperature during daylight for these months was higher than other months 23-26°C, and the humidity during daylight ranged between 37-47%. There was typically intermittent sunlight (20-23°C) and humidity (25-28%) during May, June, July, and August. Fruit and vegetable gluts typically coincide with periods of sufficient sunlight, namely January to April and September to December (Table 2.5 and Figure 3.7), as these are the most suitable months for drying. Even though these months are also wet seasons, solar drying is suitable because it protects the products from rain and gaining of moisture at the night.

CHAPTER FOUR

DRIER DESIGN, TRIAL AND METHODOLOGY FOR PRODUCT SENSORY EVALUATION

A simple solar drier was designed and tested by drying three fruits and three vegetables that were tested for acceptability and preferences by community garden members from the rural community of Maphaphetheni. This chapter describes the design of the solar drier, pre-treatment of the produce, methodology for the sensory evaluation, and methodology used to evaluate the moisture content of the dried products.

4.1 Solar drier design

The Solar drier used in this study is similar to the Ugandan solar cabinet drier (described in section 2.4.1). The experimental drier was smaller, was fitted with a solar-powered fan to prevent moisture condensation inside the drier, and was covered with a 3 mm polycarbonate top and 3 mm transparent acrylic for sides (Figure 4.1). The drier was constructed of wood and measured 100 centimetres long, 105 centimetres wide, 45 centimetres high at the back, and 70 centimetres high at the front. The main body of the drier was 65 centimetres above the ground. The drier held three trays with a total drying area of 3 m^2 and was capable of carrying between 9 to 12 kg of fresh produce. The trays were covered with mosquito mesh to allow air movement.

Vent holes (150 mm in diameter) were made at the bottom front of the drier and top of the back of the drier to create convection and provide an outlet for moisture-laiden air. The vents were covered with fine plastic mosquito mesh to prevent the entry of insects and dust. The bottom of the drier was lined with black cardboard to absorb more heat from the sun. The fan was installed in the top back corner of the drier. A75 mm diameter computer fan was operated by solar power at 12 V and 0.37W as Maphaphetheni households were part of an experimental solar energy project.

Figure 4.1: The solar drier used for the study (manufactured by the Mechanical Instrument Workshop, University of Natal), April 2003

4.2 Selection of fruits and vegetables for solar drying experimentation

The fruits and vegetables selected for the study were chosen according to types of fruits and vegetables available during the experimental period (April-September 2003) and could typically be produced by small scale farmers in KwaZulu-Natal. This period included autumn, winter and early spring, when humidity in the region is low, but daytime temperatures are still sufficient for solar drying. However, many subtropical and deciduous fruits are not available during this period. Regrettably the experiments could not be repeated during the summer months to compare the efficiency of the drier with periods when produce is more abundant, but temperatures and humidity are much higher.

Three fruits (banana, pineapple, and apple) and three vegetables (tomatoes, carrots, and pumpkins) were dried. Fresh produce was selected on the basis of freshness, and optimal stages of maturity (Kendall and Allen 2002, Kendall and Allen 1998, Troftgruben and Keith 1984). The selected fruits and vegetables were bought from local supermarkets (Hayfields Pick'n Pay, Scottsville Shoprite Checkers, and Woolworths). Each fruit was pre-treated with three different methods and then dried using the modified solar drier (Appendix B). The pre-treatments were chosen according to the simplicity and safety to the users. Soaking the prepared fruits in sugar solution or lemon juice did not require special equipment, extra time or work, but sulphuring desire further process. Therefore, the former is suitable to be applied by small scale farmers. Half the vegetable samples were left untreated and others were pre-treated with steam blanching before drying (Appendix C). In general, vegetables have lower sugar content and are less acidic than fruit (Fellows and Hampton 1992, p. 4, University of Idaho 1995). The high acidity and sugar content of fruit inhibits certain enzymes that cause loss of flavour and colour and decrease storage life of the products (University of Idaho 1995). Many vegetables do not have this built-in protection. For this reason, most vegetables may require blanching as it destroys the natural enzymes found in vegetables, which cause loss of flavour and colour (Reynolds 1998 b). Blanching, especially steam blanching allows vegetables to retain more water-soluble nutrients and will have better colour and flavour than control (not blanched) products (Anon 1998, Wolf *et al* 1990).

4.3 Drying experiments

The selected fruits, namely apple, pineapple, and banana, were washed carefully under clean, cold running water to remove dirt, bacteria, insects, soil, and chemical residues. Thereafter, the fresh produce was sorted for processing by separating the damaged produce from those, which were free from defects and disease. Fruit stems and fibrous or woody portions of fruits and vegetables were removed. The vegetables and fruits were peeled and cut into uniform pieces and samples were pre-treated as described in Appendix B and C.

Fruit was pre-treated using three methods, namely soaking the prepared fruit in a 35% sugar syrup and lemon juice (preserved with sulphur dioxide), soaking the prepared fruit in a 25% lemon juice [1](preserved with sulphur dioxide) solution, and soaking the

[1] The lemon juice used was purchased commercially and it is not known what concentration of preservative was present in each product.

prepared fruit in a 25% lemon juice (preserved with sodium metabisulphite) solution (Table 4.1). Half the vegetable samples (carrot, tomato, and pumpkin) were pre-treated with steam blanching, and the second half were left unblanched to evaluate the effect of the pre-treatment and their appropriateness for small scale production by small scale farmers in KwaZulu-Natal (Appendix B and C).

Table 4.1: Pre-treatments for fruit and vegetables, April 2003

Fruits		Vegetables	
Experiment	**Treatments used**	**Experiment**	**Treatment used**
1. Apple		**1. Tomato**	
Sample 1	Sugar syrup (35% solution) and lemon juice (preserved with sulphur dioxide).	Sample 1	Steam blanched
Sample 2	25% lemon juice (preserved with sulphur dioxide).	Sample 2	Not blanched
Sample 3	25% lemon juice (preserved with metabisulphite).	**2. Carrot**	
2. Banana		Sample 1	Steam blanched
Sample 1	Sugar syrup (35% solution) and lemon juice (preserved with sulphur dioxide).	Sample 2	Not blanched
Sample 2	25% lemon juice (preserved with sulphur dioxide).	**3. Pumpkin**	
Sample 3	25% lemon juice (preserved with metabisulphite).	Sample 1	Steam blanched
3. Pineapple		Sample 2	Not blanching
Sample 1	25% lemon juice (preserved with sulphur dioxide).		
Sample 2	25% lemon juice (preserved with metabisulphite).		

Twelve kilograms of fruit or vegetables were dried in sequential batches over eight of weeks. The pre-treated fruits and vegetables were arranged in single layers on the solar drier trays to dry. A sample was taken daily and observed for pliability and leathery texture (Kendall and Allen 1998). Kendall and Allen (1998) explain that fruits are deemed sufficiently dry when they are pliable and leathery and no moist area is visible in the centres when cut. The experimental produce was checked each morning. The apple and pineapple were considered dry when they were still soft, pliable, and leathery. Bananas were dried until tough and leathery. Drying took approximately four to five days. Vegetables were considered sufficiently dry when they were brittle or leathery (Andress and Harrison 1999, Kendall and Allen 2002). When dry, the products were packed in plastic zip lock bags (airtight bags) and kept at room temperature until quality parameters were measured. The oldest products were 12-16 weeks old at the time that the taste panel and moisture tests were carried out.

4.4 Efficiency of the solar drier

The efficiency of the drier was evaluated through three tests. First, a digital data logger (Boxcar Pro 4) was used to measure temperature and humidity levels inside the solar drier and was compared with daily (temperature and humidity)[2] levels of the experimental site. The difference between the temperature inside the solar drier and daily atmospheric temperature was used as a proxy measure of the efficiency of the solar drier. Second, subjective sensory evaluation was used to evaluate community members' perceptions and preferences in terms of the colour, texture, and flavour of the dried products. Third, the moisture content of the produce was determined and compared to available standards for dry fruits and vegetables. The study therefore employed both objective and subjective evaluations. Due to budgetary constraints, nutritional and microbial tests were not carried out.

4.5 Quality evaluation (sensory evaluation)

To measure the perceived quality of the dried fruits and vegetables in terms of colour, texture, and flavour, subjective sensory evaluation was used. Sixty panellists were invited

[2] The data was obtained from the University of KwaZulu-Natal, Centre for Rural Development Systems, (CERDES)

from ten Maphaphetheni community garden groups experimenting with similar but smaller solar driers. Unfortunately, only 34 community members arrived at the University Research Farm for the sensory evaluation. Thirteen University students and staff (assisting with the Maphaphetheni community visit to the farm) also participated in the taste panel to augment the number of responses. Affective sensory tests, product acceptance, and preference tests were used to evaluate the quality of the solar dried products.

Responses were recorded as five-point Hedonic scales (Appendix D), ranging from a score of one (dislike very much) to five (like very much) (Oregon State University 1998, Ranganna 1986, p. 624). As many panellists had low levels of English literacy, the scale was printed with a series of faces from frowns to smiles (Stone and Sidel 1993). The instructions on the response sheets were translated into Zulu to make communication easier and verbal instructions were given at the start of each taste session by a Zulu speaking assistant (Appendix E). Three servers were employed to assist with serving and clearing away the samples and three more assistants helped the panellists in completing the response sheets, encouraging panellists and answering questions. Samples were served sequentially to the panellists by the servers. No standard sample was provided.

Ranganna (1986) and (Daniel 1999) suggest that taste panellists should be in good health, willing to participate, and have sensory sensitivity. As it was difficult to identify the sensory sensitivity and health condition of individuals, only their willingness to participate was considered. However, to reduce the sensitivity of panellists, they were asked to avoid eating spiced food, chew gum, suck mints and cough sweets, and using strong smelling cosmetics before participating in the test (Daniel 1999, Walsh undated). The panellists were given instructions about the procedure to be followed (see Appendix E). Panellists were instructed to taste a sample, rate it, and then cleanse their palates with water before evaluating the next sample.

4.5.1 Sensory evaluation environment

Participants in a solar drier project at Maphaphetheni, KwaZulu-Natal, were invited to attend a research day at the University research farm (Ukulinga) on the 8th September 2003. The participants from Maphaphetheni community garden groups had been supplied with mini solar driers, trained in using the driers and how to dry the produce. The participants were asked to bring samples of the produce they had dried. These were evaluated by the participants for colour and visual texture for a concurrent research project. Three stations were set up for the day:

- evaluation of community produce and a tour of a sustainable livelihoods research site,
- sensory evaluation of the experimental produce dried at Ukulinga for this study, and
- completion of a questionnaire for the community project, along with serving of tea and muffins.

The community participants arrived at Ukulinga by bus at approximately 10 am, after an hour and a half journey. They were welcomed and the objectives of the day were explained in Zulu. They were served tap water and dry unsalted cream crackers. The names of the participants were recorded and they were simultaneously divided into three randomly assigned groups. The order of station rotation was arranged so that the group who completed the questionnaire and were served tea and muffins first, participated in the sensory evaluation test last. Each station took at least an hour to complete. A forth group of visitors from the KwaZulu-Natal Department of Agriculture, University students and staff helpers participated in the final sensory evaluation panel.

Taste sessions were held between 10:30 and 2:30 pm in a seminar room at the University farm. The room was quiet and comfortable. Individual booths were created with poster boards, so that panellists did not influence each other (Stone and Sidel 1993, Ranganna 1986, p. 597). Fluorescent lights and normal daylight lit the room. No air-conditioning or humidity control was available, but the accommodation was adequate and comfortable.

The room was arranged as shown in Figure (4.2). The taste session accommodated fifteen panellists at a time. Oral and written tasting instructions were provided to all panellists. Each sample was accompanied by a coded response sheet per sample.

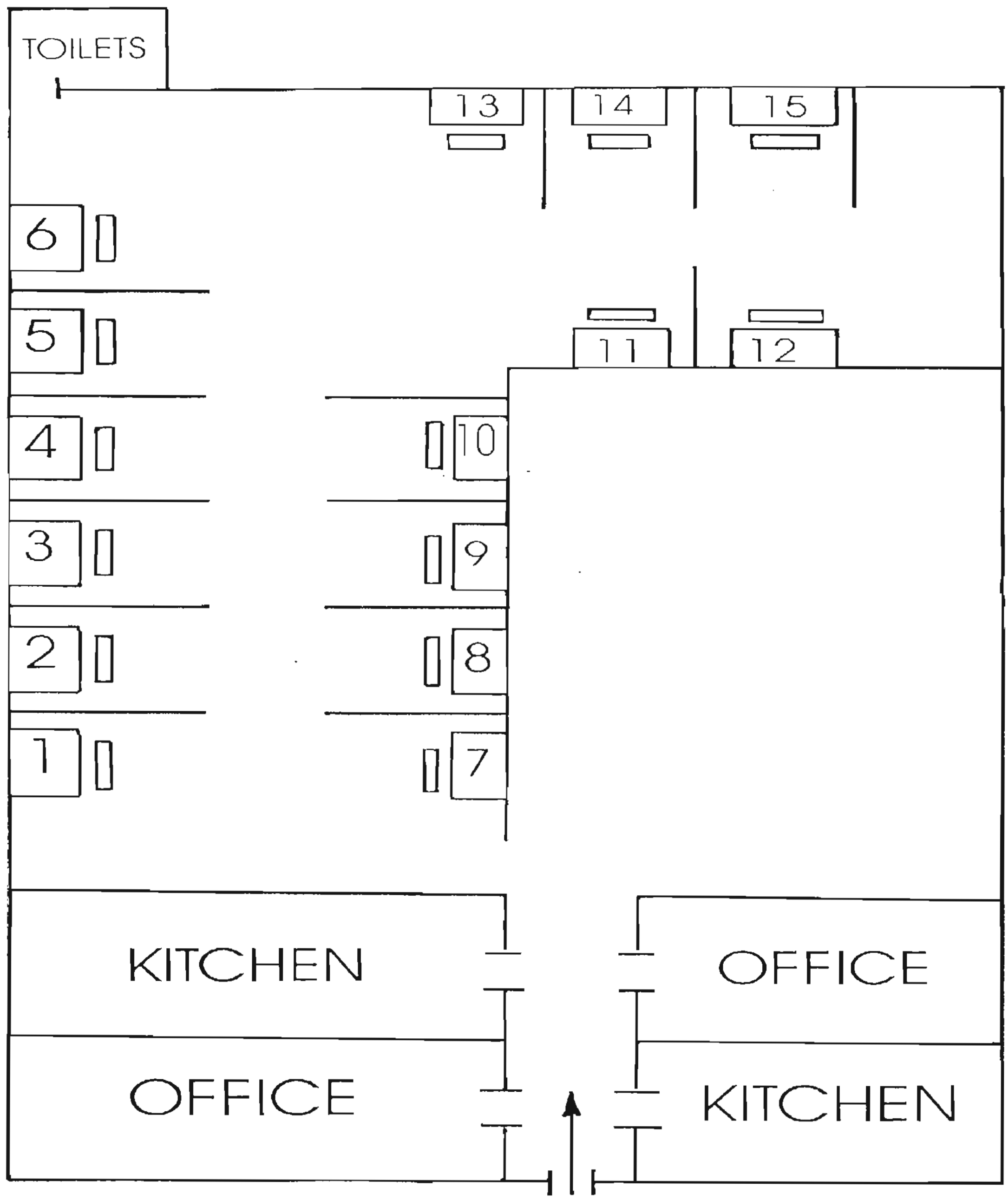


Figure 4.2: Plan of the area used for taste sessions at Ukalinga farm, September 2003.

Water and unsalted crackers were provided for panellists to cleanse their palates between tasting samples. After each test the response sheets were collected and checked for completeness. After completing the testing, lunch was served and the community members left the farm by bus at 4pm.

