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The Role of Traditional Food Processing Technologies In National Development: the West African Experience

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ABSTRACT

The capacity to preserve food is directly related to the level of technological development. The slow progress in upgrading traditional food processing and preservation techniques in West Africa contributes to food and nutrition insecurity in the sub-region. Simple, low-cost, traditional food processing techniques are the bedrock of small-scale food processing enterprises that are crucial to rural development in West Africa. By generating employment opportunities in the rural areas, small-scale food industries reduce rural-urban migration and the associated social problems. They are vital to reducing post-harvest food losses and increasing food availability. Regrettably, rapid growth and development of small-scale food industries in West Africa are hampered by adoption of inefficient and inappropriate technologies, poor management, inadequate working capital, limited access to banks and other financial institutions, high interest rates and low profit margins. While a lot still needs to be done, some successes have been achieved in upgrading traditional West African food processing technologies including the mechanization of gari (fermented cassava meal) processing, the production of instant yam flour or flakes, the production of soy-ogi (a protein-enriched complementary food), the industrial production of dawadawa (a fermented condiment) and the upgrading of the kilishi (a traditional roasted dry meat product) process and the traditional West African cheese-making process.

INTRODUCTION

High post-harvest food losses, arising largely from limited food preservation capacity, are a major factor constraining food and nutrition security in the developing countries of West Africa, where seasonal food shortages and nutritional deficiency diseases are still a major concern. Protein-energy malnutrition (PEM) and the various micronutrient deficiency disorders including vitamin A deficiency (VAD), nutritional anemias due to deficiencies of iron, folic acid and vitamin B_{12}, and iodine deficiency disorders (IDD) remain important public health problems. PEM and IDD have profound consequences on growth and mental development of children and VAD, apart from its damaging consequences on the eye (xerophthalmia and night blindness), is a major contributory factor to the high rates of child and maternal morbidity and mortality. It is estimated that about 50% of perishable food commodities including fruits, vegetables, roots and tubers and about 30% of food grains including maize, sorghum, millet, rice and cowpeas are lost after harvest in West Africa. Ineffective or inappropriate food processing technologies, careless harvesting and inefficient post-harvest handling practices, bad roads, moribund rail systems, bad market practices and inadequate or complete lack of storage facilities, packing houses and market infrastructures are some of the factors responsible for high post-harvest food losses in West African countries.

The capacity to preserve food is directly related to the level of technological development and the slow progress in upgrading traditional food processing and preservation techniques in West Africa contributes to food and nutrition insecurity in the sub-region. Traditional technologies of food processing and preservation date back thousands of years and, unlike the electronics and other modern high technology industries, they long preceded any scientific understanding of their inherent nature and consequences (32). Traditional foods and traditional food processing techniques form part of the culture of the people. Traditional food processing activities constitute a vital body of indigenous knowledge handed down from parent to child over several generations. Unfortunately, this vital body of indigenous knowledge is often undervalued. Regrettably, some of the traditional food products and food processing practices of West Africa have undoubtedly been lost over the years and the sub-region is the poorer for it. Those that the sub-region is fortunate to retain today have not only survived the test of time but are more appropriate to the level of technological development and the social and economic conditions of West African countries. Indeed, simple, low-cost, traditional food processing techniques are the bedrock of small-scale food processing enterprises in West Africa and their contributions to the economy are enormous. The objectives and main features of some of these traditional food processing techniques are presented in Table 1.

Table 1. Objectives and main features of traditional West African food processing techniques [11]

