African Journal of Biotechnology Vol. 4 (13), pp. 1612-1621, December, 2005
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2005 Academic Journals

Review

Traditional fermented protein condiments in Nigeria

O. K. Achi

Department of Microbiology, Michael Okpara University of Agriculture, PMB 7267, Umudike, Abia State, Nigeria. E-mail: omekachi@yahoo.com.

Accepted 16 September, 2005

Traditional fermented condiments (*dawadawa, iru, ogiri*) based on vegetable proteins, and consumed by different ethnic groups in Nigeria have been the pride of culinary traditions for centuries. It is evident that these products have played a major role in the food habits of communities in the rural regions serving not only as a nutritious non-meat proteins substitute but also as condiments and flavouring agents in soups. These condiments are being increasingly marketed throughout the country and beyond in informal ways. Differences in the chemical composition of fermented condiments are evident mainly because different ingredients have been used in their preparation. Traditional methods of manufacture should take advantage of biotechnological progress to assure reasonable quality and at the same time assure safety of these products. The requirements for a sustainable biotechnological development of Nigerian condiments are discussed in the scope of the microbiology and biochemical changes of the raw materials. Schemes to standardize the manufacturing stages are proposed. Emphasis is placed on the relevance of the role of starter cultures in the traditional methods of manufacture to ascertain appropriate nutritional quality and physical properties of the final product. Fermented vegetable proteins have potential food uses as protein supplements and as functional ingredients in fabricated foods. Relevant research and development activities are suggested.

Key words: Traditional condiment fermentation, *dawadawa, iru, ogiri*, manufacturing process, starter cultures.

INTRODUCTION

Traditional diets in West Africa often lack variety and consist of large quantities of the staple food (cassava, yam, maize) with supplements of plantain, cocoyam, rice, and beans depending on availability and season (Achi, 1999). Soups eaten with the staples are an essential component of the diet and may contain a variety of seeds, nuts, pulses, and leaves (Campbell-Platt, 1980). The staple foods provide the calories but are poor in other nutrients. Soups are the main sources of proteins and minerals and one of the ways to improve the diet have been to improve the nutrient content of soups.

Seeds of legumes may account for up to 80% of dietary protein and may be the only source of protein for some groups. Their cooked forms are eaten as meals and are commonly used in fermented form as condiments to enhance the flavors of foods (Odunfa, 1985c; Aidoo, 1986; Achi, 1991; Oniofiok, 1996). With high contents of protein, legume condiments can serve as a tasty complement to sauces and soups and can substitute for fish or meat.

The food flavouring condiments are prepared by traditional methods of uncontrolled solid substrate fermentation resulting in extensive hydrolysis of the protein and carbohydrate components (Fetuga et al., 1973; Eka, 1980). Apart from increasing the shelf life, and a reduction in the anti-nutritional factors (Odunfa, 1985b; Reddy and Pierson, 1999; Barimalaa et al., 1989; Achi and Okereka, 1999), fermentation markedly improves the digestibility, nutritive value, and flavors of the raw seeds.

Although fermented food condiments have constituted a significant proportion of the diet of many people, Nigerians have exhibited an ambivalent attitude in terms of consumer tastes and preferences for such foods (Achi, 2005). The introduction of foreign high technology products especially processed ones because of globalization and liberalization of the economy radically changed the Nigerian food culture into a mixed grill of both foreign and local dishes (Ojo, 1991).

Many developing countries are still preparing traditional fermented products for human consumption (Campbell-

Table 1. Traditional substrates used for food condiments.

Raw material	Local name	Reference
Soya bean (*Glycine max*)	Daddawa	Popoola and Akueshi, 1984 Ogbadu and Okagbue, 1988
Melon seed *Citrullus vulgaris*	Ogiri	Odunfa, 1981b
Castor oil seed (*Ricinus communis*)	Ogiri-igbo	Odunfa, 1985b
Fluted pumpkin seeds *Telferia ocidentalis*	Ogiri-ugu	Barber et al., 1992 Odibo and Umeh, 1989
African locust beans *(Parkia biglobosa)*	Dawadawa (Iru)	Odunfa, 1981a
African oil beans *(Pentaclethra macrophylla*)	Ugba/Ukpaka	Obeta, 1983
African yam beans *(Stenophylis stenocarpa)*	Owoh	Ogbonna et al., 2001
Cotton seeds *(Gossypium hirsitium)*	Owoh	Sanni and Ogbonna, 1991
Prosopis africana	Okpiye Okpehe Ogiri-okpei	Achi, 1992 Odibo et al., 1992 Sanni, 1993
Bambara groundnut *Vigna subterranea*	Dawadawa	Barimalaa et al., 1989

Platt, 1987). Fermented products remain of interest since they do not require refrigeration during distribution and storage. The traditional condiments have not attained commercial status due to the very short shelf life, objectionable packaging materials, stickiness and the characteristic putrid odour (Arogba et al., 1995). Fermented condiments often have a stigma attached to them; they are often considered as food for the poor.

The production of fermented vegetable proteins for use as food condiments is craft-based. Remarkably, in many areas of Nigeria today they are still made in traditional ways, with success depending upon observance of good manufacturing practices and control of environmental conditions during the manufacturing phase. Starter cultures are not normally used and therefore variations in the quality and stability of the products are often observed. As with any other fermentation process the understanding of the microbial ecology of vegetable fermentations requires the knowledge of the fermentation substrates, i.e. the seeds of the various plants as well as the products obtained thereof. Information on the manufacturing and microbiology of indigenous fermented legumes has been reported (Odunfa, 1981a, 1983a; 1985a, 1985c; Odunfa and Adewuyi, 1988a,b; Achi, 1992; Sanni, 1993; Sanni and Ogbonna, 1998). The use of these condiments, it is suggested, could be extended as a food ingredient included into most fabricated foods in order to further increase their versatility and utility (Giami and Bekebain, 1992; Achi, 1999). Fermented fluted pumpkin flour has been incorporated into weaning food formulations (Achinewhu, 1987; Banigo and Akpapunam, 1987).