4.5.2 Sensory evaluation sample preparation

The dried vegetable samples to be tasted were reconstituted before the taste tests. To reconstitute, water was added to the products to restore the dry products to conditions similar to the fresh produce (Dauthy 1995). One cup of dried carrots and a cup of pumpkin were each soaked in two cups of boiled water for one hour (Harrison and Adress undated). The dried apples and pineapples were reconstituted before being presented for tasting by soaking one cup of each sample in one cup of boiled water for one hour. Dried bananas were reconstituted by steaming for 15 minutes.

4.5.3 Sensory evaluation sample presentation

All samples should be presented in the same form, consistency and colour to prevent the taster from being distracted (Daniel 1999). Therefore, samples were uniform in serving size, product type, and colour of the serving containers (Daniel 1999). Two pieces each of dried bananas and carrot were served per sample. One piece each of apple, pineapple, tomato, and pumpkin were served per taster per sample. White polystyrene plates of the same size were used to serve the samples. Each sample was labelled with a three-digit random number in randomised order of presentation (Ranganna 1986, p. 597).

4.5.4 Sensory evaluation data analysis

The data obtained from the affective sensory method were tabulated and processed by SPSS data analysis, version 11.0 for Windows to obtain the mean values, deviations from the mean, frequencies, and percentage scores for each sample. The effect of the pre-treatment methods on the quality of the dried fruits and vegetables was determined using a completely randomised block design following the one-way analysis of variance (ANOVA) (Piggott 1988, p. 348). To state with confidence that the results obtained are statistically significant, and determine whether differences in quality between the three treatments means for apple and banana were evident, further analysis was carried out to detect significant differences between means using the least significant difference (LSD) test at the 5 percent significance level.

4.6 Moisture content test

The moisture content of dried food is conventionally the loss in mass measured under the operating conditions specified by the Association of Official Analytical Chemists, Official Method 934.06 (Helrich 1990, p. 912). The moisture content is expressed as a percentage of moisture per unit mass of sample matter (grams per 100 grams). Samples were randomly selected from the dried products. A minimum of 100 g of dried product was taken as the test sample for each product sample. The test samples were cut into small pieces of approximately 10 to 20 g and dried in an oven at approximately 105° C. After 48 hours of drying, the percentage weight loss per sample was recorded as moisture lost and used to estimate the moisture content of each sample.

The moisture content of each sample was calculated (W) as the percentage moisture by mass of the sample (approximately 100 grams) using the following formula:

$$W = \frac{M_1 - M_2}{M_1 - M_0} \times 100 \qquad \text{(Equation 1)}$$

Where:

M_0 was the mass, in grams, of the dry beaker.

M_1 was the mass, in grams, of the dry beaker, and the test portion before drying.

M_2 was the mass, in grams, of the dry beaker, and the test portion after drying.

The study findings are presented and the implication of the findings are discussed in the next chapter.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 Demographic characteristics of the taste panel participants

Of the 42 panellists, 34 were from Maphaphetheni, and the remaining 13 were Department of Agriculture employees and University of Natal students and staff. The panellists ranged from 20 to 75 years old (Table 5.1). Ten panellists (21%) had no formal education, nine (19%) had completed primary school, 14 (68%) had completed secondary school. Two (4%) panellists had diplomas, seven (15%) had honours degrees, four (9%) had masters degrees, and one (2%) panellist had a PhD (Table 5.2). Forty-two panellists were female, and five were male.

Table 5.1: Panellists' age distribution, sensory evaluation, September 2003 (n=47).

Age	Frequency	Percentage of participants
20-39	19	40.43
40-49	12	25.53
50-75	16	34.04
Total	47	100

Table 5.2: Panellists' education levels, sensory evaluation, September 2003 (n=47).

Number of years of complete schools	Frequency	Percentage of participant s
0	10	21.28
Grades 1-7	9	19.15
Grades 8-12	14	29.79
Diplomas	2	4.26
Honours	7	14.89
Masters	4	8.51
PhD	1	2.13
Total	47	100

5.2 Results of the sensory evaluation of dried fruits and vegetables

Dried fruit and vegetable samples of apple, pineapple, banana, tomato, carrot, and pumpkin were evaluated by 47 panellists using a five-point hedonic scale (Appendix D). The frequency of scores (degree of liking) is summarised in Appendices F and G and is discussed in the sections that follow. The analysis of variance of the mean scores of the sensory evaluation showed significant differences between the treatments regarding all three evaluated sensory characteristics (colour, flavour, and texture) (Table 5.3 and 5.4). To be confident that the results obtained were statistically significant, further analysis by least significant difference (LSD) at the five percent level was conducted for banana and apple (each had three samples). The results of the least significant difference test are shown in Tables 5.5 and 5.6. For dried tomato, carrot, pumpkin, and pineapple, further analysis of independent sample t- tests were conducted as each experiment had only two samples. The results of the t-tests showed that there were significant differences between the two treatments of dried tomato and pumpkin in terms of both flavour and colour. Whereas, the t-test results for carrots showed no significant difference between the two samples in terms of flavour and colour (Table 5.3).

Table 5.3: T-test results for the mean scores of sensory characteristics for dried fruits and vegetables, September 2003

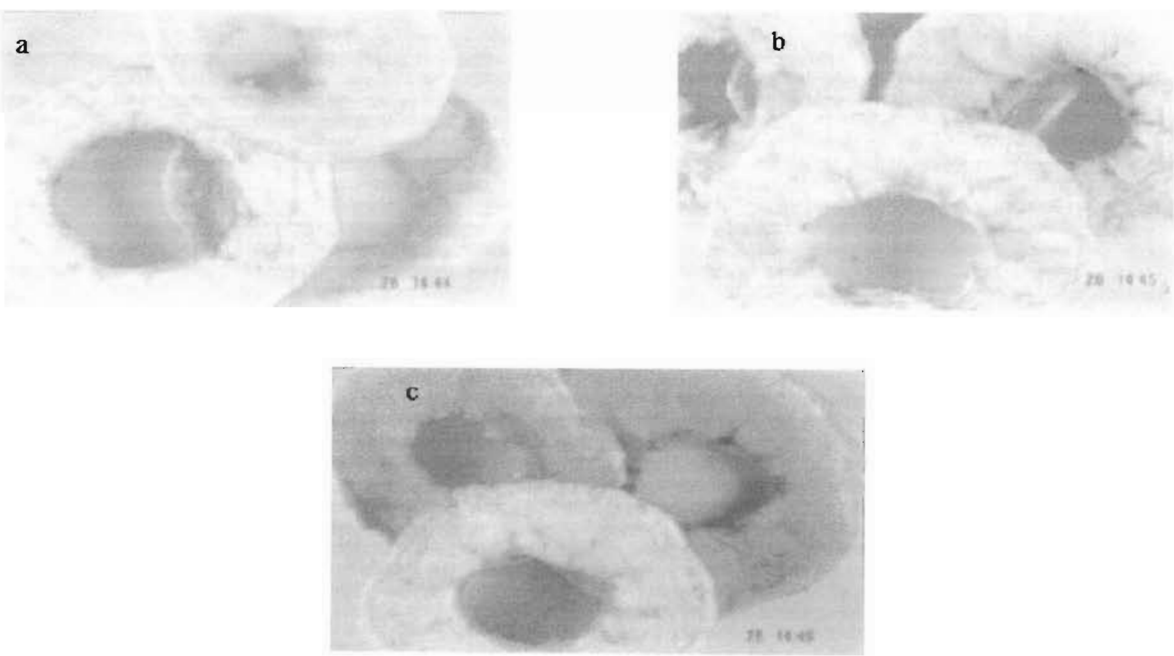
Parameter	T-test	Sig. (2-tailed)
Pineapple colour	8.702	.000*
Pineapple flavour	4.195	.000*
Pineapple texture	6.408	.000*
Tomato colour	5.008	.000*
Tomato flavour	3.522	.001*
Tomato texture	3.700	.000*
Pumpkin colour	7.515	.000*
Pumpkin flavour	3.995	.000*
Pumpkin texture	5.677	.000*
Carrot colour	1.696	.093
Carrot flavour	.931	.354
Carrot texture	1.995	.049*

* The means difference is significant at the 0.05 level of confidence

5.2.1 The effects of pre-treatments on the quality of dried apple and banana

Three treatments each were applied to apple and banana. These were soaking the fruits in a 35% solution of sugar with lemon juice preserved with sulphur dioxide, lemon juice preserved with sulphur dioxide, and lemon juice preserved with metabisulphite (Table 4.3). Sugar syrup is typically used as a pre-treatment for light-colour fruits such as apples and banana as its counteracts enzyme actions that cause browning of dried products during processing and storage (University of Idaho 1995, University of Georgia undated). Lemon juice, which is high in vitamin C, keeps the natural colour of the fruit and prevents darkening (University of Georgia undated). Panellists evaluated the samples treated with these three pre-treatments using a five-point Hedonic scale. The panellist scores for acceptance levels are summarised in Figures 5.2 and 5.3.

The colour, flavour, and texture of the dried apple and banana pre-treated with sugar syrup with lemon juice preserved with sulphur dioxide had the highest acceptance level which implies that the respondents liked the products (Figures 5.1, 5.2, 5.3 and 5.4). The dried apple and banana treated with lemon juice preserved with sulphur dioxide did not show as favourable a response as the dried apple and banana treated by sugar syrup with lemon juice preserved with sulphur dioxide. While the colour, flavour, and texture of the dried apple and banana treated with lemon juice preserved with sodium metabisulphite had the lowest acceptance level of the respondents indicating they liked the products (Figures 5.1, 5.2, 5.3, and 5.4).



a) Dried apple treated with sugar syrup b) dried apple treated with lemon juice preserved with sulphur dioxide. c) Dried apple treated with lemon juice preserved with sodium metabisulphite

Figure 5.1 Photographs of the three dried apple samples, September 2003

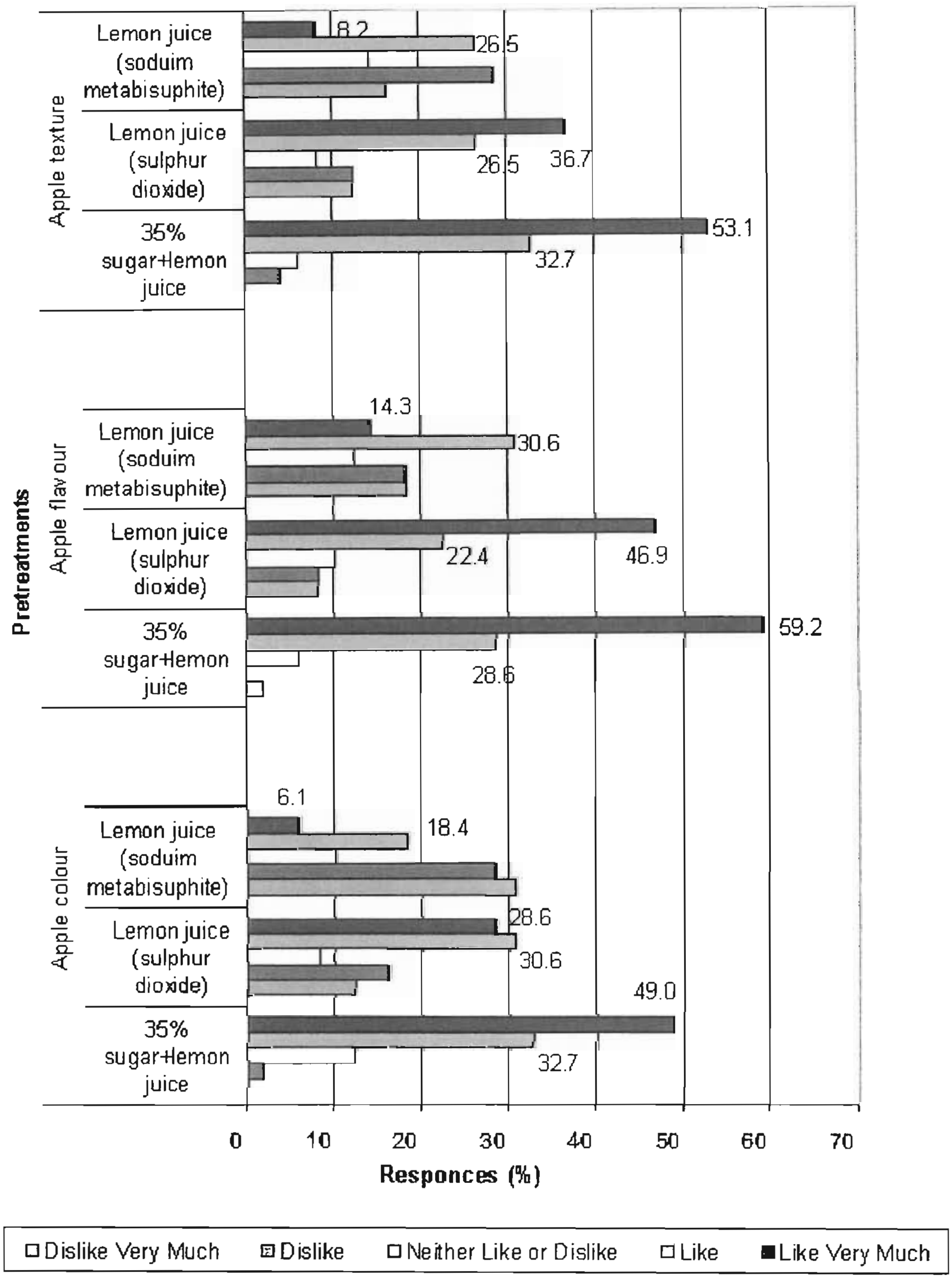


Figure 5.2: Panelists' acceptance test of dried apple by category (five-point hedonic scale, n=47)

Average values of the sensory scores for acceptance with respect to the colour, flavour, and texture are given in Table 5.4. The dried apple and banana treated by lemon juice preserved with sodium metabisulphite had the lowest rating for colour, flavour, and texture. The highest rating for colour, flavour, and texture were obtained in dried apple and banana treated with the sugar syrup and lemon juice preserved with sulphur dioxide (Table 5.4).

Table 5.4: Analysis of variance for sensory characteristics of dried fruits, September 2003 (n=47)

Experiment	Score[a]								
	Evaluation Parameters								
	Colour			*Flavour*			*Texture*		
	Sample 1[3]	Sample 2[4]	Sample 3[5]	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Apple	4.34*	3.49*	2.37*	4.49*	3.96*	3.04*	4.40*	3.66*	2.80*
Banana	4.53	4.19	3.13*	4.38	3.94	3.62*	4.53	4.23	3.83*
Pineapple	-	4.66*	2.81*	-	4.57*	3.62*	-	4.49*	3.11*

[a]The scores were 1= Dislike very much to 5= Like very much

* Means within the same raw are significantly different (at 0.05 level).

The least significant difference (LSD) test presented in Table 5.5 shows a significant difference between the three treatments of the dried apple in terms of colour, flavour, and texture. Therefore the dried apple treated with the sugar syrup and lemon juice preserved with sulphur dioxide was judged to be the best in terms of colour, flavour, and texture followed by dried apple treated by lemon juice preserved with sulphur dioxide. While dried apple treated by lemon juice preserved with sodium metabisulphite was found to be the least acceptable.

One possible explanation could be due to the action of sugar syrup in stopping enzyme action causing browning (University of Idaho 1995, University of Georgia undated). The lemon juice preserved with sulphur dioxide might also keep the natural colour and flavour of the fruit unchanged (Mason *et al* undated, University of Georgia undated). Moreover, the sulphur dioxide that was used as preservative for the lemon juice acts as an

[3] Sample 1 Treated with 35% solution of sugar with lemon juice preserved with sulphur dioxide.
[4] Sample 2 Treated with 25% lemon juice preserved with sulphur dioxide.
[5] Sample 3 Treated with 25% lemon juice preserved with sodium metabisulphite.

antioxidant and may have prevented enzymatic and non-enzymatic browning (Dauthy 1995). The sulphiting agents (sodium bisulphite, sodium sulphite, and sodium metabisulphite) must first release sulphur dioxide to act as an antioxidant agent. To release one part of sulphur dioxide 1.62 parts of sodium bisulphite is needed compared to 48 parts of sodium metabisulphite. Therefore, sodium metabisulphite is a weaker preservative (General Chemical Corporation 2003).