Technique/operation	Objectives	Main features/limitations
1. Preliminary/post-harvest operations: Threshing	To detach grain kernels from the panicle.	Carried out by trampling on the grain or beating it with sticks. Labor-intensive, inefficient, low capacity.
Winnowing	To separate the chaff from the grain.	Done by throwing the grain into the air. Labor-intensive, low capacity, inefficient.
Dehulling	To remove the grain from its outer protective casing.	Carried out by pounding the grain in a mortar with pestle. Labor-intensive, low capacity excessive grain breakage.
Peeling	To separate the peel or skin from the edible pulp.	Manual peeling with knives or similar objects. Labor-intensive, low capacity, loss of edible tissue.
2. Milling (e.g. corn): Dry milling	To separate the bran and germ from endosperm.	Carried out by pounding in a mortar with pestle or grinding with stone. Laborious, inefficient, limited capacity.
Wet milling	To recover mainly starch in the production of fermented foods e.g. ogi.	Carried out by pounding or grinding after steeping. Laborious, limited capacity, high protein losses, poor quality product.
3. Heat processing: Roasting	To impart desirable sensory qualities, enhance palatability, reduce anti-nutritional factors.	Peanuts are roasted by stirring in hot sand in a flat-bottom frying pot over a hot flame. Laborious, limited capacity.
Cooking (e.g. wara)	To contract curd and facilitate whey expulsion, reduce microbial load, inactivate vegetable rennet, impart desirable sensory qualities.	Loose curd pieces are cooked in a pot over wood fire. Limited capacity.
Parboiling (e.g. rice)	To facilitate milling and enrich milled rice with B-vitamins and minerals.	Done by steeping paddy rice in cold or warm water followed by steaming in bags in drums. Limited capacity, poor quality product.

Blanching	To inactivate plant enzymes and minimize oxidative changes leading to deterioration in sensory and nutritional qualities, e.g. enzymatic browning.	Slices (e.g. yam for elubo production) are heated in hot water in a pot for various durations. Limited capacity, poor quality product.
4. Drying: Shallow layer sun drying	To reduce moisture content and extend shelf life.	Product is spread in a thin layer in the open (roadside, rooftop, packed earth etc.). Labor-intensive, requires considerable space, moisture too high for long-term stability, poor quality.
Smoke drying (e.g. banda)	To impart desirable sensory qualities, reduce moisture content and extend shelf life.	Meat chunks after boiling are exposed to smoke in earthen kiln or drum. Limited capacity, poor quality product.
5. Fermentation	To extend shelf life, inhibit spoilage and pathogenic microorganisms, impart desirable sensory qualities, improve nutritional value or digestibility.	Natural fermentation with microbial flora selection by means of substrate composition and back-slopping. Limited capacity, variable quality.

TRADITIONAL TECHNOLOGIES AND RURAL DEVELOPMENT

The food industry in West Africa consists of large foreign-backed companies, government-owned or sponsored companies and medium-scale, small-scale and very small-scale (as small as one person) enterprises owned by indigenous operators (39). Some of the large foreign-backed food companies operating in Nigeria producing a wide range of processed foods and beverages marketed in the West African sub-region include Nestle Nigeria Plc, Cadbury Nigeria Plc, Unilever Nigeria Plc, Flour Mills of Nigeria Plc, Nigerian Bottling Company, Nigerian Breweries, Guinness Nigeria Plc and West African Milk Company affiliated to Friesland Coberco Dairy Foods. One of the first truly indigenous food companies in Nigeria that pioneered mechanized processing of local agricultural raw materials into indigenous foods such as yam flour, cowpea flour, dried milled capsicums (pepper) and egusi (*Colocynthis citrullus*) was Lisabi Mills (Nigeria) Limited established in Lagos in 1938. There is no doubt that in West Africa large-scale food industries financed through joint ventures with equity and loans from national and international financial institutions (the food multinationals) play a unique role in promoting industrial development through employment generation, value-added processing and training of skilled manpower. Although food multinationals have considerable export potentials through value-added processing, their impact is felt greatest in the urban areas.

Rural development is closely linked with the promotion of small-scale food industries that involve lower capital investment and rely on traditional food processing technologies. By generating employment opportunities in the rural areas, small-scale food industries reduce rural-urban migration and the associated social problems. They are vital to reducing post-harvest food losses and increasing food availability. It is clear from experiences with large, fully mechanized processing plants in Nigeria and other West African countries, that small-scale food industries, involving limited mechanization of the traditional methods of food processing, with possibilities for replication in the rural areas where the raw materials are produced, offer better prospects for success. Full mechanization often results in higher overhead costs. In addition, small-scale plants have the advantage of being able to match processing capacity with raw material supply and are, therefore, less adversely affected by raw material shortages than large-scale food industries. Unfortunately, rapid growth and development of small-scale food industries in West Africa are hampered by adoption of inefficient or inappropriate technologies, poor management, inadequate working capital, limited access to banks and other financial institutions, high interest rates and low profit margins (12). Small-scale food enterprises rely on locally fabricated equipment and a study of these enterprises in Nigeria identified lack of spare parts for equipment maintenance and repair as a major problem constraining their growth (61).