Apart from dawadawa prepared from the African locust bean, by far the bulk of the indigenous fermented condiments of Nigeria are to be found in the southern states of Nigeria. The north is very poor in food fermentations, which are practically confined to the staple sorghum porridges and to soured milks (Dirar, 1993). However, inter state trade and relocation has widened the scope of the spread of food condiments throughout the country and beyond (Iwuoha and Eke, 1996).

Excellent reviews of traditional fermented foods have been published by Odunfa (1985c), and Iwuoha and Eke (1996). Against the background of the significance and benefits of traditional fermented condiments, the object of this review was to evaluate the current state of knowledge of fermented food condiments dealing with aspects of manufacture, biochemical changes, and nutritional properties. Use of other raw materials other than the traditional legumes for condiment-making will be included.

NAMES AND SUBSTRATES OF FERMENTED CONDIMENTS

Throughout Nigeria, many names are applied to the multitude of fermented food condiments. Table 1 shows

Table 2. Important microorganisms found in fermented condiments after different periods of fermentation.

Product	Predominant microorganisms	Optimum condition	References
Dawadawa/Iru	*Bacillus subtilis, B. licheniformis* *Staphylococcus saprophyticus*, *Leuconostoc* spp.	3 days, 35℃ pH 7.9	Odunfa, 1981a Antai and Ibrahim, 1986 Ogbadu and Okagbue, 1988
Dadawa/Soyiru	*Bacillus* spp., *Staphylococcus* spp.	4 days 37℃	Popoola and Akueshi, 1985.
Soy-daddawa	*Bacillus subtilis, B. licheniformis* *B. pumilis*	3 days 35℃	Omafuvbe et al., 2003
Bambara-daddawa	*Staphylococcus spp., Streptococcus* *Enterococcus*	3 days 37℃ pH 7.8	Barimalaa et al., 1994 Suberu and Akinyanju, 1996
Ogiri-egusi	*Bacillus subtilis, B. megateruim,* *B. firmus E.coli,. Proteus, Pediococcus,* *Alcaligenes* spp.	3 days 29-30℃ pH 8.1-6.5	Odunfa, 1981b. Barber and Achinewhu, 1992
Ogiri-igbo	*Bacillus* spp., *Pseudomonas* spp. *Micrococcuss* spp., *Streptococcus*	3 days 30℃ pH >8.1	Odunfa, 1985b Uzogara et al., 1991
Ogiri-ugu	*Bacillus* spp., *E. coli, Staphylococcus* Spp., *Pseudomonas*	5 days, 30℃ pH 6.5-8.0	Odunfa, 1985b Barber et al., 1989
Ugba / Ukpaka	*Bacillus subtilis, Staphylococcus* spp., *Micrococcus* spp., *Corynebacterium* spp.	3 – 5 days pH 5 – 8.7 30 – 33℃	Obeta, 1983 Kolawole and Okonkwo, 1995 Njoku and Okemadu, 1998
Okpiye/Okphehe	*B. subtilis, B. licheniformis, B. megaterium, Staphylococcus epidermidis, Micrococcus* spp.	4 days 28 – 39℃ pH 6.8 – 7.9	Achi, 1992, Odibo et al., 1992 Sanni, 1993
Owoh	*Bacillius subtilis, B. licheniformis,* *B. pumilis, Staphylococcus* sp.	3 days 33 –40℃ pH 7.5	Sanni and Ogbonna, 1991 Ogbonna et al., 2001

the variety of names by which the products are known in different parts of the country. The exact origin of such names could be attributed to (a) the region or area of manufacture (b) the type of legume or oil seed used and (c) the spelling according to region or area. The Yorubas of the southwestern Nigeria locally call fermented condiments 'iru' while the Hausas who inhabit most of the northern part of Nigeria call it *dawadawa*. *Ogiri'* is the name used by the Ibos of the southeastern Nigeria. Owoh on the other hand, is the popular name among the Urhobos and Itsekiris in the Niger Delta region for food condiments. Similarly, okpiye is popular among the Igala and Idoma people of the Middle Belt region.

The conventional substrates for condiment production are diverse and each can be produced from more than one raw material. Almost any edible plant material can be subjected to fermentation. Judging by the available literature, over nine different fermented products are condiments. A list of these substrates is given in Table 1. For instance, dawadawa or iru is traditionally prepared from African locust bean (*Parkia biglobosa*) (Campbell-Platt, 1980; Odunfa, 1981a; Antai and Ibrahim, 1986), soybean (*Glycine max*) (Popoola and Akueshi, 1984; Ogbadu and Okagbue, 1988) and bambara groundnut (*Vigna subterranea)*(Barimalaa et al., 1994). Ogiri is traditionally prepared by fermenting melon seeds (*Citrullus vulgaris*) (Odunfa, 1981b; Ogundana, 1980), fluted pumpkin (*Telferia occidentale*) (Odibo and Umeh, 1989) or castor oil seed (*Ricinus communis)* (Anosike and Egwuatu, 1981; Odunfa 1985b; Barber et al., 1988). Owoh is processed from fermented seeds of the cotton plant (*Gossypium hirsutum*) (Sanni and Ogbonna, 1991; Sanni and Ogbonna, 1992) and African yam bean (*Sphenostylis stenocarpa*) (Sanni et al., 2001), while Okpiye is prepared from the seeds of *Prosopis africana* (Achi, 1992: Odibo et al., 1992; Sanni, 1993). Quite often seeds that are used for fermentation are inedible in their raw unfermented or cooked state.

BASICS OF MANUFACTURING PROCESSES

The methods employed in the manufacture of fermented condiments differ from one region to another because these processes are based on traditional systems, some of which are summarized in Table 2. A basic scheme of vegetable fermentation for production of condiments is depicted in Figure 1. According to local custom, climate conditions and the type of substrates used, specific process variations occur. In general, fermentation takes place under conditions which the producers have found to be favorable for the appropriate growth and activity of the microorganisms.