Table 5.5: Least significant difference test (LSD) for the mean scores of sensory characteristics for dried apple, September 2003 (n = 47)

Parameters	(I) Treatment	(J) Treatment	Mean Difference (I-J)	Significant
Apple colour	35% sugar syrup + lemon juice	Lemon juice (sulphur dioxide)	.85*	.001
		Lemon juice (sodium metabisulphite)	1.97*	.000
	Lemon juice (sulphur dioxide)	35% sugar syrup+ lemon juice	-.85*	.001
		Lemon juice (sodium metabisulphite)	1.12*	.000
	Lemon juice (sodium metabisulphite)	35% sugar syrup+ lemon juice	-1.97*	.000
		Lemon juice (sulphur dioxide)	-1.12*	.000
Apple flavour	35% sugar syrup + lemon juice	Lemon juice (sulphur dioxide)	.53*	.034
		Lemon juice (sodium metabisulphite)	1.45*	.000
	Lemon juice (sulphur dioxide)	35% sugar syrup + lemon juice	-.53*	.034
		Lemon juice (sodium metabisulphite)	.91*	.000
	Lemon juice (sodium metabisulphite)	35% sugar syrup + lemon juice	-1.45*	.000
		Lemon juice (sulphur dioxide)	-.91*	.000
Apple texture	35% sugar syrup +lemon juice	Lemon juice (sulphur dioxide)	.74*	.003
		Lemon juice (sodium metabisulphite)	1.60*	.000
	Lemon juice (sulphur dioxide)	35% sugar syrup + lemon juice	-.74*	.003
		Lemon juice (sodium metabisulphite)	.86*	.001
	Lemon juice (sodium metabisulphite)	35% sugar syrup + lemon juice	-1.60*	.000
		Lemon juice (sulphur dioxide)	-.86*	.001

* The mean difference is significant at the 0.05 level of confidence.

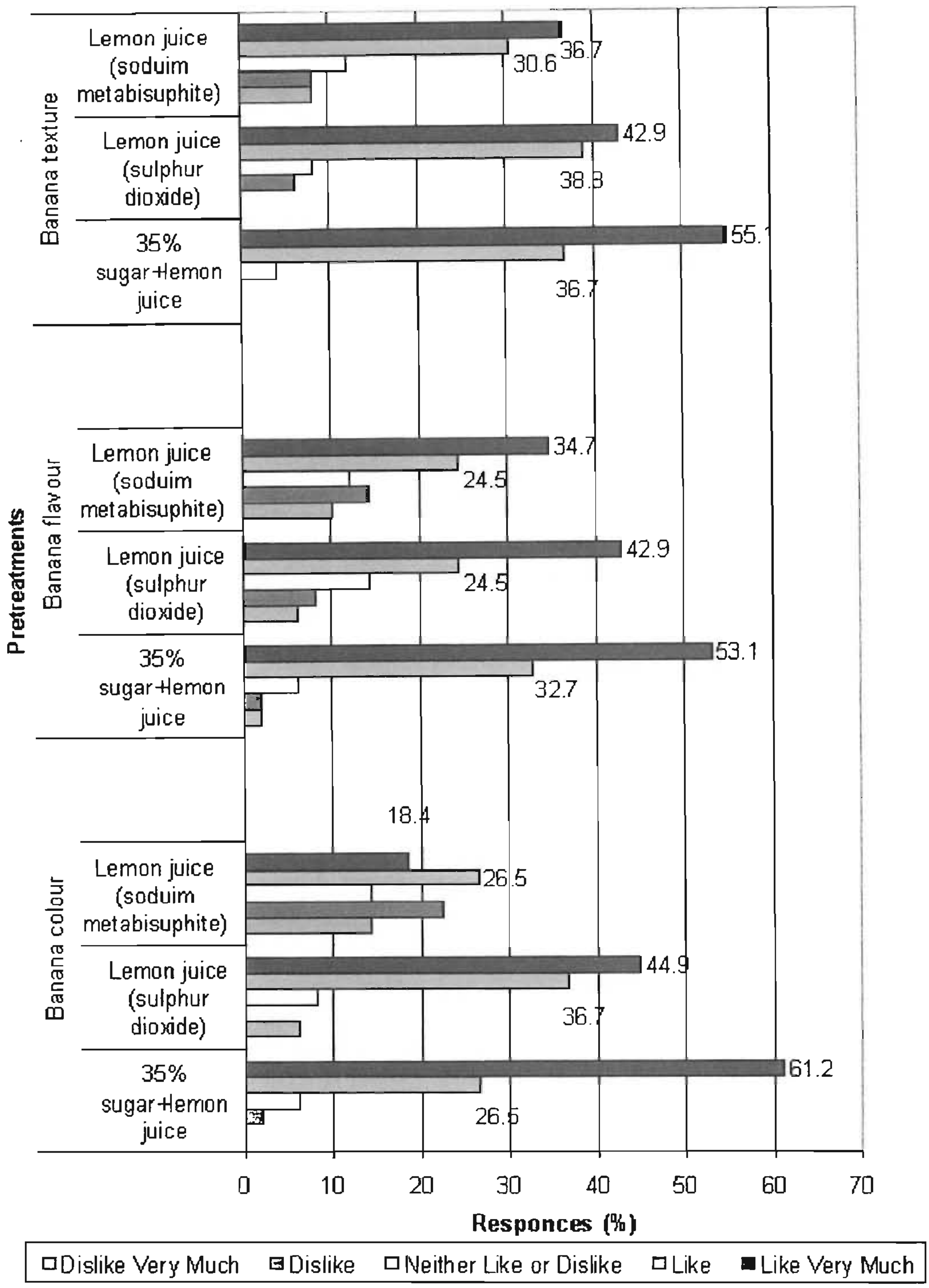


Figure 5.3: Panelists' acceptance test of dried banana by category (five-point hedonic scale, n=47)

The least significant difference (LSD) test presented in Table 5.6 shows that there is no statistically significant difference between the dried banana treated with 35% sugar syrup and lemon juice and that preserved with sulphur dioxide, and the dried banana treated with lemon juice preserved with sulphur dioxide regarding the colour, flavour, and texture of the product.

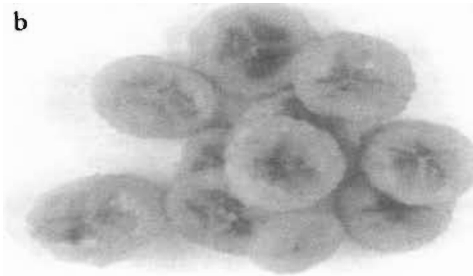
Table 5.6: Least significant difference test (LSD) for the mean scores of sensory characteristics for dried banana, September 2003 (n = 47)

Parameters	(I) Treatment	(J) Treatment	Mean Difference (I-J)	Significant
Banana colour	35% sugar syrup +lemon juice	Lemon juice (sulphur dioxide)	.34	.131
		Lemon juice (sodium metabisulphite)	1.40*	.000
	Lemon juice (sulphur dioxide)	35% sugar syrup +lemon juice	-.34	.130
		Lemon juice (sodium metabisulphite)	1.06*	.000
	Lemon juice (sodium metabisulphite)	35% sugar syrup +lemon juice	-1.40*	.000
		Lemon juice (sulphur dioxide)	-1.06*	.000
Banana flavour	35% sugar syrup +lemon juice	Lemon juice (sulphur dioxide)	.45	.071
		Lemon juice (sodium metabisulphite)	.77*	.002
	Lemon juice (sulphur dioxide)	35% sugar syrup +lemon juice	-.45	.071
		Lemon juice (sodium metabisulphite)	.32	.195
	Lemon juice (sodium metabisulphite)	35% sugar syrup	-.77*	.002
		Lemon juice (sulphur dioxide)	-.32	.195
Banana texture	35% sugar syrup +lemon juice	Lemon juice (sulphur dioxide)	.30	.131
		Lemon juice (sodium metabisulphite)	.70*	.000
	Lemon juice (sulphur dioxide)	35% sugar syrup +lemon juice	-.30	.131
		Lemon juice (sodium metabisulphite)	.40*	.041
	Lemon juice (sodium metabisulphite)	35% sugar syrup +lemon juice	-.70*	.000
		Lemon juice (sulphur dioxide)	-.40*	.041

* The mean difference is significant at the 0.05 level of confidence.

a

b



c

a) Dried banana treated with sugar syrup b) Dried banana treated with lemon juice preserved with sulphur dioxide. c) Dried banana treated with lemon juice preserved with metabisulphite.

Figure 5.4 Photographs of the three dried apple samples, September 2003.

Concerning colour and texture, the sensory scores of the sample pre-treated with 35% sugar and lemon juice preserved with sulphur dioxide were found to be the highest, each with a mean of 4.53. This did not vary significantly from products being pre-treated by lemon juice preserved with sulphur dioxide (4.19 and 4.23), but both sample means (3.13 and 3.83, respectively) were significantly greater than the sample pre-treated with lemon juice preserved with sodium metabisulphite (Tables 5.4 and 5.6).

For flavour, the mean score for the dried banana treated with sugar syrup with lemon juice preserved with sulphur dioxide was judged the best (4.38) and did not vary significantly from products pre-treated with lemon juice preserved with sulphur dioxide (3.94). Nevertheless, the pre-treated sample with sugar syrup with lemon juice preserved with sulphur dioxide was significantly greater than that of the sample pre-treated with lemon juice preserved with sodium metabisulphite (3.62). Moreover the results of LSD showed that the flavour of the sample treated with lemon juice preserved with sulphur dioxide did not vary significantly from the sample treated with lemon juice preserved with sodium metabisulphite (Table 5.6).

It can be concluded that both samples of dried banana pre-treated with 35% sugar syrup and lemon juice preserved with sulphur dioxide and the sample pre-treated with lemon juice preserved with sulphur dioxide had higher acceptance by the panellists. This could be due to the action of both the sugar and the lemon juice. The sugar syrup counteracts enzyme action, which causes browning, and lemon juice keeps the natural colour and flavour of the fruit (University of Idaho 1995, University of Georgia undated). This could also be due to the sulphur dioxide, used as preservative for the lemon juice, which prevents enzymatic and non-enzymatic browning. Therefore, the sugar and lemon juice together act to produce most acceptable products than the other two samples. Moreover the pre-treated sample with lemon juice preserved with sodium metabisulphite was found to be the least acceptable than the two samples. Mostly due to the fact that sodium metabisulphite has less strength than the popular sulphiting agents (sodium bisulphite, sodium sulphite, and sodium metabisulphite) to release sulphur dioxide, which penetrates the surface of the fruit, retarding oxidation and enzymatic browning (Post 2003, Michigan State University Extension 1999). As mentioned before, to release one part of sulphur dioxide you need to use 1.62 parts of sodium bisulphite compared to 48 parts of sodium metabisulphite (General Chemical Corporation 2003). Therefore, sodium metabisulphite is a weaker preservative.

5.2.2 The effects of pre-treatment on the quality of dried pineapple

The two treatments used for drying pineapple were lemon juice preserved with sulphur dioxide and lemon juice preserved with sodium metabisulphite (Table 4.3). The use of sugar syrup is not recommended for pre-treating pineapple. Lemon juice was recommended for treating most fruits to help keep the natural colour and prevent further darkening (Mason *et al* undated). Even though pineapple has a high vitamin C content, the sulphites used as preservatives for the lemon juice acted as antioxidants to prevent or reduce discoloration of light-colored fruits by blocking both enzymatic browning and non-enzymatic browning reactions. The frequency of panellist scores are summarised in Appendix F. The colour, flavour, and texture of dried pineapple treated with lemon juice preserved with sulphur dioxide was found to be the best acceptable product whereas, the sample treated with lemon juice preserved with metabisulphite had less acceptance in terms of colour, flavour, and texture (Figures 5.5 and 5.6). Panellists preferred the pineapple treated with lemon juice preserved with sulphur dioxide than the sample pre-treated with lemon juice preserved with metabisulphite in terms of colour, flavour, and texture (Figure 5.6)

As shown in Table 5.3, panellists rated the sample of dried pineapple pre-treated with lemon juice preserved with metabisulphite as low as (2.81) for colour, (3.62) for flavour, and (3.11) for texture as compared to dried pineapple treated with lemon juice preserved with sulphur dioxide. The analysis of an independent sample t-test showed a statistically significant difference between the two pre-treatments. Generally, dried pineapple had higher acceptance rates when pre-treated with lemon juice preserved with sulphur dioxide. Reasons for this include that the sulphur dioxide used as preservative for lemon juice retarded oxidation, enzymatic browning and prevented colour and flavour losses during drying and storage (Mason *et al* undated, University of Georgia undated).

a

b

a) Dried pineapple treated with lemon juice preserved with sulphur dioxide. b) Dried pineapple treated with lemon juice preserved with metabisulphite

Figure 5.5 Photographs of the dried pineapple, September 2003

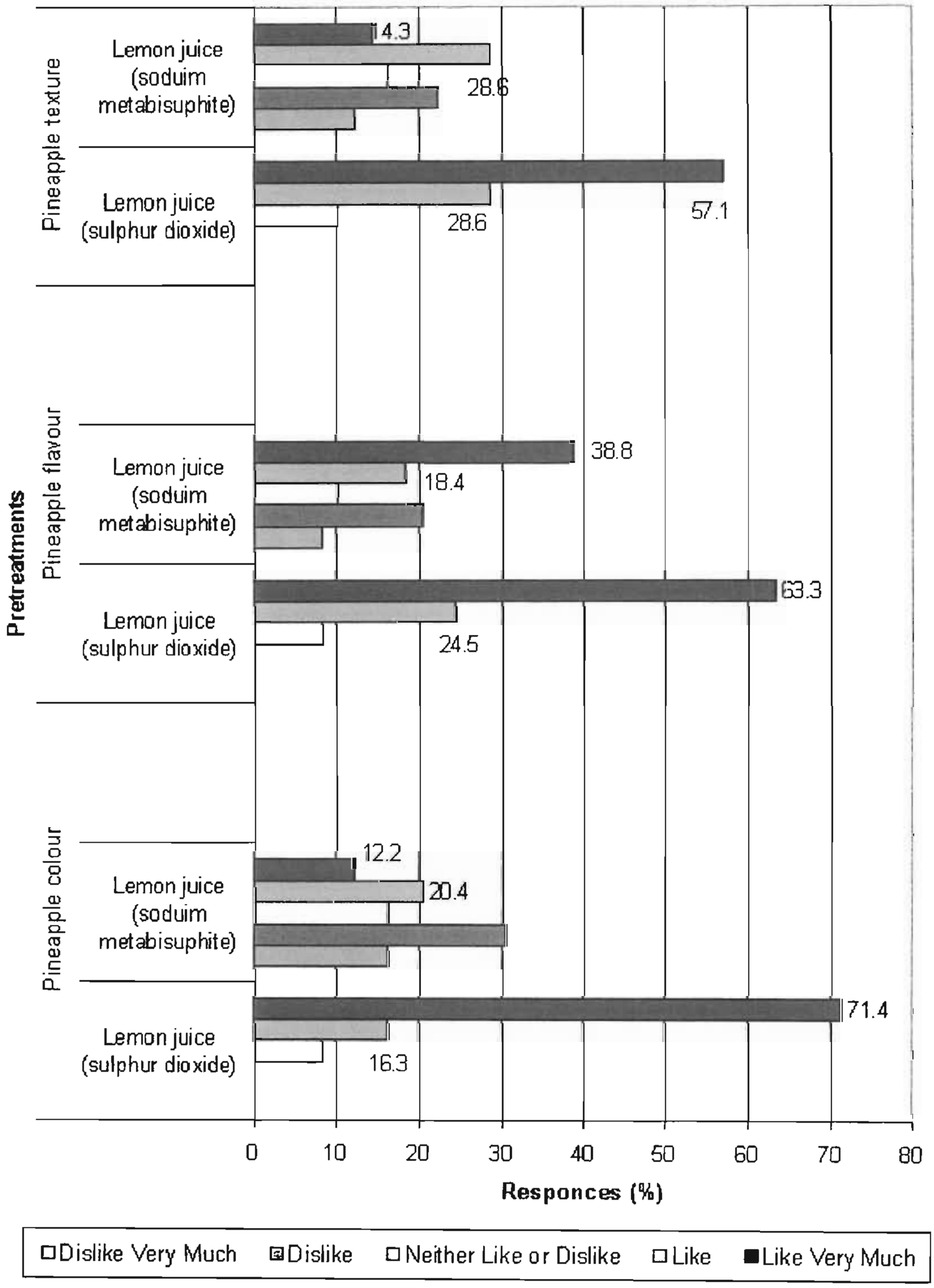


Figure 5.6: Panelists' acceptance test of dried pineapple by category (5-point hedonic scale, n=47)

5.2.3 The effects of pre-treatment on the quality of dried tomato and pumpkin

Steam blanched and control (not-blanched) tomato and pumpkin were dried. The frequency of panellist scores are summarised in Appendix G. The colour, flavour, and texture of the dried tomato and pumpkin treated with steam blanching had a higher acceptance level than the control products (Figures 5.7 and 5.9).