One of the greatest challenges facing food scientists/technologists in West Africa today is the upgrading of the traditional technologies of food processing and preservation (12, 57). In most cases, the traditional methods of food processing and preservation in West Africa remain at the empirical level. They are still rather crude, are not standardized, and are not based on sound scientific principles making them, in their present form, unsuitable to large-scale industrial production. The processes are often laborious and time consuming and invariably the quality of the products require substantial improvements. Since women are largely involved in traditional food processing, reducing the drudgery associated with traditional food processing operations, through the introduction of simple machines, would make life a lot easier for women with attendant benefits for the well-being of the family and society at large. In upgrading these technologies, the food scientist or technologist is faced with the challenge of modernizing the processes and equipment while still retaining the traditional attributes of the food products crucial to consumer acceptance. While there have been some instances where the introduction of modern techniques has resulted in products unacceptable to consumers, a number of successes have been recorded. Some of these include the mechanization of gari production, the production of instant yam flour or flakes, the production of soy-ogi, the industrial production of dawadawa and the upgrading of the kilishi process and the traditional West African cheese-making process.

TRADITIONAL FERMENTATIONS

Fermentation is one of the oldest and most important traditional food processing and preservation techniques. Food fermentations involve the use of microorganisms and enzymes for the production of foods with distinct quality attributes that are quite different from the original agricultural raw material. The conversion of cassava (*Manihot esculenta, Crantz* syn. *Manihot utilissima* Pohl) to gari illustrates the importance of traditional fermentations. Cassava is native to South America but was introduced to West Africa in the late 16th century where it is now an important staple in Nigeria, Ghana, Ivory Coast, Sierra Leone, Liberia, Guinea, Senegal and Cameroon. Nigeria is one of the leading producers of cassava in the world with an annual production of 35-40 million metric tons (23). Over 40 varieties of cassava are grown in Nigeria and cassava is the most important dietary staple in the country accounting for over 20% of all food crops consumed in Nigeria. Cassava tubers are rich in starch (20-30%) and, with the possible exception of sugar cane, cassava is considered the highest producer of carbohydrates among crop plants.

Despite its vast potential, the presence of two cyanogenic glucosides, linamarin (accounting for 93% of the total content) and lotaustralin or methyl linamarin, that on hydrolysis by the enzyme linamarase release toxic HCN, is the most important problem limiting cassava utilization. Generally cassava contains 10-500 mg HCN/kg of root depending on the variety, although much higher levels, exceeding 1000 mg HCN/kg, may be present in unusual cases. Cassava varieties are frequently described as sweet or bitter. Sweet cassava varieties are low in cyanogens with most of the cyanogens present in the peels. Bitter cassava varieties are high in cyanogens that tend to be evenly distributed throughout the roots. Environmental (soil, moisture, temperature) and other factors also influence the cyanide content of cassava (20). Low rainfall or drought increases cyanide levels in cassava roots due to water stress on the plant. Apart from acute toxicity that may result in death, consumption of sub-lethal doses of cyanide from cassava products over long periods of time results in chronic cyanide toxicity that increases the prevalence of goiter and cretinism in iodine-deficient areas. Symptoms of cyanide poisoning from consumption of cassava with high levels of cyanogens include vomiting, stomach pains, dizziness, headache, weakness and diarrhea (7). Chronic cyanide toxicity is also associated with several pathological conditions including konzo, an irreversible paralysis of the legs reported in eastern, central and southern Africa (31), and tropical ataxic neuropathy, reported in West Africa, characterized by lesions of the skin, mucous membranes, optic and auditory nerves, spinal cord and peripheral nerves and other symptoms (55).