Traditionally, raw beans are cooked for upward of 12 h

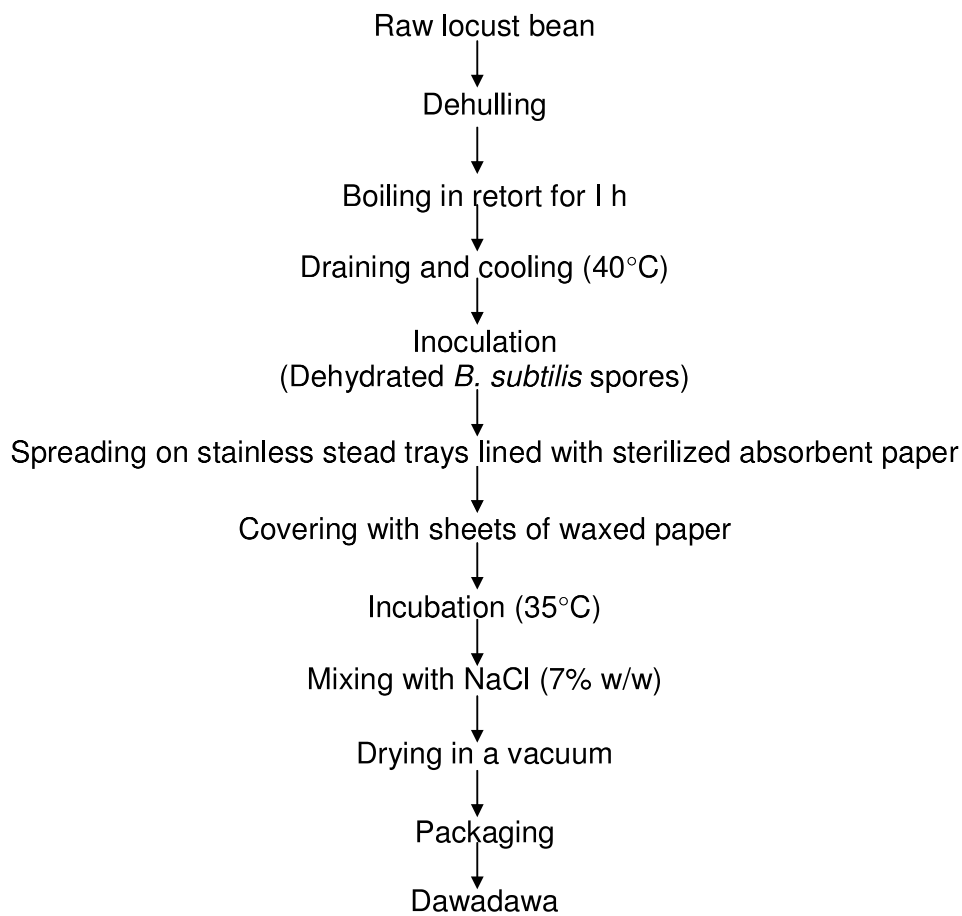

Figure 1. Flow chart of condiment production.

in excess water until they are very soft to allow for hand de-hulling. The length of time of cooking depends on the strength of the testa and on the de-hulling efficiency of the seeds. *Parkia biglobosa* can be cooked for 8-12 h (Oyewole and Odunfa, 1990), though *Prosopis africana* can be cooked for 5-6 h (Achi, 1992). Boiling in 0.1 M Na_2CO_3 reduces the cooking time to 4 h and increases the de-hulling efficiency to 89% (Achi and Okereka, 1999). While *Telferia* seeds require minor cooking for 30 to 60 min, *Citrullus vulgaris* and castor seeds are de-shelled before cooking.

At present, most de-hulling processes rely on the tedious method of hand separation. Abrasive de-hulling of dry beans of *Parkia* or *Prosopis* is not possible because of the strong adherence of hulls to the seed. Nevertheless, roasting prior to boiling in water has been identified as a technique for effecting reduction in cooking time (Ijabo et al., 2000). Boiling in excess water serves not only the purpose of partial cooking, but facilitates microbial penetration and human digestion. The bitter and beany taste of soybean disappears in less than 15 min at 95°C (Nout et al., 1985).

After cooking and de-hulling processes have been completed, the cotyledons are prepared for fermentation. For some seeds, such as the African oil bean (*Pentaclethra macrophylla*), the cotyledon may be boiled again for 1-2 h. A softening agent ‘kaun’ (potassium carbonate) may be added to aid softening of the cotyledons (Odunfa, 1985c; Ikenebomeh et al., 1986). Ugba is produced from the sliced seeds of *Pentaclethra macrophylla*. These slices are mixed well with salt and wrapped in banana leaves. A three-day fermentation provides the delicacy, while 5 days of fermentation produces the soup condiment (Odunfa and Oyeyiola, 1985). Other substrates are pounded into a batter before wrapping in banana leaves or other suitable leaves. Incubation takes 72-96 h at 28-42°C. The process involves moist solid substrate fermentation by spontaneous natural inoculation. This is unlike most other Nigerian fermented foods, which take place in a liquid environment. The imperative incubation condition could be described as that of oxygen starvation, allowing microbial growth. In practice this is achieved by wrapping with suitable leaves so that the package can be opened for aeration and cooling if necessary. Insufficient packaging density with consequent pockets of air, non-

Table 3. Details of some traditional methods employed for the manufacture of condiments from different plant proteins.

Name of Product	Substrate	Processing Stages	Reference
Dawadawa/Iru	African locust bean *Parkia filicoidea*	Locust bean seeds are boiled for 12 – 24 h to soften the hard testa after which they are dehulled by hand. The separated cotyledons are boiled for another 2 h to soften them.	Odunfa, 1981 Antai and Ibrahim, 1986
	Soybean Bambara nut	The cotyledons are spread in a raffia basket lined with banana leaves and then covered with several layers of the banana leaves. This is left to ferment for 2-3 days. Wood ash may be added. The fermented product is then sun dried for 1-2 days to yield a dark brown or black product. Form into irregular small pieces.	Omafuvbe et al., 2002 Barimalaa et al., 1994
Ogiri-egusi	Melon seeds *Citrullus vulgaris*	Dehulled melon seeds boiled for 2 – 3 h. The seeds are ground into a paste. Ash from burnt palm bunch is added which imparts a grey colour to the paste. The paste is wrapped In small portions with leaves and left in a warm place until the characteristic aroma of the condiment is developed. It is further sun dried for 7 days on straw mats.	Odunfa, 1981b.
Ogiri-igbo	Castor seed *Ricinus communis*	Castor seeds are dehulled, wrapped in banana leaves and boiled for 6 – 8 h. The boiled seeds which are still wrapped in the leaves are left to ferment for 4 – 6 days. Later the seeds are mixed with ash from oil palm bunch and ground into a paste. This is wrapped in leaves in small portions and allowed to develop the characteristic flavour.	Barber et al., 1988 Uzogara et al., 1990

slicing of African oil bean, including packaging in polyethylene bags and other factors may result in fermentation failure as reported by Ogbonna et al. (2001).