The panellists preferred the colour, flavour, and texture of dried tomato and pumpkin treated with steam blanching more than the control products (Figures 5.7, 5.8, 5.9, and 5.10). Results of mean ratings for colour, flavour, and texture of the treated and controlled (not blanched) dried tomatoes and pumpkins were presented in Table 5.7. The control tomato sample had lower mean ratings of 3.40, 3.24, and 3.36 for colour, flavour, and texture, respectively. The t-test for tomato shows that the two dried samples had statistically significant differences (Table 5.3).

Table 5.7: Analysis of variance for the sensory characteristics of the dried vegetables, September 2003 (n=47)

Experiment	**Score**[a]					
	Evaluation Parameters					
	Colour		*Flavour*		*Texture*	
	Sample 1[6]	Sample 2[7]	Sample 1	Sample 2	Sample 1	Sample 2
Tomato	4.45*	3.40*	4.17*	3.24*	4.19*	3.36*
Carrot	4.72	4.49	4.36	4.15	4.53*	4.19*
Pumpkin	4.74*	3.34*	4.47*	3.45*	4.57*	3.32*

[a]The scores were 1= Dislike very much to 5= Like very much.

* Means within the same raw are significant different (0.05 level).

---

[6] treated with steam blanching.

[7] not blanched (control).

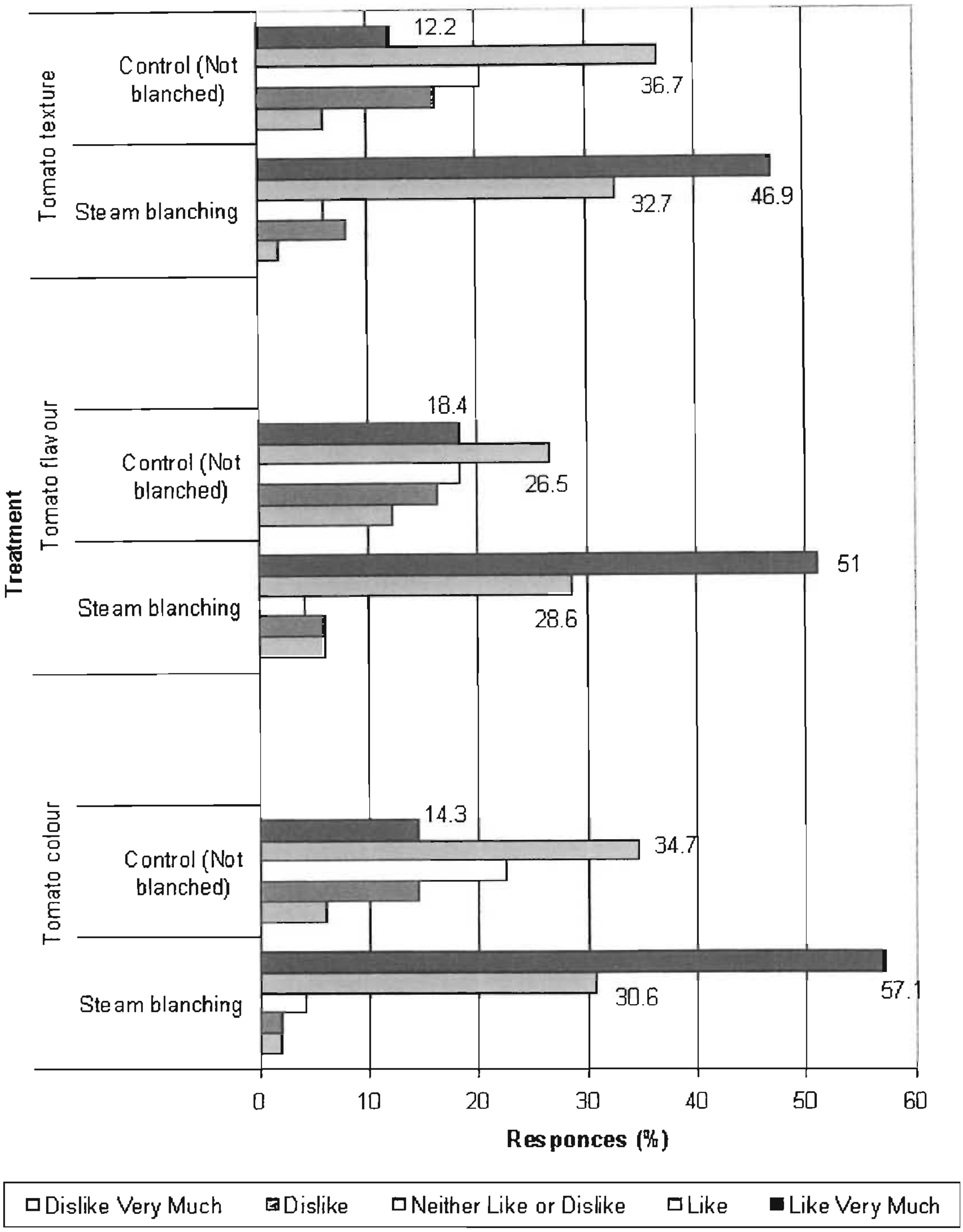
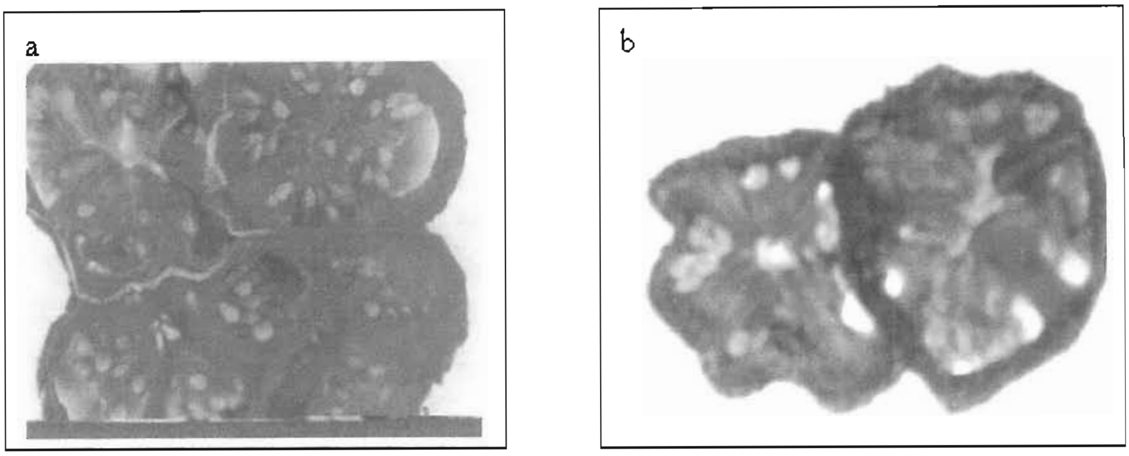


Figure 5.7: Panelists' acceptance test of dried tomato by category (5-point hedonic scale, n=47)



a) Dried tomato treated with steam blanching. b) Not blanched (control) dried tomato
Figure 5.8 Photographs of the dried tomato, September 2003

Based on results reported in Table 5.7 and Figures 5.7 and 5.9 the dried tomato and pumpkin treated with steam blanching was more acceptable in terms of colour, flavour, and texture. Blanched vegetables, when dried, have better flavour and colour than unblanched ones (Anon 1998, University of California 1998, Wolf *et al* 1990). Possible reasons may be that blanching slows or stops enzyme action, which can cause the vegetables to loose flavour, colour, and texture (Azam-Ali *et al* 2003, p. 57, Herman 1998, Kovach 1999, Owner 1998). Blanching destroys enzymes that cause loss of flavour and colour, speed up drying by softening vegetable cells, allow water to escape more easily, and makes them easier and faster to rehydrate, and since they are already slightly cooked they require less cooking time (Azam-Ali *et al* 2003, p.57, Reynolds 1998 b).

Likewise, the control (not blanched) pumpkin had a lower rating for colour, flavour, and texture than pumpkin treated with steam blanching (Table 5.7). Further analysis, by independent sample t-tests, showed a statistically significant difference between the two pumpkin samples in terms of colour, flavour, and texture (Table 5.3). This could also be due to the ability of blanching to destroy the enzymes that cause loss of flavour, colour, and texture (Azam-Ali *et al* 2003, p. 57, Herman 1998, Kovach 1999, Owner 1998, Reynolds 1998 b).

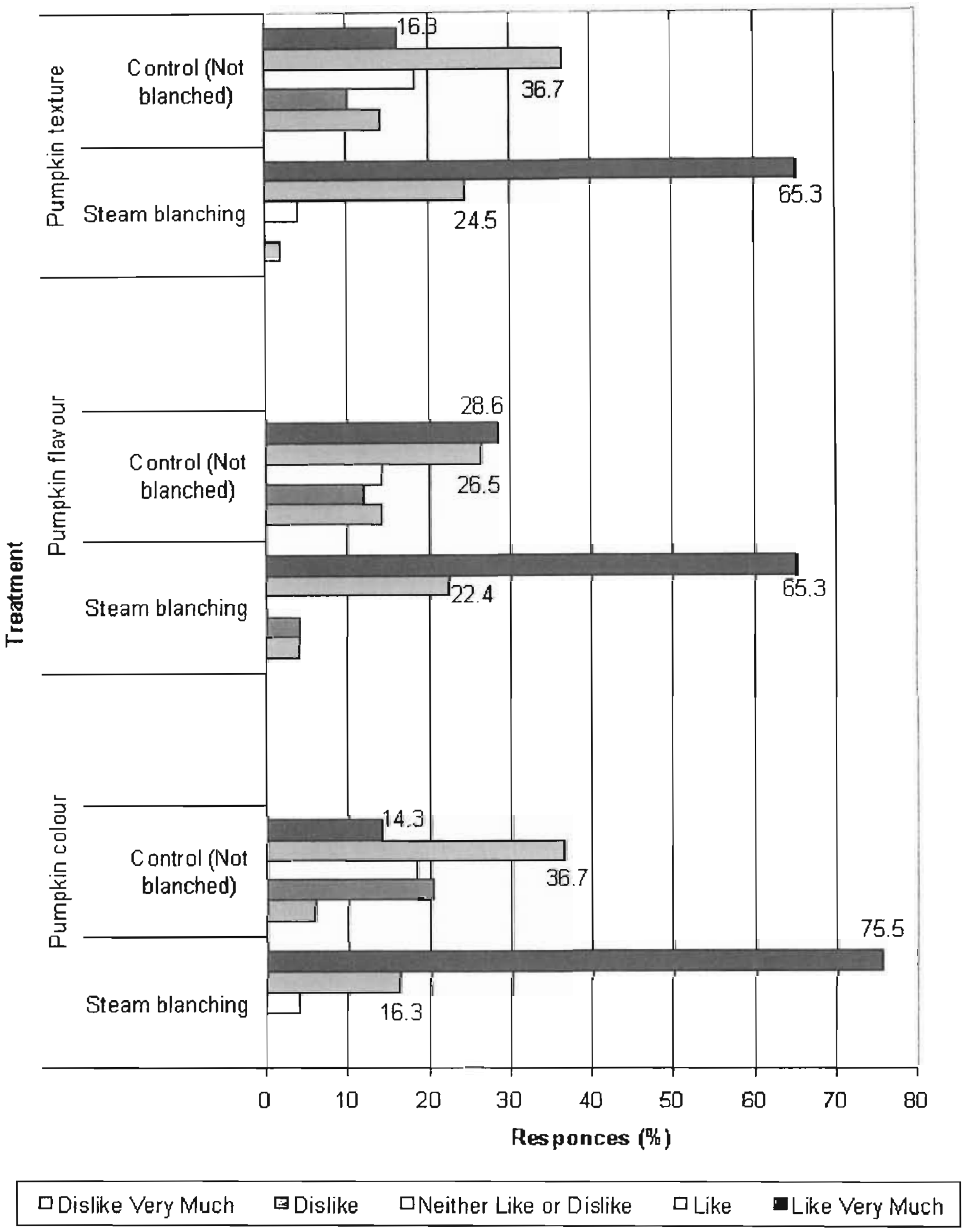
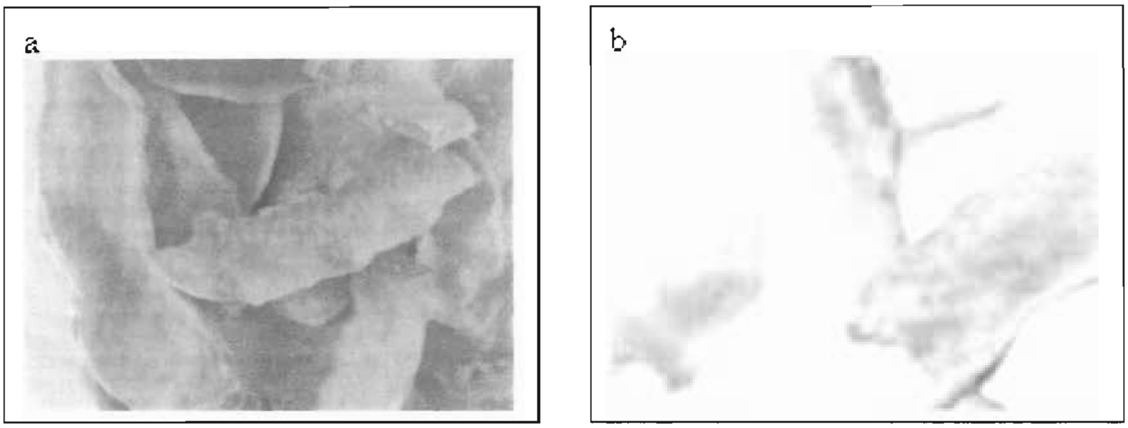


Figure: 5.9: Panelists' acceptance test of dried pumpkin by category (five-point hedonic scale, n=47)

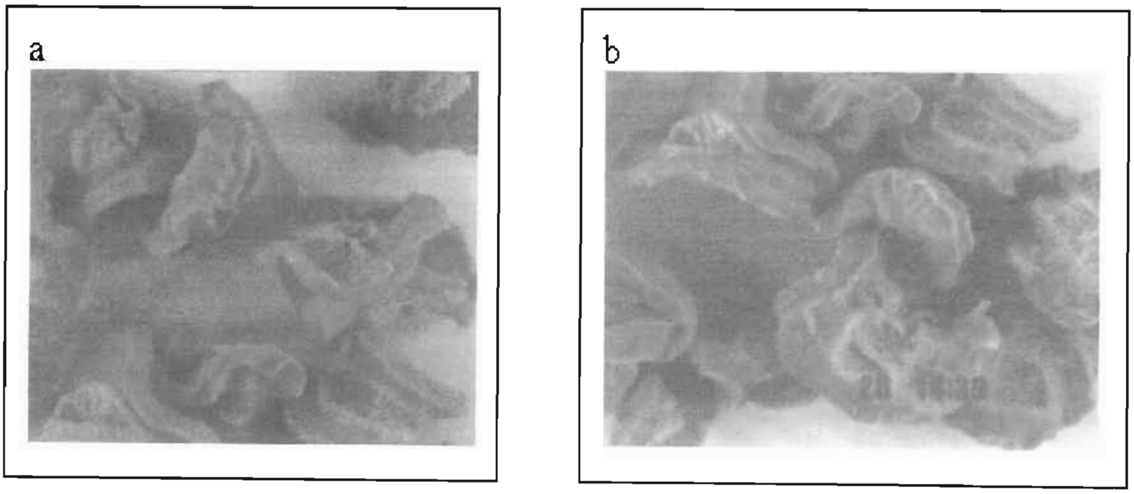


a) Dried pumpkin treated with steam blanching b) Not blanched (control) dried pumpkin

Figure 5.10 Photographs of the dried pumpkin, September 2003.