Without the benefits of modern science, a process for detoxifying cassava roots by converting potentially toxic roots into gari was developed, presumably empirically, in West Africa. The process involves fermenting cassava pulp from peeled, grated roots in cloth bags and after dewatering, the mash is sifted and fried (see Figure 1).

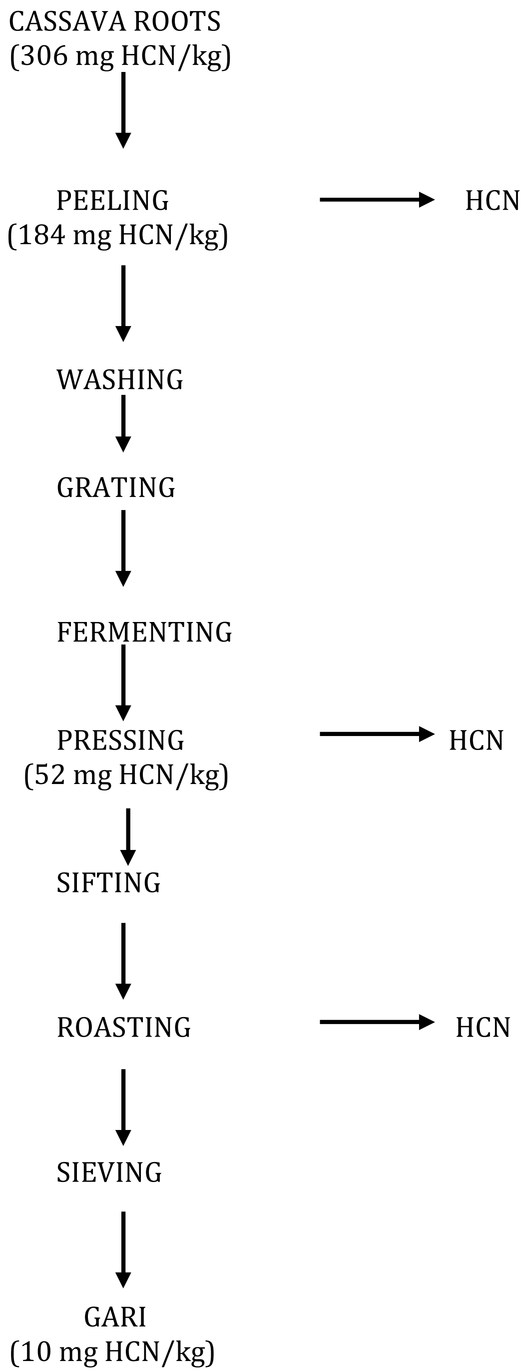

Figure 1. Process flow chart for gari production showing points of cyanide removal (HCN values are from [51])

During fermentation, endogenous linamarase present in cassava roots hydrolyze linamarin and lotaustralin releasing HCN. Crushing of the tubers exposes the cyanogens which are located in the cell vacuole to the enzyme which is located on the outer cell membrane, facilitating their hydrolysis. Most of the cyanide in cassava tubers is eliminated during the peeling, pressing and frying operations (Figure 1). Processing cassava roots into gari is the most effective traditional means of reducing cyanide content to a safe level by WHO standards (30) of 10 ppm, and is more effective than heap fermentation and sun drying, commonly used in eastern and southern Africa (22). Apart from 'gari' there is a vast array of traditional fermented foods produced in Nigeria and other West African countries (Table 2). These include staple foods such as fufu, lafun and ogi; condiments such as iru (dawadawa), ogiri (ogili) and ugba (ukpaka); alcoholic beverages such as burukutu (pito or otika), shekete and agadagidi; and the traditional fermented milks and cheese. Lactic acid bacteria and yeasts are responsible for most of these fermentations (25). The fermentation processes for these products constitute a vital body of indigenous knowledge used for food preservation, acquired by observations and experience, and passed on from generation to generation.