The consistency of the fermenting vegetable mash as fermentation progressed could be described as a thick cheesy pudding. After fermentation for 72-96 h, the mash become soft and dark and has a characteristic strong ammoniacal odour resembling Japanese natto (Odunfa, 1985c, 1986; Achi, 1992; Barimalaa et al., 1994). Fermented condiments do not keep well if the fermentation is allowed to continue long uninhibited. If fermentation is prolonged, the environment will be changed to become suitable for yeast growth (Campbell-Platt, 1987). Furthermore, over-fermentation is capable of generating unacceptable levels of volatile fatty acids.

MICROBIAL ECOLOGY

The dynamics of fermentation in any food matrix is a complex microbiological process involving interactions between quite different microorganisms (Daeschel, 1987). The contribution of the accompanying flora of fermenting substrates is determined by the substrate composition and hygiene during production. During fermentation, the microorganisms use the nutritional components of the seeds, converting them into products that contribute to the chemical composition and taste of the condiment. Quite a number of *Bacillus* species have been isolated from various fermented food condiments (Table 3). Although yeasts and other bacteria are also seen, only part of them can be considered to play a substantial role in fermentation processes. For example, non-fermenting species may just be ubiquitous contaminants although they may affect the flavour of the final product when occurring in high numbers. Other bacteria present include *Staphylococcus* spp. Proteolytic and salt-tolerant microorganisms have been detected in appreciable numbers (from 10^4 to 10^6 cfu/g) in samples of fermenting *Parkia* seeds after 36 h (Odunfa, 1981a). The spore-forming species *B. subtilis* and *B. lichenformis* were identified as the main bacteria present. The predominance of *Bacillus* species has been demonstrated in other fermenting legume proteins (Achi, 1992; Barimalaa et al., 1994; Barber et al., 1998; Omafuvbe et al., 2002). The codominance of *Staphylococcus* and *Bacillus* spp. was typical of the microflora of fermenting beans (Obeta, 1983; Antai and

Ibrahim, 1986; Achi, 1992). *Staphylococcus* species have been associated with fermenting foods of plant origin especially vegetable proteins (Odunfa and Komolafe, 1989; Jideani and Okeke, 1991). Fresh fruits and vegetable often carry high levels of these organisms as part of their normal flora.

Members of the Enterobacteriacceae also contributed to the ecology of fermenting plant proteins especially at the early stages (Mulyowidarso et al., 1989; Achi, 1992). These species do not survive until the end of the fermentation, presumably because of the modified environment, which had developed at later stages.

In view of the fact that the major constituents of vegetable seeds are proteins, the organisms responsible for fermenting them must be capable of utilizing these constituents (Antai and Ibrahim, 1986; Ouoba et al., 2003a). *Bacillus* species isolated from variable sources have been reported to be proteolytic and are able to breakdown oils (Frazier, 1967; Forgarty and Griffin, 1973; Ouoba et al., 2003b). It is evident that production of fermented condiments is initially mediated by a diverse microbial flora, which eventually becomes Gram-positive flora (a reflection of many African fermented foods) (Odunfa, 1985c). The contribution of this accompanying flora of bacteria to the properties of the legume product is only partly understood (Iwuoha and Eke, 1996). Most probably, they play a role in flavour development and influence the chemical composition through substrate modification and synthesis of vitamins (Nout and Rombouts, 1995). However it is necessary to ascertain the contribution of these organisms in vegetable fermentations. Undoubtedly, traditionally fermented condiments have not been incriminated in relation to food poisoning.

STARTER DEVELOPMENT

The fermentation process for condiment production is still being carried out by the traditional village-art method. There is need to apply modern biotechnological techniques like the use of starter cultures in improving traditional food processing technologies (Achi, 2005). It has been suggested that even though hitherto most fermentation processes used in developing countries do not use innocula or extrinsic cultures, these processes could be improved by using starter cultures, and also by backslopping, which entails application of brine from prior fermentation cycles (Holzapfel, 2002; Naiba, 2003). Starter cultures have been found to reduce fermentation time as well as guarantee product quality. In the traditional method of manufacture, the fermentation of the legume seeds is achieved by indigenous microflora or the addition of fermented material from a previous production through back slopping. Thus, it may be assumed that undefined starter cultures have traditionally been employed in the manufacture of these products. (Suberu and Akinyanju, 1996; Omafuvbe et al., 2002; Ouoba et al., 2003 a,b; Dakwa et al., 2005).

A pure culture starter is essential for controlled experimental fermentations, and for this purpose a number of *Bacillus* species, *Staphylococcus* and *Streptococcus enterococcus* have been explored (Suberu and Akinyanju, 1996; Omafuvbe et al., 2003; Ouoba et al., 2003a,b). Controlled fermentation of soybeans was achieved by using pure single cultures of *Bacillus subtilis, B. licheniformis* or in combinations (Suberu and Akinyanju, 1996; Sarkar et al., 1993). Mixed cultures of *B. subtilis* and *B. licheniformis* were highly recommended by the same authors and fermentation was achieved in 72 h. Omafuvbe et al. (2003) on the other hand, tested three *Bacillus* species namely *B. subtilis, B. licheniformis* and *B. pumilis* singly and in combinations for their ability to ferment soybean for the production of daddawa. *B. subtilis* as single or member of a mixed starter produced soy-daddawa, which was considered most suitable as it gave acceptable pure culture condiment supposedly due to its proteolytic enzyme activity and high level of free amino acid.