5.2.4 The effect of pre-treatment on the quality of dried carrot

The same approach was used before drying carrots (steam blanching and control) (Table 4.3). As summarised in Appendix G, the frequency of panellists' scores for colour, flavour, and texture of the dried carrot treated with steam blanching had higher acceptance levels of the respondents, indicating that they were more in favour of the blanched product (Figures 5.11 and 5.12).



a) Dried carrot treated with steam blanching b) Not blanched (control) dried carrot

Figure 5.11 Photographs of the dried carrot, September 2003.

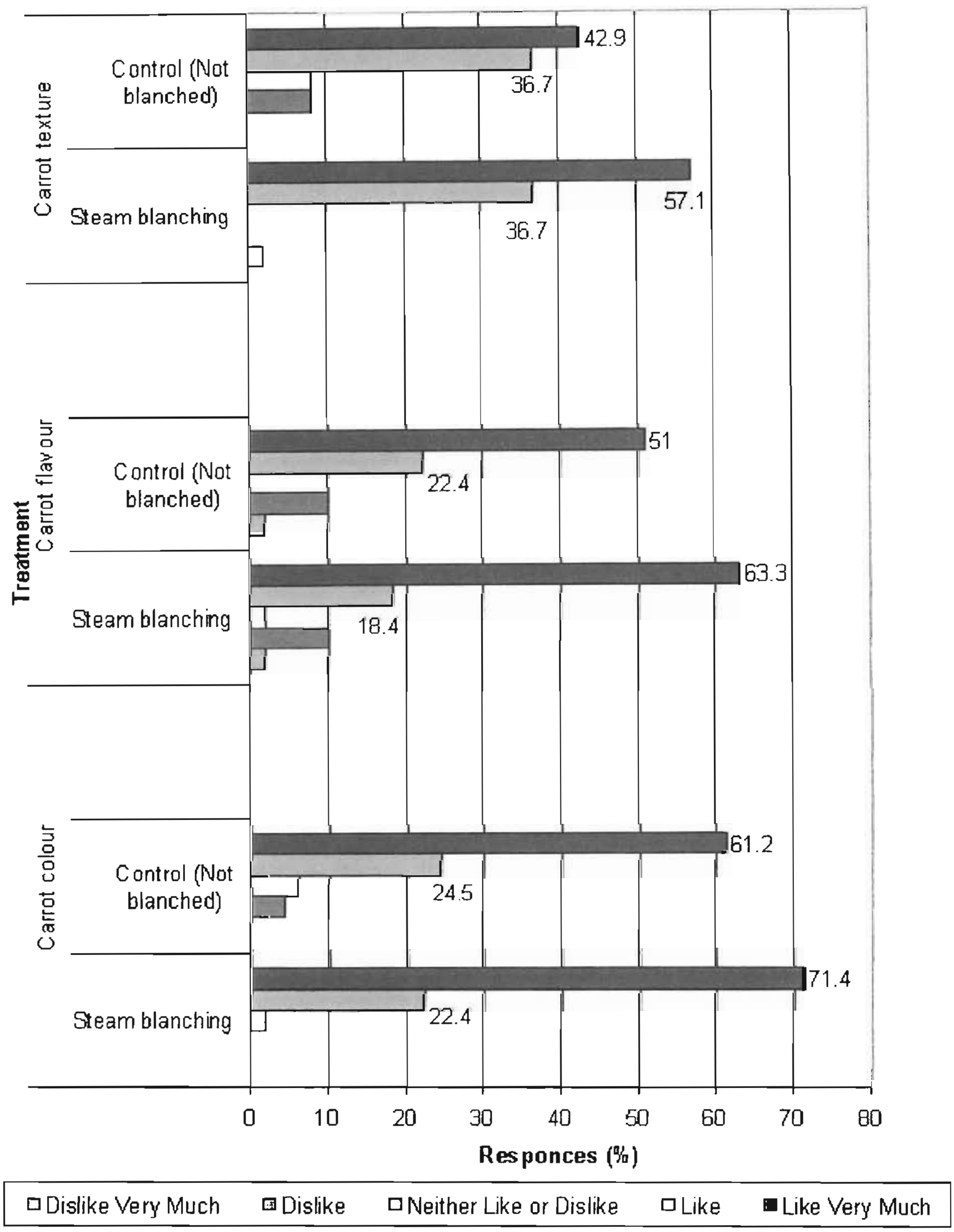


Figure 5.12: Panelists' acceptance test of dried carrot by category (5-point hedonic scale, n=47)

Table 5.7 presents the results for colour, flavour, and texture of the blanched and control samples. The control carrot sample (not blanched) was rated lower than the steam blanched sample in terms of colour (4.49), flavour (4.15), and texture (4.19). The dried carrot treated with steam blanching was rated higher for colour, flavour, and texture (4.72), (4.36), and (4.53), respectively.

The t-statistics for the same samples indicated that there are statistically significant differences between the steam blanched sample and the control one only for texture (Table 5.3). However, there was no significant difference between the dried carrot treated with steam blanching and the control in terms of flavour and colour. Although (Azam-Ali *et al* 2003, Herman 1998, Kovach 1999, Owner 1998) suggest that blanching vegetables destroy the enzymes present in the tissue that cause loss of flavour, colour, and texture. The results of the study indicated that steam blanching preserves the texture of the dried carrots but neither preserves the colour nor prevents flavour loss during drying. That means panellists failed to detect differences in colour and flavour between the steams blanched sample and the control sample (not blanched).

5.3 Evaluation of the moisture content of the dried samples

According to Figure 5.13, the moisture content of dried apple pre-treated with sugar syrup was the highest (22.31% w.b.), followed by apple treated with lemon juice preserved with sulphur dioxide (20.39% w.b.) and then the sample pre-treated with lemon juice preserved with metabisulphite (20.24% w.b.). No significant differences were found in the moisture contents of dried apple pre-treated with sugar syrup, and apple pre-treated with lemon juice preserved with sulphur dioxide, and apple treated with lemon juice preserved with sodium metabisulphite. Generally, the water content of properly dried food can vary from 5 to 25 percent (Kendall and Allen 2002, University of California 1998).

FAO/WHO Food Standards report that the moisture content of the dried apple treated with (soaking in sulphur or ascorbic acid) should be less than 25% and the treated apple without soaking should be not more than 20% (Alwater Foods 2001, FAO undated). The moisture content of the dried apple was found below the standard for all samples.

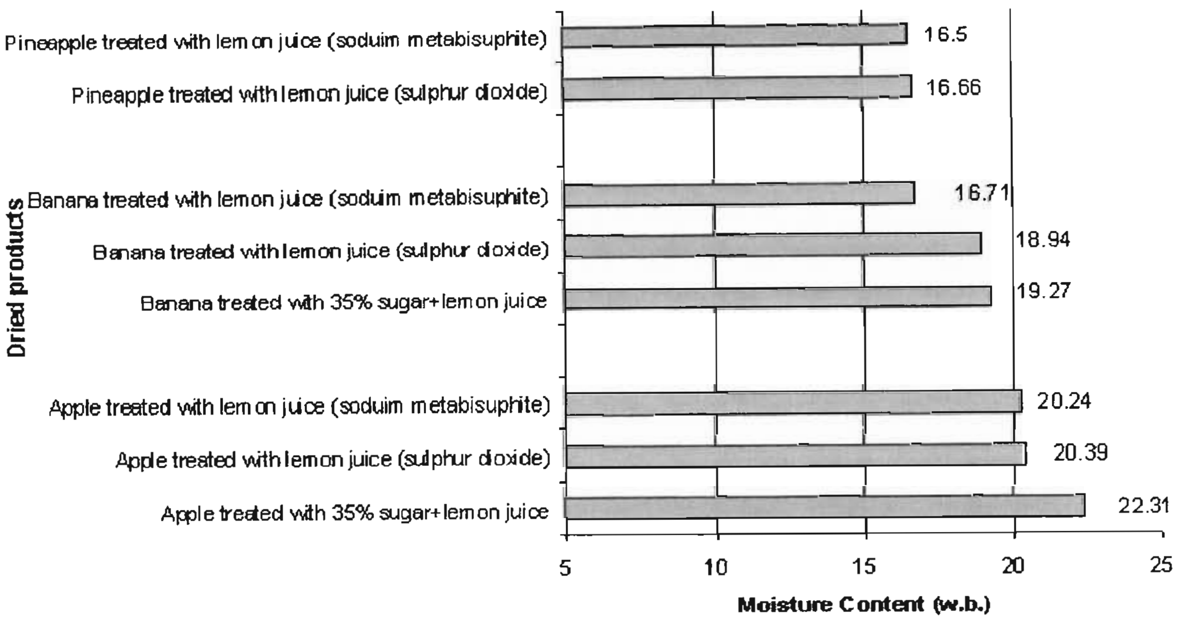


Figure 5.13: Moisture content of dried apple, banana, pineapple treated by different treatments.

For dried banana, the moisture content of the three pre-treatments was between 15-20%. No comparative literature studies were found to compare the results, but Dauthy (1995) and Owner (1998) assert that the moisture content of dried fruits should fall between 15 to 20%. As a result, the moisture content of the three samples were consistent with the reported by Dauthy (1995) and Owner (1998). This means that the solar drier and the pre-treatments is proficient to produce dried products with desirable final moisture content.

The moisture contents of the dried tomato, carrot and pumpkin samples were 8-9% (Figure 5.14). Andress and Harrison 1999, Azam-Ali *et al* 2003, p. 16, Owner (1998), and Reynolds (1993 c), report that the moisture content of dried vegetables should be less than 10%. The moisture content of the samples fell below this. Therefore, pre-treatments did not affect the final moisture content of the dried products.

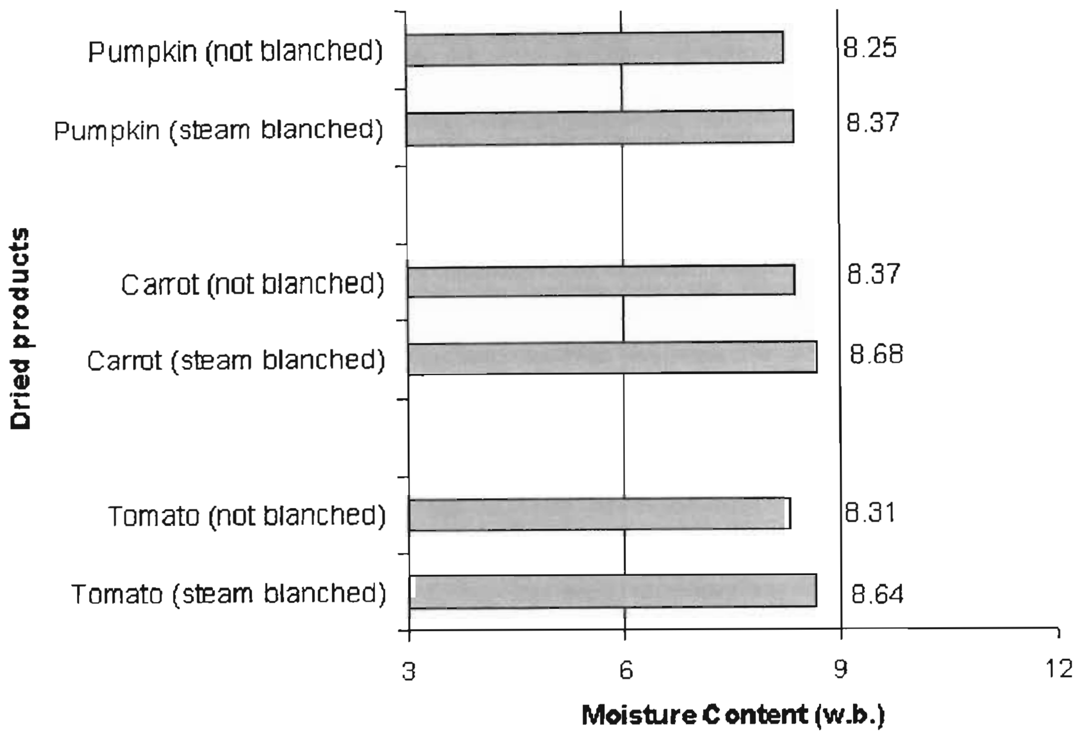


Figure 5.14: Moisture content of dried pumpkin, carrot, and tomato treated with steam blanching and not blanched (control).

5.4 Difference in temperatures inside and outside the solar drier

Temperatures and humidity inside the solar drier was recorded with a digital data logger and compared to data collected at the farm for the atmospheric temperatures and humidity during drying periods in July and August. On average, the internal solar drier temperatures were 20-29°C higher than the atmospheric temperatures (Figures 5.15 and 5.16).

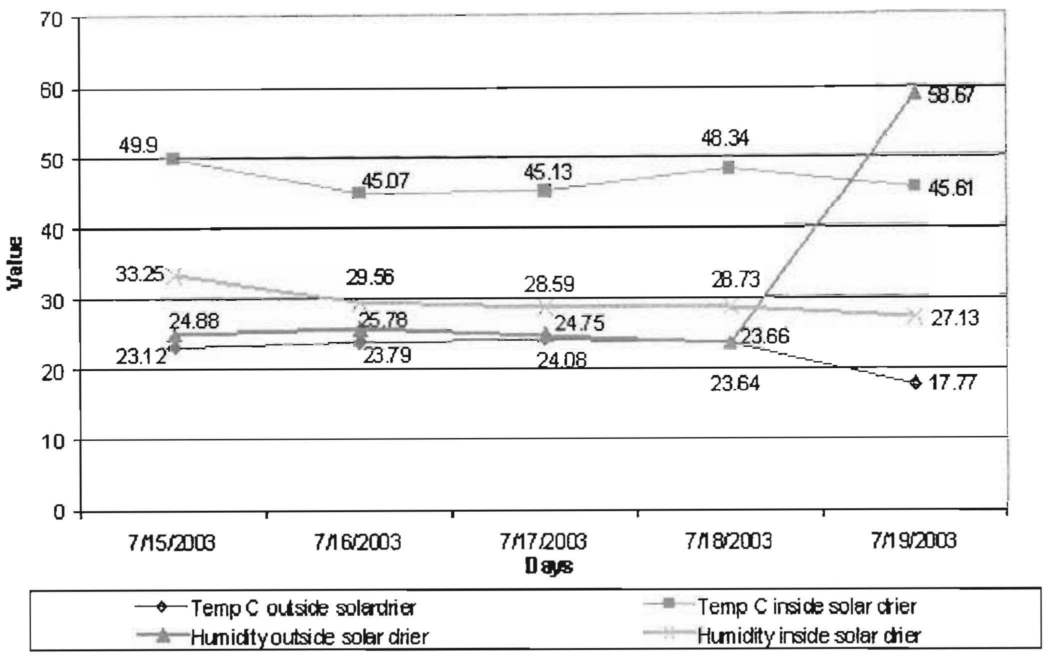


Figure 5.15: Average temperature and humidity inside and outside the solar drier during the drying process at Ukulinga farm, July 2003

Hughes and Willenberg (1994) recommend that internal solar drier temperatures in should be 20-30°C higher than atmospheric temperatures. The humidity inside the solar drier was found to be higher than outside during the first three days of drying and then the internal humidity dropped below the atmospheric temperature (Figures 5.5 and 5.16). This could be due to the fact that evaporation rates during the first three days of the drying process were higher than later in the drying process, meaning the marginal evaporation rate of the products decreases in the course of the drying process. Successful drying needs a minimum temperature of 29°C and humidity below 60 percent (Reynolds 1993 b).