Table 2. Some traditional Nigerian fermented foods

Fermented Food	**Raw Material (Substrate)**	**Microorganisms involved**	**Uses**
Gari	Cassava pulp	*Leuconostoc* spp. *Lactobacillus* spp. *Streptococcus* spp. *Geotrichum candidum*	Main meal
Fufu	Whole cassava roots	*Lactobacillus* spp. *Leuconostoc* spp.	Main meal
Lafun	Cassava chips	*Leuconostoc* spp. *Lactobacillus* spp. *Corynebacterium* spp. *Candida tropicalis*	Main meal
Ogi	Maize, sorghum, millet	*Lactobacillus plantarum* *Streptococcus lactis* *Saccharomyces cerevisiae* *Rodotorula* spp. *Candida mycoderma* *Debaryomyces hansenii*	Breakfast cereal, weaning food
Iru (Dawadawa)	African locust bean (*Parkia biglobosa)* Soybean	*Bacillus subtilis* *B. licheniformis*	Condiment
Ogiri (Ogili)	Melon seed (*Citrullus vulgaris*), Fluted pumpkin (*Telfairia occidentalis*), Castor oil seed (*Ricinus communis*)	*Bacillus* spp. *Escherichia* spp. *Pediococcus* spp.	Condiment
Kpaye	*Prosopsis africana* (algarroba or mesquite)	*Bacillus subtilis* *Bacillus licheniformis* *Bacillus pumilus*	Condiment
Ugba (Ukpaka)	African oil bean (*Pentaclethra macrophylla*)	*Bacillus licheniformis* *Micrococcus* spp. *Staphylococcus* spp.	Delicacy usually consumed with stock fish or dried fish
Palm wine	Palm sap	*Saccharomyces* spp. Lactic acid bacteria Acetic acid bacteria	Alcoholic drink
Burukutu/Pito/Otika	Sorghum Millet & maize	*Saccharomyces* spp. Lactic acid bacteria	Alcoholic drink

Shekete	Maize	*Saccharomyces* spp.	Alcoholic drink
Agadagidi	Plantain	*Saccharomyces* spp.	Alcoholic drink
Nono (Fermented milk)	Milk	Lactic acid bacteria	Drink or converted to butter
Fura-da-nono Kunu-da-nono	Milk-cereal mixtures	Lactic acid bacteria	Drink
Warankasi (Soft cheese)	Milk	Milk coagulated by plant rennet. Lactic acid bacteria produce lactic acid from lactose.	Meat substitute

Apart from detoxification by the elimination of naturally-occurring nutritional stress factors, other benefits of traditional fermentations include reduction of mycotoxins such as aflatoxins as in ogi processing and the conversion of otherwise inedible plant items such as African locust bean (*Parkia biglobosa* Jacq) and African oil bean (*Pentaclethra macrophylla* Benth) to foods, i.e. iru and ugba respectively, by extensive hydrolysis of their indigestible components by microbial enzymes. Fermentation improves the flavor and texture of raw agricultural produce, imparting a desirable sour taste to many foods, such as gari and ogi, and leading to the production of distinct flavor components characteristic of many fermented foods. Fermentation may lead to significant improvement in the nutritional quality of foods by increasing the digestibility of proteins through hydrolysis of proteins to amino acids, increasing bio-availability of minerals such as calcium, phosphorus, zinc and iron through hydrolysis of complexing agents such as phytate and oxalate, and increasing nutrient levels, especially B-vitamins, through microbial synthesis (11).

Mechanization of Gari Processing

The mechanization of gari processing underscores the role that improvements in traditional food processing technologies can play in national development. Labor requirements for traditional processing of cassava into gari, fufu, lafun and other products are huge. Excluding labor for harvesting the tubers, about 415 man-hours are required to process a 10 ton per ha yield of cassava to gari (38). Considerable man-hours are spent on peeling, sifting and frying (Fig. 3). Hand peeling is a major bottleneck in traditional cassava processing. It is slow and labor intensive with an output of 25-30 kg/man-hr. Abrasive peelers with much greater capacities are less efficient than hand peeling because of greater loss of edible tissue and the need for extensive manual trimming. There is some prospect for lye peeling of cassava roots but there is as yet no commercial practice (60).