Most authors now agree that there is a predominant development of *Bacillus* species during the various legume fermentation processes (Aderibigbe and Odunfa, 1990; Odunfa and Oyewole, 1986; Achi, 1992; Odibo et al., 1992; Ouoba et al., 2003a). The use of a single strain would seem too restrictive for the production of a foodstuff with a generous range of organoleptic characteristics. The use of a mixture of microorganisms with complementary physiological and metabolic properties seems to be the best approach for obtaining a product with the nutritional and sensory properties desired. Understanding of the phenomena of succession of the different populations involved in these natural processes is therefore required. The significant point in the comprehension of the mechanism of effecting degradation of legume proteins lies in the analysis of the amino acids produced by the isolated bacteria. The study of the starters contributing to the production of amino acids is still meager (Ouoba et al., 2003a) compared to the research works conducted on other aspects fermentation.

BIOCHEMICAL CHANGES ACCOMPANYING FERMENTATION

Since the major constituents of legumes and oilseeds used in condiment production are proteins, fats and fewer carbohydrates, the organisms responsible for the hydrolysis must be capable of utilizing these constituents.

Changes in carbohydrates

Bacillus species have been reported as producers of certain enzymes such as amylase, galactanase, galactosidase, glucosidase and fructofuranosidase, which are involved in the degradation of carbohydrates (Aderibigbe and Odunfa, 1990; Sarkar et al., 1997b; Omafuvbe et al., 2000; Kiers et al., 2000). Microbial amylases hydrolyze carbohydrates into sugars, which are then readily digestible by humans. Similarly, galactanases soften the texture of the seeds and liberate sugars for digestion.

Most legumes contain large amounts of non-digestible carbohydrates, which may include arabinogalactan, stachyose, sucrose and raffinose (Irvine, 1961; Odunfa, 1983). Soybean may contain in addition, verbascose. These carbohydrates are associated with abdominal distention and flatulence in humans (Sarkar et al., 1997b; Naczk et al., 1997). Fermentation reduced total flatus factors from 16.5 to 2.0 mg/g in soybeans (Winarno and Reddy, 1986), and from 0.16% to <0.1% in groundnut (Fardiaz and Markakis, 1981). Trypsin inhibitor activity of Bambara groundnut (Barimalaa et al., 1994) was also reduced during fermentation.

Changes in amino acids

In most fermented high-protein products, the extent of protein hydrolysis is one of the most important factors in the changes in texture and flavour (Whitaker, 1978). Soluble low molecular weight peptides and amino acids that contribute to flavour are produced through the enzymatic breakdown of proteins (Odunfa, 1985c; Njoku and Okemadu 1989; Ogbonna et al., 2001; Ouboa et al., 2003a). Condiment of good quality has a characteristic strong smell of ammonia, a dark colour and is semi hard. Amino acids produced because of protein metabolism are responsible for the gradual pH increase and leveling off towards 7.5-8.0 (Barimalaa et al., 1989; Achi, 1992; Barber and Achinewhu, 1992; Sarker et al., 1997a) (Table 3). The increase in pH into the alkaline range may be physiologically important for tolerance and adaptation of fermenting microorganisms in the environment. However, pH increases due to the formation of ammonia from amino acids may consequently encourage growth of spoilage organisms such as lactobacilli and pediococci. The effect of vegetable protein fermentation on total nitrogen is negligible. However, slight increases may be observed in some legume seeds (Winarno and Reddy, 1986; Achinewhu et al., 1992). Free amino acids increase but longer fermentation results in losses of lysine or other essential amino acids (Winarno and Reddy, 1986).

Changes in lipids

The significant lipolysis of legumes yields predominantly oleic, linoleic and linolenic acids (Achinewhu, 1987b; Ouoba et al., 2003b; Nout and Rombouts, 1990). Free fatty acids, particularly oleic, linoleic and linolenic acids were associated with non-specific antitryptic activity (Winarno and Reddy, 1986). As such, extensive hydrolysis could diminish nutritional quality. Although oils constitute up to 40% of the legumes used in food fermentations, extensive lipolysis does not take place. Odunfa (1985c) reported low levels of lipase activity in *Parkia biglobosa* during dawadawa production. The same author had earlier reported low levels of lipase in melon seed fermentation (Odunfa, 1983b). Similarly, Njoku and Okemadu (1989) observed minimal participation of lipase in *Pentachletera macrophylla* during ugba production. Low lipase activity in some fermented foods has been considered desirable because of problems of objectionable taste and development of rancidity (Yong and Wood, 1977; Odunfa, 1983b, 1985b). However, there are reports of beneficial effects of lipase in the developments of characteristic flavours and aroma (Whitaker, 1978, Ouoba et al.2005). These results appear contradictory and require further study. An interesting area would involve the effects of change of lipid quantity and quality on the organoleptic characteristics of fermented condiments. Darweesh et al. (1991) have reported that aldehydes resulting from oxidation of lipids cause off-flavour and odour problems. However, organic solvent treatment of fermented condiments from locust bean, melon seed and soya bean on the objectionable odour, did not show any appreciation of the odour (Arogba et al., 1995). Not much can be said about the flavouring components of fermented vegetable proteins used as condiments as no research has been carried out on this aspect. However, there is no doubt that amines, peptides and glutamic acid all contribute to this flavour.

NUTRITIONAL QUALITY OF FERMENTED CONDIMENTS

Classical techniques for assessment of bioavailability of nutrients generally involve *in vitro* tests with animals. Protein utilization measured as Protein Efficiency Ratio (PER) and the digestibility of soya bean and some legumes are hardly improved by fermentation (Obizoba, 1998; Nout and Rombouts, 1990). It was reported that rats do not utilize proteins from fermented soybean any better than from the cooked substrate. Nevertheless, some reports indicate otherwise. Achinewhu (1983) reported that fermentation and heat treatment improved apparent digestibility, feed conversion efficiency and protein efficiency ratio when rats were fed on diets of African oil bean seed rations.

Eka (1980) studied the effect of fermentation on the nutrient content of locust beans and reported that protein and fat increased when fermented whereas the quantity of carbohydrates decreased. Increased levels of the amino acids were also reported except for arginine, leucine and phenylalanine. Similar results were reported for other seed legumes (Odunfa, 1985b; Achinewhu, 1988; Sarkar et al., 1998). Soluble products increased during fermentation of melon seeds resulting in high digestibility of the fermented product. Alanine, lysine and glutamic acid were the predominant amino acids, with arginine and proline occurring in small amounts (Odunfa, 1983a; Aidoo, 1986). The improved nutritive values were attributed to the increase in amino acid profiles due to fermentation.