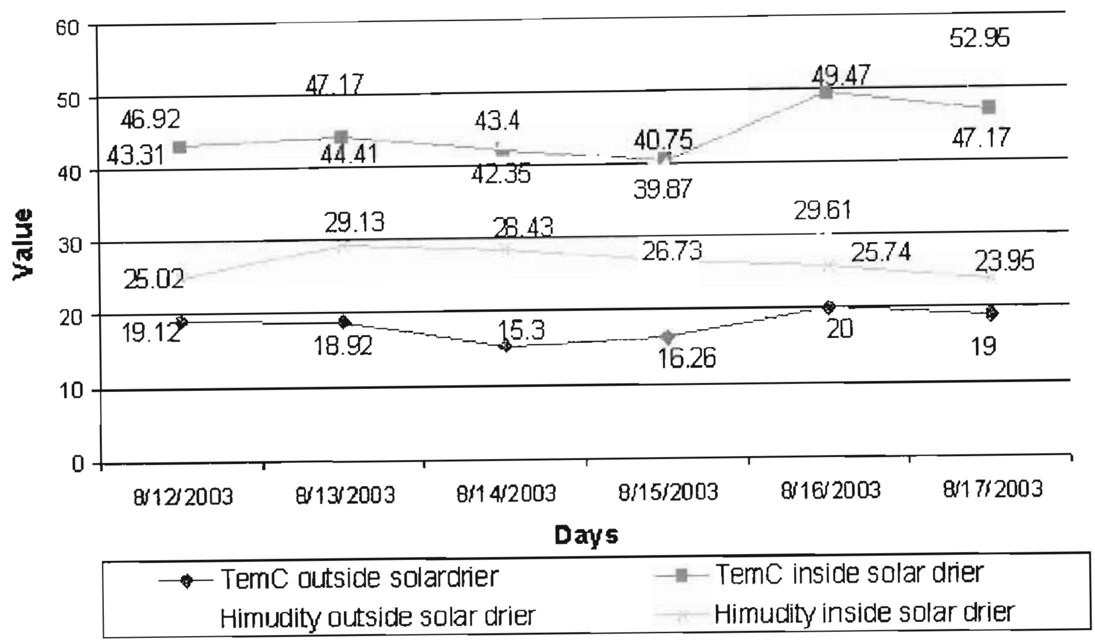


Figure 5.16: Average temperature and humidity inside and outside the solar drier during the drying process in Ukulinga farm, August 2003

The internal drier temperatures ranged from 40-49°C during the drying process and the humidity ranged between 25-33%. These results concur with Headley and Hinds (1999) findings where ideal internal drier temperatures for onions were found to be between 40 and 45°C.

5.5 Efficiency of the solar drier

As part of evaluation the solar drier efficiency of the solar drier three tests were carried out. A sensory test was done to evaluate the quality of dried products produced by the solar drier. The results of the sensory evaluation of the dried products as discussed above indicated that panellists liked most of the dried products produced by the solar drier. Also the solar drier is capable of drying fresh fruits and vegetables to a final moisture content of between 15% - 25% w.b. for fruits and 8-10% w.b. for vegetables. Moreover, the ability of the solar drier to maintain the desired level of temperature and humidity inside the drier indicates its efficiency. On average, the internal solar drier temperatures were

20-29°C higher than the atmospheric temperatures. The levels of temperature and humidity are found to be similar with the results of many previous studies. Hughes and Willenberg (1999) reported that the internal solar drier temperature should be 20-30°C higher than atmospheric temperatures. Moreover, the quality characteristics such as colour, flavour, texture, and moisture content of the dried fruits and vegetables support that the solar drier was efficient.

CHAPTER SIX

CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS FOR FURTHER STUDY

The potential of solar driers in the KwaZulu-Natal midlands, South Africa was investigated through the assessment of the availability of commercial dried products with opportunities for small scale production, evaluating the quality of the dried fruits and vegetables in terms of colour, flavour, texture, and moisture content, and study the efficiency of a specially designed solar drier. This study had three sub problems. First, to identify the possibility of production and what types of products could be dried, a survey was conducted at four main supermarkets namely: Pick'n Pay (Hayfields), Shoprite Checkers (Cascades branch), Woolworth's, and Park Lane Spar. For this part of the study, types of treatments, drying methods, and packaging used commercially were identified. The weather conditions[8] (temperature, humidity, and rain fall) of the study area that cover the period of 1959 to 1994 were considered to identify the most appropriate seasonality for drying. Second, to evaluate the quality of the solar dried products, both objective and subjective methods were used. On the subjective method, sensory evaluation was used to evaluate how community members perceive and prefer dried products in terms of their colour, texture, and flavour. Objective evaluation was used to determine the moisture content of the produce and to compare with available standards moisture level of the dried fruits and vegetables.

Third, the efficiency of the solar drier was studied by evaluating the quality of experimental dried products in terms of colour, flavour, texture, and moisture content. Moreover, the efficiency of the solar drier was evaluated by comparing the conditions in the drier to available standards of other similar studies. The quality characteristics of the solar dried products and the moisture content as it is presented in the second sub problem both subjective and objective methods, respectively were used. The condition (temperature and humidity) of the solar drier was measured using a data logger (Boxcar Pro 4) to evaluate the temperature and humidity levels inside and outside the solar drier

[8] The data was obtained from the University of KwaZulu-Natal Department of Agro-metrology.

and it was compared with daily temperature data recorded by the Agro-meteorology Department at the farm. The difference was used as a proxy measure of the efficiency of the solar drier.

The summary of the market survey indicated that most dried products were dried by sun energy (direct sun drying or solar drying), which is less expensive than using dehydrators or ovens. Plastic (polyethylene bags) was found to be applicable as packaging material for most dried products, which was affordable to small scale farmers. In terms of pre-treatments, sulphur dioxide was the most commonly used method for treating fruits followed by ascorbic acid and citric acid. Farmers in KwaZulu-Natal grow most of the raw materials used in drying the products surveyed. The climatic conditions of the study area indicated that the drying process could be applied almost all year round. January-April and October- December were the best months for drying because of the appropriate temperature (these months are also the peak season for some fruits and vegetables). Moreover, May, June, July, and August, in which this study was conducted, were found to be good times for drying fruits and vegetables, but not much produce is available (especially fruits).

The effect of various treatments on the quality of the experimental dried fruits and vegetables was examined. Apple, and banana were treated by three methods, namely 35% sugar syrup with lemon juice preserved with sulphur dioxide, lemon juice preserved with sulphur dioxide, and lemon juice preserved with metabisulphite. Pineapples were treated with lemon juice preserved with sulphur dioxide, and lemon juice preserved with metabisulphite. Half the vegetables (carrot, tomatoes, and pumpkin) were pre-treated with steam blanching, and the remaining acted as not blanched (control).

Generally, pre-treated fruits and vegetables were found to be efficient in keeping the quality of the dried products, but the effectiveness of the treatments varied according to the type of treatments used. The study of the effects of various treatments on the quality of the dried fruits and vegetables indicated that different treatment methods used had significant difference on the quality of the final products.

Results of the sensory evaluation indicated that the dried apple and banana treated by sugar syrup with lemon juice preserved with sulphur dioxide had the highest rating for colour followed by that of lemon juice with sulphur dioxide and lemon juice preserved with sodium metabisulphite. For flavour and texture the sensory scores of the products treated by sugar syrup with lemon juice sulphur dioxide were the greatest and differed significantly from both samples that were treated by lemon juice with sulphur dioxide and by lemon juice with sodium metabisulphite. It can, therefore, be concluded that preserved apple and banana had higher acceptability when pre-treated with sugar syrup with lemon juice preserved with sulphur dioxide followed by samples treated with lemon juice preserved with sulphur dioxide. The results of sensory data of the dried pineapple treated with lemon juice sulphur dioxide had the higher rating for colour, flavour, and texture than dried pineapple treated with lemon juice preserved with sodium metabisulphite.

The colour, flavour and texture of the dried pumpkin and tomato treated by steam blanching were found to be better and significantly different from the un-treated samples. There was no significant difference between the dried carrots treated with steam blanching and the control sample in terms of flavour and colour, but a significant difference was found between the steam blanched sample and the control one in terms of texture. Thus, tomato and pumpkin should be treated by steam blanching and carrot can dry without treatments.

The results of temperature records indicated that the solar drier used was efficient to raise the temperature inside the solar drier sufficiently higher than the temperature outside of the solar drier (e.g. from 20-29°C above atmosphere temperature). The results of the sensory evaluation of the dried products produced by the solar drier indicated that the contribution of the solar drier to products is strong evidence for the effectiveness of the drier.

6.1 Conclusions

The study hypothesised that quality produce can be dried on a small scale using an efficient solar drier. Analysis of the first subproblem identified the possibility of production and what types of products could be dried. The results of markets survey showed that, the drying methods used, treatment, packaging, raw material, and processing practical are all appropriate to be applied by small scale farmers. Moreover, the range of the dried products found in the market survey indicated that there is a market opportunity for small scale farmers' products. Although the study was conducted in a short period during which most produce were not available, it seems that it may be possible to dry many products produced by small scale farmers in KwaZulu-Natal, because of the climatic conditions of the study area indicated that the solar drying process could be applied almost all year round.

The analysis of the second subproblem showed that the quality of the dried fruits and vegetables could be improved by using the solar drier and appropriate pre-treatments before drying the products. Results indicated that dried apple and banana treated with sugar syrup with lemon juice preserved with sulphur dioxide and the other samples treated with lemon juice preserved with sulphur dioxide had higher acceptability in terms of colour, flavour, and texture. Sample dried pineapple treated with lemon juice preserved with sulphur dioxide and tomato and pumpkin treated with steam blanching had high acceptability in terms of colour, flavour, and texture. Moreover, the dried carrot treated with steam blanching and the control sample (not blanched) were both found to have high quality characteristics. It is therefore recommended that small scale farmers should use the solar drier to produce good quality final products in order to achieve adequate micronutrient intake the whole year round.

Analysis of the data for the third subproblem found that the solar drier used was efficient. The high panellists' rating for the dried products implies that the products were acceptable to the consumers. Moreover, the capability of the solar drier to attain the standard level of moisture and the ability of the solar drier to maintain the desired level of temperature and humidity inside the drier indicates its efficiency.

6.2 Recommendations

It is recommended that small scale farmers or household level production can use the sun's energy for small scale solar drying. Moreover, small scale farmers could use plastic (polyethylene bags) as packaging material for most dried products. In May, June, July, and August it is recommended that small scale farmers in KwaZulu-Natal dry surpluses of banana, pineapple, cabbage, and carrot. Moreover, during January-April and October-December small-scale farmers could dry banana, beans, cabbage, carrot, mango, onion, papaya, potato, pumpkin, and tomato.

It is recommended that small-scale farmers use appropriate pre-treatment methods to treat their products before drying. Apples and bananas should be treated with sugar syrup with lemon juice preserved with sulphur dioxide or lemon juice preserved with sulphur dioxide. Pineapples should be treated with lemon juice preserved with sulphur dioxide. For treating tomatoes and pumpkins, steam blanching is recommended, while carrot can be dried without pre-treatment.

Solar energy is a renewable energy source. Since it uses sunlight to evaporate the moisture from food items, simple low cost technology is easy to learn, reduces contamination, and it has great potential for social acceptance. Thus solar drying is a much faster process and is suitable to use in KwaZulu-Natal during July-August. This is because the climate is humid and the maximum average temperature is less than 30°C which is not sufficient for drying by using traditional solar methods (direct sun drying).

Solar drying is simple and could be used by small scale farmers, but they need information about how the drier works, the use of pre-treatments and sanitation practices. Therefore, it recommended that small scale farmers are trained in all aspects of drying fruits and vegetables, such as the use of the drier, how the drier works, how to maintain it in good working order, how to prepare the fruit and vegetables, packaging, labelling, how to stock the products, marketing, and uses in the diet.

To improve the quality of the dried products, the following factors must be considered. First, the use of improved drying methods (solar driers). Second, the use of practical pre-treatments to preserve the colour, aroma, flavour, and to extend the shelf life of the final products. Third, the use of appropriate packaging material for packaging the dried products to extend the shelf life of the products, ensures that products reach customers in the best possible condition, and makes food more attractive to increase sales.

Another matter of concern is whether the products made by small-scale farmers is of a particular standard to compete with larger commercial farms/ companies. It is recommended that small-scale farmers make efficient use of the solar drier ensuring a high quality product. Small scale farmers should be innovative, for instance using attractive packaging relating to South Africa's cultural diversity. This will assist in attracting consumers and therefore in the competition against other established brands offering a greater variety at a higher standard.

6.3 Implications for further research

More research is needed to determine the profitability of solar drying fruits and vegetables in comparison to other alternatives available to the farmers. As an extension to this study, evaluation of the shelf life of the dried products, microbial testing, and evaluation of the nutritional value of the dried products needs to be investigated to assure that the solar drier maintains vitamins A and C of the dried products.

This research focused on developing an on-farm solar drier for small scale farmers and the efficiency of the solar drier by evaluating the quality of the final dried products, thus as an extension to this research, the cost and benefit analysis of the drier and the dried products should be carried out to support the effectiveness of the drier.

REFERENCES

Agona J.A, Nabawanuka J, Kalunda P. (2002). **A market overview of the dried fruit sector in Uganda.** A foodnet grants award project. National post harvest programme. [WWW document]. URL: http://www.foodnet.cgiar.org/Projects/Dried_Fruits_Ug.pdf (Accessed 01 January 2004).

Alwater Foods (2001). **Dried fruit.** Dried apple products. [WWW document]. URL: http://www.atwaterfoods.com/driedapple.html (Accessed 14 December 2003).

Andress E L, Harrison J A (1999). **Drying: Packaging and storing dried foods.** National Centre for Home Food Preservation. University of Georgia, Cooperative Extension Service. [WWW document]. URL: http://www.uga.edu/nchfp/how/dry/pack_store.html (Accessed 01 March 2003).

Anon (1996). **PH control: Why the concern?** Centre for Food Safety and Applied Nutrition. United State Food and Drug Administration. [WWW document]. URL: http://www.cfsan.fda.gov/~dms/ph-cntrl.html

Anon (1998). **Blanching vegetables.** Romweel Real Cooking. [WWW document]. URL: http://www.romwell.com/cookbook/Preserve/blanch.shtml (Accessed 23 December 2003).

Anon (2000). **Approximate pH of foods and food products.** Centre for Food Safety and Applied Nutrition. U.S. Food and Drug Administration. [WWW document]. URL: http://www.cfsan.fda.gov/~comm/lacf-phs.html (Accessed 12 December 2003).

Arfaoui Y (undated a). **Commercialisation of the solar drier.** (UNEP) United Nations Environment Programe. African Rural Energy Enterprise Development Initiative (AREED). Denmark. [WWW document]. URL:

http://www.areed.org/training/technology/solar_dryer/dryer_1.pdf (Accessed 10 March 2003).

Arfaoui Y (Undated b). (UNEP) United Nations Environment Programe. **African rural energy enterprise development initiative (AREED): The case study of Uganda.** [WWW document]. URL: http://www.areed.org/training/technology/solar_dryer/dryer_annex1.pdf (Accessed 27 April 2003).