Figure 3. Gari frying over a wood fire by the traditional method

While it is true that traditional technologies are constrained by reliance on manual operations, full-scale mechanization, even when technically feasible, is not always economically justifiable as experiences with large, fully mechanized cassava processing plants in Nigeria have shown (5). Within the two extremes (traditional and full-scale mechanization), there is a wide ranging technology-mix suitable for different scales of processing operations (24, 37). Large, fully mechanized gari processing plants were largely unsuccessful in Nigeria because of low capacity utilization, high overhead costs, poor management and lack of requisite technical expertise for operation and maintenance of sophisticated, capital-intensive equipment.

In contrast, tremendous success has been recorded with small-scale gari processing factories in which some of the tedious manual operations of traditional cassava processing such as grating, pressing and sifting are replaced by machines while still retaining other manual operations. In these factories, the traditional method of grating cassava roots which involves rubbing of peeled cassava roots against the raised surface of nail-pierced metal sheets is replaced with the use of mechanical graters. The traditional method is not only laborious and time consuming; it is unsafe as accidental bruising of hands occurs frequently. Apart from mechanized grating, pressing and sifting, frying of dewatered cassava mash is done in sheltered communal fryers with chimneys that have much greater capacities than the traditional cast-iron pans. In addition, they are comfortable and the inhalation of smoke and potentially toxic fumes is minimized (Fig. 4). These small-scale gari processing factories have sufficient flexibility, allowing processing capacity to be matched with raw material supply. They provide employment in the rural areas, reduce post-harvest cassava losses and provide a good source of income to farmers and processors.

Figure 4. Gari frying in a sheltered communal fryer with chimney

Dawadawa Fermentation

Dawadawa or iru is the most important food condiment in Nigeria and many countries of West and Central Africa (21). It is made by fermenting the seeds of the African locust bean. The seeds are rich in fat (39-47%) and protein (31-40%) and dawadawa contributes significantly to the intake of energy, protein and vitamins, especially riboflavin, in many countries of West and Central Africa. For the production of dawadawa, African locust bean seeds are first boiled for 12-15 hr or until they are tender. This is followed by dehulling by gentle pounding in a mortar or by rubbing the seeds between the palms or trampling under foot. Sand or other abrasive agents may be added to facilitate dehulling. The dehulled seeds are boiled for 30 min to 2 hr, molded into small balls and wrapped in banana leaves. A softening agent called 'kuru' containing sunflower seed and trona or 'kaun' (sodium sesquicarbonate) may be added during this second boiling to aid softening of the cotyledons (43). The seed balls are then covered with additional banana leaves or placed in raffia mats and allowed to ferment for 2-3 days covered with jute bags (46). Alternatively, the dehulled seeds, after boiling, are spread hot on wide calabash trays in layers of about 10 cm deep, wrapped with jute bags and allowed to ferment for about 36 hrs. The fermented product is salted, molded into various shapes and dried (42). The main microorganisms involved in dawadawa fermentation are *Bacillus subtilis* and *Bacillus licheniformis* and one of the most important biochemical changes that occurs during fermentation is the extensive hydrolysis of the proteins of the African locust bean. Other biochemical changes that occur during dawadawa fermentation include the hydrolysis of indigestible oligosaccharides present in African locust bean, notably stachyose and raffinose, to simple sugars by α- and β-galactosidases, the synthesis of B-vitamins (thiamin and riboflavin) and the reduction of antinutritional factors (oxalate and phytate) and vitamin C (29, 42). An improved process for industrial production of dawadawa involves dehulling African locust bean with a burr (disc) mill, cooking in a pressure retort for 1 hr, inoculating with Bacillus subtilis starter culture, drying the fermented beans and milling into a powder (42). Cadbury Nigeria Plc in 1991 introduced cubed dawadawa but the product failed to make the desired market impact and was withdrawn. It would appear that consumers preferred the granular product to the cubed product.