Food condiments made from vegetable proteins maybe a good source of certain B vitamins, but are deficient in ascorbate and some fat-soluble vitamins, which are lost during fermentation. Achinewhu and Ryley (1986) have shown that fermentation significantly increased the content of thiamine, riboflavin and niacin in the African oil bean. Similar changes were observed during the fermentation of melon seed and fluted pumpkin seed (Achinewhu, 1986a,b). Ogbonna et al. (2001) observed increases in calcium, phosphorus and potassium when African yam bean was fermented for condiment production. This is in contrast to previous results of Achinewhu (1986b), which reported decrease in calcium, copper and phosphorus but increased iron and zinc in fluted pumpkin. It is evident that fermented food condiments is a good source of nutrients and could be used to produce complementary food supplements. Macronutrients in fermented legumes contribute to enhanced food quality.

FUTURE OF FERMENTED CONDIMENTS OF NIGERIA

A substantial literature documents the successful fermentation of vegetable proteins for condiment production. Both microbial and biochemical changes involved therein have received much attention. A further understanding about the interactions of the microorganisms and plant materials is necessary to improve the quality of fermented condiments. Such understanding will aid in further development and control of the fermentation process.

Selection of starter cultures for large-scale industrial processes may require genetic modification to introduce a number of properties. These may offer nutritional benefit in the form of increased protein production or compatibility to mixed culture fermentations. Fermented condiments have a characteristic organoleptic quality, which probably are the most important factors for consumers. There are a few data on the flavour components of fermented condiments and how this can be improved by fermenting microorganisms (Dakwa et al., 2005). Further research is needed in these areas.

Taking into account the increasing demand particularly by urban populations in Nigeria, there are certainly prospects for industrialization of traditional fermented condiments. Commercial availability of ready-to-use fermented products saves much labour and time in the household (Nout and Sarkar, 1999). Better control of fermentation and quality of fermented foods is required in the scaling up process. Mention was made already of the choice of raw materials, fermentation conditions, and starter cultures used (Achi, 2005).

REFERENCES

Achi OK (1992). Microorganisms associated with natural fermentation of *Prosopis africana* seeds for the production of *okpiye* Plant Foods. Hum. Nutr 42: 297-304.

Achi OK (1999). Quality attributes of fermented yam flour supplemented with processed soy flour Plant Foods. Hum. Nutr. 54:151-158.

Achi OK, Okereka EG (1999). Proximate composition and functional properties of *Prosopis africana* seed flour. J. MgtTechnol. 1: 7-13.

Achi OK (2005). The upgrading of traditional fermented foods through biotechnology. Afr. J. Biotechnol. 4: 375-380.

Achinewhu SC (1982). Composition and food potential of the African oil bean (*Pentaclethra macrophylla*) and velvet bean (*Mucuna uriens*). J. Food Sci. 27: 1736-1737.

Achinewhu SC (1983a). Chemical and nutrient composition of fermented products from plant foods. Nig. Food J. 1: 115-117.

Achinewhu SC (1983b). Protein quality of the African oil bean seed (*Pentaclethra macrophylla*). J. Food Sci. 48: 1374-1375.

Achinewhu SC (1986a). The effect of fermentation on carbohydrate and fatty acid composition of the African oil bean (*Pentaclethra macrophylla*). Food Chem. 19: 105-116.

Achinewhu SC (1986b). Some biochemical and nutritional changes during the fermentation of fluted pumpkin (*Telferia occidentale).* Plant Foods Hum. Nutr. 36: 97-106.

Achjnewhu SC, Ryley J (1987). Effects of fermentation on thiamin, riboflavin and niacin content of melon seed (*Citrullus vulgaris*) and the African oil bean seed (*Pentaclethra macrophylla*). Food Chem. 20: 243-252.

Aderibigbe EY, Odunfa SA (1990). Growth and extra cellular enzyme production by strains of *Bacillus* species isolated from fermenting African locust bean*, iru*. J. Appl. Bacteriol. 69: 662-671.

Aidoo KE (1986). Lesser-known fermented plant foods. Trop. Sci. 26: 249-258.

Banigo EB, Akpapunam MA (1987). Physico-chemical and nutritional evaluation of protein-enriched fermented maize flour. Nig. Food J. 5: 30-36.

Anosike EO, Egwuatu CK (1981). Biochemical changes during the fermentation of castor oil (*Ricinus communis*) seeds for use as a seasoning agent Plants. Foods Hum. Nutr. 30:181-184.

Antai SP, Ibrahim MH (1986). Microorganisms associated with African locust bean (*Parkia filicoidea* Welw) fermentation for dawadawa production. J. Appl. Bacteriol. 61: 145-148.

Arogba SS, Ademola A, Elum M (1995). The effect of solvent treatment on the chemical composition and organoleptic acceptability of traditional condiments from Nigeria. Plant Foods Hum. Nutr. 48: 31-38.

Barber L, Achinewhu SC, Ibiama EM (1988) The microbiology of ogir production from castor seeds (*Ricinus communs*). Food Microbiol. 5:177-182.

Barber LA, Ibiama EM, Achinewhu SC (1989). Microorganisms associated with fluted pumpkin (*Telferia occidentals*). Int. J. Sci. Technol. 24: 189-194.

Barber LA, Achinewhu SC (1992). Microbiology of *ogiri* production from melon seeds (*Citrullus vulgaris*). Nig. Food J. 10: 129-135.

Barimalaa IS, Achinewhu SC, Yibatima I, Amadi EN (1989). Studies on the solid substrate fermentation of bambara groundnut (*Vigna subterranea (*L) Verdc). J. Sci. Food Agric. 66: 443-446.

Campbell-Platt G (1980). African locust bean (Parkia species) and its West African fermented food products, Dawadawa. Ecol. Food Nutr. 9: 123-132.

Campbell-Platt G (1987). Fermented Foods of the World-a dictionary and guide. Butterworths, London, UK.

Daeschel MA, Anderson RE, Fleming HP (1987). Microbial ecology of fermenting plant materials FEMS Microbiol. Rev. 46: 357-367.