Arthey D. (1991). **Vegetable processing.** Blackie and Son, New York.

Arthey V.D (1975). **Quality of horticultural products: Nutritional value.** Butterworth, London.

Azam-Ali, Judge E, Fellows P, Battcock M (2003). **Small-scale Food Processing.** ITDG Publishing: London.

Barbosa-Canovas G. V, Fernaadez-Molina J.J, Alzamora S.M, Tapia M. S, Lopez-Malo A, Chanes J. W. (2003). **Handling and preservation of fruits and vegetables by combined methods for rural areas.** Food and Agriculture Organization of The United Nations, Rome. [WWW document]. URL: http://www.fao.org/DOCREP/005/Y4358E/y4358e00.htm#Contents (Accessed 12 December 2003).

Blum M (2000). **Mobilizing nutrition efforts in South Africa.** Nutriview, Roche Vitamins Europe Ltd, Basel, Switzerland. [WWW document]. URL: http://www.nutrivit.org/vic/staple/N2000_4.pdf (Accessed 9 March 2003).

Bower JP (2003). Personal communication. Head of Discipline: Horticultural Science, School of Agriculture and Agribusiness. University of KwaZulu-Natal. (10 November 2003).

Brady P.L. (2003 a). **Drying fruits**. University of Arkansas, Cooperative Extension Service. [WWW document]. URL: http://www.uaex.edu/Other_Areas/publications/HTML/FSHED-55.asp (Accessed 02 December 2003).

Brady P.L. (2003 b). **Drying vegetables**. University of Arkansas, Cooperative Extension Service. [WWW document]. URL: http://www.uaex.edu/Other_Areas/publications/HTML/FSHED-56.asp (Accessed 02 December 2003).

Brett, A., Cox, D.R.S., Trim, D.S, Simmons, R, Anstee, G. (1996) a. **Producing Solar Drier Fruit and Vegetables for Micro-and Small-Scale Rural Enterprise Development.** Handbook 2-Dryer Construction. UK: Natural Resources Institute. Chatham.

Brett, A., Cox, D.R.S., Trim, D.S, Simmons, R, Anstee, G. (1996) b. **Producing Solar Drier Fruit and Vegetables for Micro-and Small-Scale Rural Enterprise Development.** Handbook 1: Assessing Opportunities. UK: Natural Resources Institute. Chatham.

Brennand C.P (1994). **Home drying of food.** Utah State University. [WWW document]. URL: http://extension.usu.edu/publica/foodpubs/fn330.pdf (Accessed 17 September 2003).

FAO (undated). Codex Alimentarius **Current official standard.** FAO/WHO Food Standards. [WWW document]. URL: ftp://ftp.fao.org/codex/standard/en/CXS_130e.pdf (Accessed 15 December 2003).

CTA (1997). **Preservation of Fruits and Vegetables: Drying of vegetables and fruits.** Agrodok 3. Agromisa Human Nutrition and Food Processing Group, Wageninge.

CTA (2000). **Small-scale Food Processing Sector in South Africa.** Technical Centre for Agricultural and Rural Cooperation URL: [WWW document]. http://www.agricta.org/pubs/wd8014/wd8014.pdf

Daniel J R. (1999). **Sensory evaluation of foods.** Department of Foods and Nutrition. Purdue University. [WWW document]. URL: http://www.cfs.purdue.edu/fdsnutr/fn453/ld_sensy.html (Accessed 26 November 2003).

Dauthy M. E. (1995). **Fruit and vegetable processing: Deterioration factors and their control.** FAO, Rome. [WWW document]. URL: http://www.fao.org/docrep/V5030E/V5030E00.htm#Contents (Accessed 14 January 2003).

Droits D. (1985). **Expert consultation on planning the development of sun drying techniques in Africa.** Proceedings of the Expert Consultation on Planning the Development of Sun drying Techniques in Africa. Rome. [WWW document]. URL: http://www.fao.org/inpho/vlibrary/x0018f/X0018F00.htm#Contents (Accessed 03 March 2003).

FAO (1997 a). **Agriculture, Food and Nutrition for Africa: A resource book for teachers of agriculture.** Food and Agriculture Organization of The United Nation. Rome.

FAO (1997 b). **Preventing micronutrient malnutrition: A guide to food-based approaches. A manual for policy makers and programme planners.** [WWW document]. URL: http://www.fao.org/docrep/X5244E/X5244e04.htm#P515_67769 (Accessed 15 July 2003).

FAO (1993). **Food, nutrition and agriculture: Seven strategies to combat micronutrient deficiencies.** [WWW document]. URL: http://www.fao.org/docrep/V1610t/v1610t00.htm#Contents (Accessed 15 July 2003).

FAO (1992). **Major issues for nutrition strategies.** International Conference on Nutrition. [WWW document]. URL: http://www.who.int/nut/documents/icn_issues.pdf (Accessed 13 November 2003).

FAO (1989). **Prevention of post-harvest food losses fruits, vegetables and root crops: A training manual.** [WWW document]. URL: http://www.fao.org/docrep/T0073E/T0073E00.htm#Contents (Accessed 01 March 2003).

FAO (1981). **Food loss prevention in perishable crops.** Agricultural Services Bulletin No.43, FAO. Rome [WWW document]. URL: http://www.fao.org/docrep/s8620e/S8620E0a.htm#4.%20Fruits%20and%20vegetables (Accessed 05 July 2003).

Fellows P (1997 a). **Traditional Foods: Processing for profit.** Intermediate Technology. London.

Fellows P (1997 b). **Guidelines for Small-Scale Fruit and Vegetables Processors.** FAO Agricultural Services Bulletin 127.

Fellows P, Hampton A (1992). **Small-scale Food Processing: A guide to appropriate equipment.** Intermediate Technology Publications. London.

Frank F., Kristensen E (1999). **Survey on solar dryers for drying of food and wood in Ghana.** Danish Technological Institute. [WWW document]. URL: http://www.risoe.dk/solenergi/rapporter/pdf/sec-r-4.pdf (Accessed 04 March 2003).

Gast B. L. K (undated). Post harvest management of commercial horticultural crops. **Storage conditions: Fruits & vegetables.** University of Maine Cooperative Extension. Bulletin#4135. [WWW document]. URL:

http://www.umext.maine.edu/onlinepubs/htmpubs/4135.htm (Accessed 27 February 2003).

GAIA-Movement (undated). **How to get vitamins year round: Solar drying fruit and vegetables.** [WWW document]. URL: http://www.gaia-movement.org/files/Booklet%202e%20%20Solar%20Drying.pdf (Accessed 19 March 2003).

General Chemical Corporation (2003). **Sodium Metabisulphite.** A Gen Tek Inc. Company. [WWW document]. URL: http://www.genchemcorp.com/products/sodmetabi.shtml (Accessed 11 December 2003).

Georgia University (undated). **Drying Fruits and Vegetables.** Georgia Cooperative Extension Service. College of Family and Consumer Sciences. [WWW document]. URL: http://www.uga.edu/nchfp/publications/uga/uga_dry_fruit.pdf (Accessed 23 December 2003).

Goldman L, Elliott J (1984). **Solar and energy conservation food technologies: A training manual.** [WWW document]. URL: http://mng-unix1.marasconewton.com/peacecorps/Documents/T0017/t0017e/t0017e00.htm#Contents (Accessed 17 April 2003).

Green G. M, Schwarz D (2001). **Solar drying technology for food preservation.** Gate Information. [WWW document]. URL: http://www5.gtz.de/gate/techinfo/techbriefs/E014E_2002.pdf (Accessed 04 March 2003).

GTZ-ITFSP (undated). **Fruit and vegetables drying.** Processing of tree crops: A farmer trainer training manual. [WWW document]. URL: http://www.gtz-treecrops.org/Downloads/Manuals/Processing/Module3.pdf. (Accessed 25 June 2003).

Harrison J. A, Adress E. L. (undated). **Preserving Foods: Drying fruits and vegetables.** University of Georgia College of Agricultural and Environmental Sciences. [WWW. Document]. URL: http://resources.caes.uga.edu/publications/PDF/FDNS-E43-10.pdf (Acessed 19 September 2003).

Harrison J (1993) **Drying fruits.** Cooperative Extension Service, The University of Georgia. http://hgic.clemson.edu/factsheets/HGIC3084.htm (cessed 23 August 2003).

Headley O, Hinds W (1999). **Medium scale solar crop dryers for agricultural products.** University of West Indies, St Augustine, Trinidad. [WWW document]. URL: http://wire0.ises.org/wire/doclibs/SWC1999.nsf/id/1267482C3CF90EABC1256920003D6168/$File/070.pdf (Accessed 01 December 2003).

Helrich K. (1990). **Official Methods of Analysis, Association of Official Analytical Chemists.** Moisture in Dried Fruits. Volume two, fifteenth edition. Washington, DC, USA

Herman M. (1998). **Blanching vegetables: Why and how. University of Minnesota. [WWW document]. URL:** http://www.extension.umn.edu/info-u/nutrition/BJ9676.htm (Accessed 23 December 2003).

Herregods (1998). **Post-harvest of horticultural crops: Storage issues.** [WWW decument]. URL: http://www.agrsci.unibo.it/wchr/wc2/herregod.html(Accessed 1 April 2003).

Herringshaw D. (1994). **Food drying.** Adapted from Bell M. Complete Dehydrator Cookbook. [WWW document]. URL: http://www.bagelhole.org/article.php/Food/125/ (Accessed 11 November 2003).

Holdsworth, S.D. (1983). **The Preservation of Fruit and Vegetables Food Products.** The Machmillan Press LTD,London.

Hughes, Willenberg J. (May 1994). **Quality for keeps: Drying foods.** Department of Food Science and Human Nutrition, University of Missouri. Columbia. [WWW document]. URL: http://muextension.missouri.edu/xplor/hesguide/foodnut/gh1562.htm (Accessed 10 January 2003).

ISHS (undated). International Society for Horticultural Science **Horticulture research international: South Africa.** [WWW document]. URL: http://www.hridir.org/countries/south_africa/ (Accessed 27 March2003).

Intermediate Technology Development Group (2002 a). **Drying of foods.** [WWWdocument]. URL. http://www.itdg.org/html/technical_enquiries/docs/drying_of_foods.pdf (Accessed 01 February 2003).

Intermediate Technology Development Group (2002 b). **Small scale drying technologies.** [WWWdocument]. URL. http://www.itdg.org/html/technical_enquiries/docs/drying_technology.pdf (Accessed 01 February 2003).

Intermediate Technology Development Group (2002 c). **Food poisoning and its prevention.** [WWWdocument]. URL. http://www.itdg.org/html/technical_enquiries/docs/food_poisoning.pdf (Accessed 27 February 2003).

Jackson N, Tingha NSW. (Undated). **Organic gardening: Food drying facts.** [WWW document]. URL: http://www.organicdownunder.com/solar_dryer.htm#Food%20Drying%20Facts Accessed 5 January 2003).

Kader A. A, Kasmire R. F, Mitchell F. G, Reid M S, Sommer N. F, Thompson J. F. (1992). **Post harvest technology of horticultural crops.** Second edition. Cooperative

Extension University of California Division of Agriculture and Natural Resources. Publication 3311. Agriculture and Natural Resources Publication, Berkeley.

Kenawi M.A.(2000). **Effect of different blanching methods on chemical and sensory evaluation of some selected vegetables.** Institute of Food Technologists. Annual Meeting, Technical Program Listing. Dallas. [WWW document]. URL: http://ift.confex.com/ift/2000/techprogram/paper_2216.htm (Accessed 02 December 2003).

Kendall P, Allen L (1998). **Drying Fruits.** Colorado State University Cooperative Extension. [WWW document]. URL: http://www.ext.colostate.edu/pubs/foodnut/09309.html (Accessed 23 June 2003).

Kendall P, Allen L (2002). **Drying Vegetables.** Colorado State University Cooperative Extension. [WWW document]. URL: http://www.ext.colostate.edu/pubs/foodnut/09308.html (Accessed 23 June 2003).

Kovach T.R (1999). **Blanching vegetables.** Backwoods Home Magazine. [WWW document]. URL: http://www.backwoodshome.com/articles/kovach59.html (Accessed 23 December 2003).

Labadarios D (2000). The National Food Consumption Survey (SFCS): **Children aged 1-9 years, South Africa 1999.** [WWW document]. URL: http://www.defra.gov.uk/exports/downloads/sareport.pdf (Accessed 09 June 2003).

Linton B, Westell T (2001). **Agriculture in South Africa: International relations and export promotion division.** [WWW document]. URL: http://www.defra.gov.uk/exports/downloads/sareport.pdf (Accessed 30 March 2003).

Mason C, Evers W.D, Hanley E (undated). **Consumer and Family Sciences: Drying foods at home.** [WWW document]. URL: http://www.agcom.purdue.edu/Agcom/pubs/CFS-146-W.pdf (Accessed 24 August 2003).

Michigan State University Extension (1999). **Pre-Drying Fruit Treatment.** [WWW document]. URL: http://www.msue.msu.edu/msue/imp/mod01/01600525.html (Accessed 22 December 2003).

Minnaar A. (undated). **Food handling and processing technologies in rural communities**. In: D'Haese L and Kirsten J (editors). *Fundamentals of Nutrition Security in Rural Development.*

Modi AT (2003). Personal communication. Senior lecturer, Crop Science, School of Agriculture and Agribusiness. University of KwaZulu-Natal. (10 November 2003).

Mulokozi G., Mselle C., Mugyabuso J.K.L., Ndossi G.D. (March 2000). **Improved solar drying of vitamin A-rich food by women's groups in the Singida district of Tanzania.** [WWW document]. URL: http://www.icrw.org/docs/Tanzaniareport.pdf (Accessed 03 May 2003).

National Department of Agriculture (2000 a). **Trend in the agricultural sector: Dried Fruit. Pretoria.** [WWW document]. URL: http://www.nda.agric.za/docs/Trends2000/dried_fruit.htm (Accessed 01 June 2003).

National Department of Agriculture (2000 b). **Trends in the agricultural sector: Subtropical fruit.** [WWW document]. URL: http://www.nda.agric.za/docs/Trends2000/subtropical_fruit.htm (Accessed 27 March 2003).

National Department of Agriculture (2000 c). **Trend in the agricultural sector: Citrus fruit.** [WWW document]. URL: http://www.nda.agric.za/docs/Trends2000/citrus_fruit.htm (Accessed 27 March2003).

National Department of Agriculture (2000 d). **Trends in the agricultural sector: Deciduous fruit.** [WWW document]. URL: http://www.nda.agric.za/docs/Trends2000/horticulture.htm (Accessed 27 March2003).

Oregon State University (1998). **Sensory Evaluation:** Sensory Evaluation and The Hedonic Scale. Food Resource, Nutrition and Food Management, Oregon State University. [WWW document]. URL: http://food.oregonstate.edu/sensory/dena.html (Accessed 01 September 2003).

Owner (1998). **Drying and preserving food part three.** Recipe Source. [WWW document]. URL: http://www.recipesource.com/misc/hints/01/rec0154.html (Accessed 04 October 2003).

Piggott J.R (1988). **Sensory Analysis of Foods: Statistical Analysis of Sensory Data.** Second edition. Elsevier Science Publisher LTD, UK.

Post A. (2003). **Preparing fruits and vegetables to be dried.** [WWW document]. URL: http://www.preservedgardens.com/fruits-vegetables.htm (Accessed 02 January 2004).

Pryor T. (2001). **Solar drying.** [WWW document]. URL: http://acre.murdoch.edu.au/unep/papers/Pryor%20Drying.pdf (Accessed 10 March 2003).

Ranganna S. (1986). **Handbook of Analysis and Quality Control for Fruit and Vegetable Products: Sensory Evaluation.** Second edition, Tata Mcgraw-Hill Publishing Company Limited, New Delhi.