PRODUCTION OF COMPLEMENTARY FOODS

It is generally agreed that breast milk is adequate both in quantity and quality to meet the nutrient and energy requirements of the infant up to the age of four to six months. Beyond this period, complementary or weaning foods are required to supplement the mother's breast milk. The weaning period is the most critical in the life of infants and preschool children, with serious consequences for growth, resistance to diseases, intellectual development and survival if the child's nutritional needs are not met. Unfortunately, in West Africa and other parts of Africa, traditional complementary foods are made from cereals, starchy roots and tubers that provide mainly carbohydrates and low quality protein. These complementary foods exemplified by ogi are the leading cause of protein-energy malnutrition in infants and preschool children in Africa (9, 28). African infants experience a slower growth rate and weight gain during the weaning period than during breastfeeding due primarily to the poor nutritional qualities of traditional African complementary foods such as ogi. Apart from their poor nutritional qualities, traditional African cereal-based gruels used as complementary foods have high hot paste viscosity and require considerable dilution before feeding; a factor that further reduces energy and nutrient density (40). Although nutritious and safe complementary foods produced by food multinationals are available in West African countries, they are far too expensive for most families. The economic situation in these countries necessitates the adoption of simple, inexpensive processing techniques that result in quality improvement and that can be carried out at household and community levels for the production of nutritious, safe and affordable complementary foods.

COMPLEMENTARY FOODS FROM CEREAL-LEGUME BLENDS

As cereals are generally low in protein and are limiting in some essential amino acids, notably lysine and tryptophan, supplementation of cereals with locally available legumes that are high in protein and lysine, although often limiting in sulfur amino acids, increases protein content of cereal-legume blends and their protein quality through mutual complementation of their individual amino acids. This principle has been utilized in the production of high protein-energy complementary foods from locally available cereals and legumes. Community-based weaning food production using 4:1 ratio of locally available cereals and legumes have proved successful in many African countries. 'Weanimix', a weaning food made from a cereal-legume blend, developed by the Nutrition Division of the Ministry of Health in Ghana was introduced on a large scale in the country in 1986 (59). To promote the production of weaning foods from locally available cereals and legumes at the household level, grinding mills were provided to rural women groups in Ghana with UNICEF assistance (56). Although legume supplementation increases protein content and protein quality of cereal-legume blends, the types of cereal and legume involved as well as the blending ratios are critical. Increasing legume concentration in the blend generally increases the protein score until a new limiting amino acid is imposed. Using a blend quality prediction procedure based on the amino acid scores of mixtures of cereals and legumes, the relative performance of maize, millet and sorghum supplemented with cowpea, groundnut, pigeon pea, soybean and winged bean in various weaning formulations has been estimated (56). Mixtures of cereals with groundnut produced the poorest quality blends due to the relative inadequacy of groundnut protein in complementing cereal amino acids. Soybean and winged bean produced the best quality blends with cereals, followed by cowpea and pigeon pea in that order (56).

IMPROVED TECHNOLOGY FOR OGI PRODUCTION

Large-scale industrial production of weaning foods involves sophisticated technology including drum drying, spray drying and extrusion cooking. For the production of weaning foods at household and community levels, capital-intensive, sophisticated technology is inappropriate. Ogi, koko and similar products from locally available cereals remain the most important complementary foods in West African countries especially Nigeria, Benin, Ghana and Senegal. Consequently, efforts at improving the nutritional quality of complementary foods in the West African sub-region have been directed predominantly at ogi. The traditional preparation of ogi involves steeping maize, millet or sorghum in water for 1-2 days, followed by wet-milling, wet-sieving and fermentation for 2-3 days. The major microorganisms associated with the fermentation of ogi are lactic acid bacteria (*Lactobacillus plantarum* and *Streptococcus lactis*) and yeasts (*Saccharomyces cerevisiae, Rodotorula* spp*., Candida mycoderma* and *Debaromyces hansenii*). Considerable nutrient losses occur during ogi manufacture and depending on the processing method used protein losses may be as high as 50% (47, 4).