Dakwa S, Sakyi-Dawson E, Diako C, Annan NT, Amoa-Awua WK (2005). Effect on the fermentation of soybeans into dawadawa (soy-dawadawa). Int. J. Food Microbiol. 104: 69-82.

Darweesh LL,Toma RB, Lee HC, Weiss TJ (1991). Chemical and sensory evaluation of lipid blends used in pie crusts. Food Chem. 39: 87-98.

Dirar HA (1993). The indigenous fermented foods of the Sudan. A study in African Food and Nutrition. CABS International Wallingford. pp.???

Eka OU (1980). Effect of fermentation on the nutrient status locust beans. Food Chem. 5: 305-308.

Fardiaz D, Markakis P (1981). Degradation of phytic acid in oncom (fermented peanut press cake). J. Food Sci. 46: 523-525.

Fetuga BL, Babatunde GM, Oyenuga VA (1973). Protein quality of some Nigerian foodstuffs 1: Chemical assay of nutrients and amino acid composition J. Sci. Food Agric. 24: 1505-1514.

Forgarty WM, Griffin PJ (1973). Production and purification of metalloproteases of *Bacillus polymyxa.* Appl. Microbiol. 26: 191-195.

Frazier WC (1967). Food Microbiology 2nd edn New York McGraw-Hill.

Giami SY, Bekebain DA (1992). Proximate composition and functional properties of raw and processed full-fat fluted pumpkin (*Telfairia occidentalis*) seed flour. J. Sci. Food Agric. 59: 321-325.

Holzapfel WH (2002). Appropriate starter technologies for small scale fermentation in developing countries. Int. J. Food Microbiol. 78: 119-131.

Ibrahim MH, Antai SP (1986). Chemical changes during the fermentation of African locust bean (*Parkia filicoidea* Welw) seeds for the production of *daddawa.* Plant Foods Hum. Nutr. 36: 179-184.

Ikenebomeh MJ, Kok R, Ingram JM (1986). Processing and fermentation of the African locust bean (*Parkia filicoidea* Welw) to produce *dawadawa.* J. Sci. Food Agric. 37: 273-282.

Irvine FN (1961). Woody Plants of Ghana Oxford Univ. Press London.

Iwuoha CI, Eke OS (1996). Nigeria indigenous fermented foods: Their traditional process operations, inherent problems, improvements and current status. Food Res. Int. 29: 527-540.

Jideani IAO, Okeke CR (1991). Comparative study of microorganisms and sensory attributes of condiments from the fermentation of different seeds. Plant Foods Hum. Nutr. 41: 27-34

Kiers JL, Van Laekan AEA, Rombouts FM, Nout MJR (2000). *In vitro* digestibility of *Bacillus* fermented soya bean. Int. Food Microbiol. 60: 163-169.

Kolawole DO, Okonkwo BA (1985). Microbiology of traditional fermentation of oil bean (*Pentaclethra macrophylla* Benth) seeds for *ukpaka*, a Nigerian condiment. Nig. Food J. 3: 149-152.

Mulyowidarso RK, Fleet GH, Buckle KA (1989). The microbial ecology of soybean soaking for tempe production. Int. J. Food Microbiol. 8: 35-46.

Naczk M, Amarowicz R, Shashidi F (1997).α-Galactosidase of sucrose in foods: Composition, Flatulence-causing effect and removal. ACS Symposium Series 662: 127-151.

Niba LL (2003). The relevance of biotechnology in the development of functional foods for improved nutritional and health quality in developing countries. Afr. J. Biotechnol. 2: 631-635.

Njoku HO, Okemadu CP (1989). Biochemical changes during the natural fermentation of the African oil bean for the production of *ugba.* J. Sci. Food Agric. 49: 457-465.

Nout MJR, Bonants-van Laarhoven TMG, De Dreu R, Gerats IAGM (1985). The influence of some process variables and storage conditions on the quality and shelf life of soybean tempeh. Ant Leeuwenhoek 51: 532-534.

Nout MJR, Rombouts FM (1990). Recent developments in tempe research. J. Appl. Bacteriol. 69: 609-633.

Nout MJR, Sarkar PK (1999). Lactic acid food fermentation in tropical climates. Ant Leeuwenhoek. 76: 395-401.

Obeta JAN (1983). A note on the microorganisms associated with the fermentation of seeds of African oil bean seed (*Pentaclethra macrophylla*). J. Appl. Bacteriol. 54: 433-435.

Odibo FJC, Umeh AI (1989). Microbiology of the fermentation of *Telferia* seeds for ogiri production Mircen J. Appl. Microbiol. Biotechnol. 5: 217-222.

Odibo FJC, Ugwu DA, Ekeoha DC (1992). Microorganisms associated with the fermentation of *Prosopis* seeds for ogiri-okpei production. J. Food Sci. Technol. (Mysore) 29: 306-307.

Odunfa SA (1981a). A note on the microorganisms associated with the fermentation of African locust bean (*Parkia filicoidea*) during iru production. J. Plant Foods 3:245-250.

Odunfa SA (1981b). Microbiology and amino acid composition of ogiri – a food condiment from fermented melon seeds. Die Nahrung 25: 811-816.

Odunfa SA (1983a). Carbohydrate changes in fermenting locust bean during iru preparation. Plant Foods Hum. Nutr. 32: 1-10.

Odunfa SA (1983b). Biochemical changes during the production of ogiri, a fermented melon (*Citrullus vulgaris* Schrad) product. Plant Foods Hum. Nutr. 32: 11-18.

Odunfa SA (1985a). Biochemical changes in fermenting African locust bean (*Parkia biglobosa*) during iru fermentation. J. Food Technol. 20: 295-303.

Odunfa SA (1985b) Microbiological and toxicological aspect of fermentation of castor oil seeds for *ogiri* production J. Food Sci. 50: 1758-1759.

Odunfa SA (1985c). African Fermented Foods. In: Microbiology of Fermented Foods vol 2 ed. BJB Wood. Elsevier Applied Science. pp. 155-191.

Odunfa SA (1986). Dawadawa. In: Legume-based Fermented Foods eds. Reddy NR, Pierson MD Salunkhe DK. CRC Press Boca Raton. pp. 173-189.