Reynolds, S.M (1993 a). **Drying prepared fruits.** Georgia University Cooperative Extension Service. Third edition. [WWW document]. URL: http://www.agen.ufl.edu/~foodsaf/he522.html (Accessed 15 June 2003).

Reynolds, S.M. (1993 b). **Drying foods out-of-doors.** University of Georgia Cooperative Extension Service. [WWW document]. URL: http://www.agen.ufl.edu/~foodsaf/he520.html (Accessed 05 September 2003).

Reynolds, S.M. (1993 c). **Drying vegetables.** Georgia University Cooperative Extension Service. Third edition. [WWW document]. URL: http://www.agen.ufl.edu/~foodsaf/he526.html (Accessed 15 June 2003).

Reynolds, S.M (1998 a). **Pre-treating fruits for drying.** Cooperative Extension Service, University of Florida. [WWW document]. URL: http://edis.ifas.ufl.edu/pdffiles/HE/HE52300.pdf (Accessed 11 December 2003).

Reynolds, S.M (1998 b). **Pre-treating vegetables.** Cooperative Extension Service, University of Florida. [WWW document]. URL: http://edis.ifas.ufl.edu/pdffiles/HE/HE52300.pdf (Accessed 11 December 2003).

Roberts T (1999). **Drying Fruits and Vegetables.** Virginia Cooperative Extension. [WWW document]. URL: http://www.ext.vt.edu/pubs/foods/348-597/348-597.html (Accessed 11 November 2003).

Rodriguez-Amaya D. B. (2003). **Enhancing the carotenoid levels of foods through agriculture and food technology.** [WWW.document]. URL: http://foodafrica.nri.org/nutrition/internetpapers/DeliaBRodriguez.pdf (Accessed 17 September 2003).

Sekiku J (2003). **Technical and economic considerations for construction of solar dryers and preparing solar dried products.** [WWW document]. URL: http://www.organic-research.com/research/Papers/solardry.asp (Accessed 27 April 2003).

Schmutz P.H, Hoyle E.H (undated). **Drying vegetable.** Home and Garden information Center. [WWW document].URL: http://hgic.clemson.edu/PDF/HGIC3085.pdf (Accessed 12 December 2003).

Scholl J. (undated). **Tasty tidbits-food experiment solutions.** Agricultural Extension Education. Pennsylvania State University. [WWW document]. URL: http://agexted.cas.psu.edu/docs/29503663.html (Accessed 11 December 2003).

Smith D.S, Cash J.N, Nip W.K, Hui Y.H. (1997). **Processing Vegetables.** Science and Technology. Technomic Publishing Company, Basel.
Smith K.L (Undated). **Drying foods**. The Ohio State University Extension, Human Nutrition. [WWW document]. URL: http://ohioline.osu.edu/hyg-fact/5000/5347.html (Accessed 12 December 2003).

Somogyi L.P, Barrett D.M, Hui Y.H. (1996). **Processing fruits.** Science and Technology. Technomic publishing company, Basel.

Stapleton B (2000). **Water Activity in Dried Fruits.** CEO-Stapleton-Spence Packing Co. [WWW document]. URL: http://www.stapleton-spence.com/CustomerService/wateractivityprunes.htm (Accessed 15 December 2003).

Stone H, Sidel J. L. (1993). **Sensory Evaluation Practices: The organization and Operation of sensory evaluation programs.** Second edition, Academic Press Limited, London.

Toma R, Fanster L.T. Knipe M.T, (1990). **World food shortage: The third dimension.** [WWW decument]. URL: http://www.arec.umd.edu/arec365/castpharv.htm (Accessed 06 February 2003).

Trade Partners (2003). **Agriculture, horticulture and fisheries market in South Africa: Overview** [WWW document]. URL: http://www.tradepartners.gov.uk/agriculture/south_africa/profile/overview.shtml (Accessed 13 June 2003).

Troftgruben J, Keith M (1984). **Drying food.** [WWW document]. URL: http://www.ag.uiuc.edu/~vista/html_pubs/DRYING/dryfood.html (Accessed 15 March 2003).

Tropical Wholefoods (undated). **Products-Dried Fruits.** Tropical Wholefoods Company. [WWW document]. URL: http://www.fmfoods.co.uk/tw/Products_Fruit.htm (Accessed 02 July 2003).

UNIDO (undated). **Solar drying of fruits in Senegal.** [WWW document]. URL: http://www.unido.org/userfiles/PuffK/Women_environ.pdf (Accessed 03 May 2003).

UNIFEM (1993). Food Cycle Technology Source Books: **Fruit and Vegetable Processing.** Intermediate Technology, London.

University of California (1998). **Drying foods at home.** Calaveras County Cooperation Extension. [WWW document]. URL: http://cecalaveras.ucdavis.edu/dry.htm (Accessed 22 December 2003).

University of Georgia Cooperative Extension Service (undated). **Preserving food: Drying fruits and vegetables.** [WWW document]. URL: http://www.uga.edu/nchfp/publications/uga/uga_dry_fruit.pdf (Accessed 27 April 2003).

University of Idaho (1995). **Drying fruits and vegetables. 2nd Edition.** [WWW document]. URL: http://info.ag.uidaho.edu/Resources/PDFs/PNW0397.pdf (Accessed 03 August 2003).

University of Illinois, College of Agricultural, (1995). **Food self-life recommendation.** [WWW document]. URL: http://www.solareagle.com/PREP/SHLFLIFE.HTM (Accessed 10 April 2003).

Vanderhulst P, Lanser H, Bergmeyer P, Foeth F, Albers R. (1990). **Solar energy: Small scale applications in developing countries.** [WWW document]. URL: http://www.student.utwente.nl/~wot/ssadc/index.html (Accessed 5 February 2003).

Walsh C. (undated). **Sensory Evaluation: Introduction to Sensory Evaluation, Sensory tests and test conditions.** Liverpool John Moores University. [WWW document]. URL: http://cwis.livjm.ac.uk/ecs/con_st/cs2033/Lect1.ppt (Accessed 01 September 2003).

Welch C, Alemu B, Msaki T, Sengendo M, Kigutha H, Wolff Antonia (2000). **Improving Household Food Security.** [WWW document]. URL: http://www.wisc.edu/ltc/live/basprog6.pdf (Accessed 16 November 2003).

Whitfield D E (2000). **Solar Cooking: Solar drying.** [WWWdocument]. URL: http://solarcooking.org/drying/Whitfield-drying1.htm (Accessed 5March 2003).

Wolf I.D, Labuza T.P, Olson W.W, Schafer W. (1990). **Drying foods at home.** University of Minnesota Extension Service. [WWW document]. URL: http://www.extension.umn.edu/distribution/nutrition/DJ0820.html (Accessed 12 december 2003).

Appendix A: Frequency and percentage of dried products used as ingredients in PMB stores April 2003.

Dried Product	*Frequency Available*	*Percent% Available*
Apple	7	14
Banana	2	4
Pear	6	12
Raisins	3	6
Figs	4	8
Nectar	0	0
Golden sultan	1	2
Seed less raisins	1	2
Mango	4	8
Sultanas	2	4
Dates	0	0
Prune	6	12
Nuts	1	2
Pineapple	1	2
Apricot	13	26
Guava	3	6
Peach	9	18
Tomato	17	34
Mushroom	0	0
Carrot	6	12
Onion	12	24
Potato	2	4
Herbs	2	4
Chillies	9	18
Garlic	8	16
Spice	4	8
Black pepper	3	6
Spinach	2	4

Appendix B: The three treatments for treating apple, banana, and pineapple

Apples: -

After washing the selected apples were peeled then cut into 5mm uniform rings and received three different treatments before drying.

Experiment	Treatment used
Experiment I	**Sugar syrup:** Sugar solution were prepared by combining two litre of water with 700 grams of sugar and 500 ml of lemon juice. The solution was brought to boil then the apples rings were placed in to the solution for 10 minutes. The treated apples were drained on paper towels and arranged in single layers on the drier trays.
Experiment II	**Lemon juice (treated by sulphur dioxide) solution:** This was prepared by adding 250 ml lemon juice to one- litre of bowl water. Then the apple rings were placed immediately in the solution and left for five minutes. The treated apples were drained on paper towels and arranged in single layers on the drier trays.
Experiment III	**Lemon juice (treated by sodium metabisulphite) solution:** This was prepared by adding 250 ml lemon juice into one- litre of bowl of water. Then the apple rings were placed immediately in the solution and left for five minutes. The treated apples were drained on paper towels and arranged in single layers on the drier trays.

Pineapples: -

After washing the selected pineapples were peeled then cut into 8mm uniform rounds slices and received two different treatments before drying.

Experiment	Treatment used
Experiment I	**Lemon juice (treated by sulphur dioxide) solution:** This was prepared by adding 250 ml lemon juice to one- litre of bowl water. Then the rounds slices were placed immediately in the solution and left for five minutes. The treated pineapples were drained on paper towels and arranged in single layers on the drier trays.
Experiment II	**Lemon juice (treated by sodium metabisulphite) solution:** This was prepared by adding 250 ml lemon juice to one- litre bowl water. Then the rounds slices were placed immediately in the solution and left for five minutes. The treated pineapples were drained on paper towels and arranged in single layers on the drier trays.

Banana: -

After washing the selected bananas were peeled then cut into 5mm uniform coin slices. Then the prepared bananas were treated by three different treatments before drying.

Experiment	Treatment used
Experiment I	**Sugar syrup:** Sugar syrup: Sugar solution were prepared by combining two litre of water with 700 grams of sugar and 500 ml of lemon juice. The solution was brought to boil then the rounds bananas were placed in to the solution for 10 minutes. The treated bananas were drained on paper towels and arranged in single layers on the drier trays.
Experiment II	**Lemon juice (treated by sulphur dioxide) solution:** This was prepared by adding 250 ml lemon juice to one- litre of bowl water. Then the rounds slices of bananas were placed immediately in the solution and left for five minutes. The treated bananas were drained on paper towels and arranged in single layers on the drier trays.
Experiment III	**Lemon juice (treated by sodium metabisulphite) solution:** This was prepared by adding 250 ml lemon juice to one- litre of bowl water. Then the rounds slices of bananas were placed immediately in the solution and left for five minutes. The treated bananas were drained on paper towels and arranged in single layers on the drier trays.

Appendix C: The two treatments for treating tomato, carrot, and pumpkin

Tomatoes: -

After washing the selected tomatoes were cut into uniform 5mm slices and received two different treatments before drying.

Experiment	Treatment used
Experiment I	**Steam blanching:** The sliced tomato was placed in a colander to circulate steam freely around the slices of tomatoes. The colander with the sliced tomato was placed loosely over a large kettle two-thirds full of water then brought to a boiling point. The sliced tomato was steam blanched for three minutes. The blanched tomato was sprinkled with 50 grams of salts per kilogram and then drained on paper towels and were finally arranged in single layers on the drier trays.
Experiment II	**Untreated:** The sliced tomato was sprinkle with salt (50 grams per one kilogram) then arranged in single layers on the drier trays.

Carrots: -

Carrots were cut into 5mm uniform slices and received two different treatments before drying.

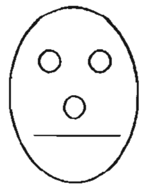
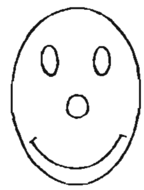
Experiment	Treatment used
Experiment I	**Steam blanching:** The sliced carrot was placed in a colander to circulate steam freely around the slices of carrots. The colander with the sliced carrot was placed loosely over a large kettle two-thirds full of water then brought to a boiling point. The sliced carrot was steam blanched for four minutes. Then were drained on paper towels and arranged in single layers on the drier trays.
Experiment II	**Untreated:** The sliced carrot was arranged in single layers on the drier trays.

Pumpkin: -

Pumpkin were cut into 8mm slices and received by two different treatments before drying.

Experiment	Treatment used
Experiment I	**Steam blanching:** The sliced pumpkin was placed in a colander to circulate steam freely around the slices of pumpkins. The colander with the sliced was placed loosely over a large kettle two-thirds full of water then brought to a boiling point. The sliced pumpkin was steam blanched for four minutes. Then were drained on paper towels and arranged in single layers on the drier trays.
Experiment II	**Untreated:** The sliced pumpkin was arranged in single layers on the drier trays.

Appendix D: Hedonic scale table for evaluation of sensory attributes of dried fruits and vegetables.

Quality attributes	Dislike very much 	Dislike 	Neither like nor dislike 	Like 	Like very much 
Colour					
Flavour					
Texture					

Appendix E: Panel instructions

The following instructions were read out to the panellists before testing the samples:

- Please fill the blank places on the top of the questionnaire; name, age, sex, sample code, and date.
- Please keep the taste session without interruptions and distractions to help you for concentrate on the test.
- Each questionnaire had a picture of the fresh fruit/vegetable from which the sample is generated.
- You will be given one sample of food to eat and you are asked to say about the sample how much you like it or dislike it interim of the colour, flavour, and texture.
- Use the appropriate scale to show your attitude by checking at the point that best describes your feeling about the sample.
- Rinse your mouth out before proceed to the next sample. If necessary you may re-taste the sample, but only once.
- When you have finished on giving your feeling about the color, flavor, and texture of the sample, check that the answer sheet is complete.
- An assistant will help you in remove the sample and the answer sheet in front of you and bring the next sample.
- The orders of serving are provided randomly of each subject.
- Keep in mind that you are the only one who can tell what you like.
- An honest expression of your personal feeling will help as to decide.

Thank you

Appendix F: Frequency tabulation of the panellists' scores for degree of liking for dried fruits.

Variables	Scale rating frequency*				
	1	2	3	4	5
Experiment 1 Dried Apple					
Treatment 1					
Colour	0	1	6	16	24
Flavour	1	0	3	14	29
Texture	0	2	3	16	26
Treatment 2					
Colour	6	8	4	15	14
Flavour	4	4	5	11	23
Texture	6	6	4	13	18
Treatment 3					
Colour	15	14	5	9	3
Flavour	9	9	6	15	7
Texture	8	14	7	13	4
Experiment 2 Dried Banana					
Treatment 1					
Colour	0	1	3	13	30
Flavour	1	1	3	16	26
Texture	0	0	2	18	27
Treatment 2					
Colour	3	0	4	18	22
Flavour	3	4	7	12	21
Texture	0	3	4	19	21
Treatment 3					
Colour	7	11	7	13	9
Flavour	5	7	6	12	17
Texture	4	4	6	15	18
Experiment 3 dried Pineapple					
Treatment 1					
Colour	0	0	4	8	35
Flavour	0	0	4	12	31
Texture	0	0	5	14	28
Treatment 2					
Colour	8	15	8	10	6
Flavour	4	10	5	9	19
Texture	6	11	8	14	7

*Scale used for degree of liking rating was as follows: 5=Like very much, 4=Like, 3=neither like nor dislike, 2=Dislike, 1= Dislike very much.

Appendix G: Frequency tabulation of the panellists' scores for degree of liking dried vegetables.

Variables	Scale rating Frequency*				
	1	2	3	4	5
Experiment 1 Dried Tomato					
Treatment 1					
Colour	1	1	2	15	28
Flavour	3	3	2	14	25
Texture	1	4	3	16	23
Treatment 2					
Colour	3	7	11	17	7
Flavour	6	8	9	13	9
Texture	3	8	10	18	6
Experiment 2 Dried Carrot					
Treatment 1					
Colour	0	0	1	11	35
Flavour	1	5	1	9	31
Texture	1	0	0	18	28
Treatment 2					
Colour	0	2	3	12	30
Flavour	1	5	5	11	25
Texture	0	4	4	18	21
Experiment 3 dried pumpkin					
Treatment 1					
Colour	0	0	2	8	37
Flavour	2	2	0	11	32
Texture	1	0	2	12	32
Treatment 2					
Colour	3	10	9	18	7
Flavour	7	6	7	13	14
Texture	7	5	9	18	8

*Scale used for degree of liking rating was as follows: 5=Like very much, 4=Like, 3=neither like nor dislike, 2=Dislike, 1= Dislike very much.