Odunfa SA, Komolafe OB (1989). Nutritional characteristics of *Staphylococcus* species from fermenting African locust bean (*Parkia biglobosa*). Die Nahrung 33: 607-615.

Odunfa SA, Oyeyiola GF (1985). Microbiological study of the fermentation of ugba- a Nigerian indigenous fermented food flavour. J. Plant Foods 6: 155-163.

Odunfa SA, Adewuyi EY (1985a). Optimization of process condition for the fermentation of African locust bean *Parkia biglobosa.* 1: Effect of temperature and humidity. Chem. Mikrobiol. Technol. Lebensm. 9: 6-11.

Odunfa SA, Adewuyi EY (1985b). Optimization of process condition for the fermentation of African locust bean *Parkia biglobosa.* 11: Effect of starter cultures. Chem. Mikrobiol. Lebensm. 9: 118-122.

Odunfa SA, Oyewole OB (1986). Identification of *Bacillus* species from *iru*, a fermented African locust bean product. J. Basic Microbiol. 26: 101-108.

Ogbadu CO, Okagbue RN (1988). Bacterial fermentation of soybeans for daddawa production. J. Appl. Bacteriol. 65: 353-356.

Ogbonna DN, Sokari TG, Achinewhu SC (2001). Development of an owoh-type product from African yam beans (*Sphenostylis stenocarpa*) Hoechst ex. A.Rich) Harms) by solid substrate fermentation. Plant Foods Hum. Nutr. 56: 183-194.

Ogundana SK (1981). The production of ogiri a Nigerian fermented soup condiment. Lebensm-Wiss Technologie. 13: 334-336.

Ojo MO (1991). The role agro-industries in promoting a food culture in Nigeria. CBN Econ. Fin. Rev. 29: 306-314.

Omafuvbe BO, Shonukan OO, Abiose SH (2000). Microbiological and biochemical changes in the traditional fermentation of soybean for soy- daddawa -a Nigerian food condiment. Food Microbiol. 17: 469-474.

Omafuvbe BO, Abiose SH, Shonukan OO (2003). Fermentation of soybean (*Glycine max*) for soy-daddawa production by starter cultures of *Bacillus*. Food Microbiol. 19: 561-566.

Oniofiok N, Nnayelugo DO, Ukwondi BE (1996). Usage patterns and contributions of fermented foods to the nutrient intake of low-income households in Emene Nigeria. Plant Foods Hum. Nutr. 49: 199-211.

Ouoba LII, Rechinger KB,Barkholt V,Diawara B, Traore AS, Jakobsen M (2003a). Degradation of proteins during the fermentation of African locust bean (*Parkia biglobosa)* By strains of *Bacillus subtilis* and *Bacillus pumilus* for production of Soumbala.J.Appl.Microbiol 94: 396-402.

Ouoba LII, Cantor MD, Diawara B, Traore AS, Jakobsen M (2003b). Degradation of African locust bean oil by *Bacillus subtilis* and *Bacillus pumillus* isolated from soumbala, a fermented African locust bean condiment.J.Appl. Microbiol 95:868-873

Ouoba LII Diawara B, Annan NT, Poli L, Jakobsen M. (2005).Volatile compounds of soumbala, a fermented African locust bean *(Parkia biglobosa)* food condiment J.Appl Microbiol.99:1413-1421.

Oyewole OB, Odunfa SA (1990). Effect of cooking method on the water absorption and ease of dehulling in preparation of African locust bean for *iru* preparation. Int. J. Food Sci. Technol. 25: 461-463.

Popoola TOS, Akueshi CO (1984). Microorganisms associated with the fermentation of soybean for the production of soybean daddawa (as condiment). Nig. Food J. 2&3: 194-196.

Reddy NR, Pierson MD (1999). Reduction in antinutritional and toxic components in plant foods by fermentation. Food Res. Int. pp. 281-290.

Sanni AI (1993). Biochemical changes during the production of *okpehe* a Nigerian fermented soup condiment. Chem. Mikrobiol. Technol. Lebensm. 15: 97-100.

Sanni AI, Ogbonna DN (1991). The production of owoh-A Nigerian fermented seasoning agent from cotton seed (*Gossypium hirsitiumL*). Food Microbiol. 8: 223-229.

Sanni AI, Ogbonna DN (1992). Biochemical studies on *owoh*-A Nigerian fermented soup condiment from cottonseed. Food Microbiol. 9: 177-183.

Sanni AI, Onilude AA (1997). Characterization of *Bacillus* species isolated from *okpehe* a fermented soup condiment from *Prosopis africana*. Nig. J. Sci. 31: 49-52.

Sarkar PK,Cook PE, Owens JD (1993). *Bacillus* fermentation of soybeans. World J. Microbiol. Biotechnol. 9: 295-299.

Sarkar PK, Jones L, Craven GS, Somerset SM, Palmer C (1997a). Amino acid profile of *kinema*, a soybean fermented food. Food Microbiol. 59: 69-75.

Sarkar PK, Jones L, Craven GS, Somerset SM, Palmer C (1997b). Oligosacharide profiles of soybeans during kinema production. Lett. Appl. Microbiol. 24: 337-339.

Sarkar PK, Morrison E, Tinggi U, Somerset SM, Craven GS (1998). B-vitamin and mineral contents of soybeans during *kinema* production. J. Sci. Food Agric. 78: 498-502.

Suberu HA, Akinyanju JA (1996). Starter culture for the production of soyiru. World J. Microbiol. Biotechnol. 12: 403-404.

Uzogara SG, Agu LN, Uzogara EO (1990). A review of traditional fermented foods, condiments and beverages in Nigeria: Their benefits and possible problems. Ecol. Food Nutr. 24: 267-288.

Whitaker JR (1978). Biochemical changes during the fermentation of high protein foods. Food Technol. 32: 175-190.

Winarno FG, Reddy NR (1986). Tempe. In: Legume-based Fermented Foods ed. Reddy NR, Pierson MD, Salunkhe DK. Boca Raton CRC Press. pp. 95-117.

Yong FM, Wood BJB (1977). Biochemical changes in experimental soysauce koji. J. Food Technol. 12: 163-175.