Several approaches have been adopted in improving the quality of ogi. Instant dry ogi powder was produced by drum drying the slurry from the fermentation of dry-milled high lysine maize flour with starter cultures of *Lactobacillus plantarum*, *Streptococcus lactis* and *Saccharomyces rouxii* (18). The product had a higher lysine content relative to ogi produced by the traditional method. Another approach was to drum dry ogi slurry from regular maize followed by fortification with lysine and other amino acids (1). For the production of dry ogi powder at community level, hot air cabinet drying of ogi is preferred to drum drying because it is less sophisticated and simpler in content and operation. An upgraded traditional process involving wet-milling, wet-sieving with gyrating shaker and sieves, fermenting, de-watering with a screw press, followed by drying in a cabinet dryer, milling, sieving and packaging is particularly suited for production of ogi powder at community level (2). Co-fermentation of maize and locally available legumes has also been used to improve the nutritional quality of ogi. 'Soy-ogi' and 'cowpea-ogi' or 'ewa-ogi' are two of such products (6, 8, 45). Soy-ogi developed by the Federal Institute of Industrial Research, Oshodi, Lagos, Nigeria is made by milling steeped maize and soybeans into a paste that is allowed to ferment. The fermented slurry is fortified with minerals and vitamins, pasteurized and then spray dried. Apart from improvement in protein content and quality, co-fermentation also reduces flatulence and anti-nutritional factors associated with legumes. Sprouting has also been used to improve the nutrient content of ogi and cereal-legume blends used as complementary foods (58, 48).

A variety of complementary foods have been developed in which ogi powder is enriched by the incorporation of legume or defatted oil seed flours (19, 52). A novel approach was the supplementation of ogi at levels of up to 25 % with tempe flour, an Indonesian product, made by fermenting soybeans with the mold *Rhizopus oligosporus*. Addition of tempe flour improved the nutrient content of ogi with significant increases in lysine and tryptophan (26). Maize-based complementary foods made from whole maize flour or ogi powder and supplemented with soybean, cowpea and groundbean tempe had high protein quality, with nutrient contents within the range prescribed by the FAO/WHO pattern for processed weaning foods (53, 54). They were comparable with commercial baby foods produced by food multinationals in Nigeria and can support the growth of infants in developing countries especially during the critical weaning period (27, 53).

PRODUCTION OF INSTANT YAM FLOUR

Yam, possibly the oldest cultivated food plant in West Africa, is of major importance to the economy of the sub-region that accounts for the bulk of world production of the crop. By far the most important product derived from white yam (*Dioscorea rotundata* Poir) is fufu or pounded yam, popular throughout West Africa. Traditionally, pounded yam is prepared by boiling peeled yam pieces and pounding using a wooden mortar and pestle until a somewhat glutinous dough is obtained. Arising from the need to have a convenience food and reduce the drudgery associated with the preparation of pounded yam, various brands of instant yam flour are now available in West Africa since the introduction of "poundo yam", which is no longer in the market, by Cadbury Nigeria Ltd in the 1970s. Instant yam, on addition of hot water and stirring, reconstitutes into a dough with smooth consistency similar to pounded yam. The product is so popular that considerable quantities are exported to other parts of the world, especially Europe and North America, where there are sizable African populations.. Commonly, instant yam flour is produced by sulfiting peeled yam pieces, followed by steaming, drying, milling and packaging in polyethylene bags (37). Instant yam flour can also be produced by drum drying cooked, mashed yam and milling the resultant flakes into a powder using a process similar to that used for production of dehydrated mashed potato (49, 50).

WEST AFRICAN CHEESE-MAKING

The scientific study of traditional West African cheese-making offers another example of the growing understanding of the inherent nature, strength and limitations of traditional African food processing and preservation techniques. Cheese-making is one of the oldest methods of preserving excess milk and is a major business worth billions of dollars in many industrialized countries. Indeed, cheeses are now unique products in their own right and cheese-making has advanced beyond being merely a food preservation technique. Cheeses are produced by the coagulation of milk casein by an enzyme preparation (rennet) or an acid, usually lactic acid. Calf rennet derived from the abomasa of 10 to 30-day-old milk-fed calves, containing rennin or chymosin, is the coagulant of choice for industrial cheese-making. It is preferred to microbial and plant rennets because of its low proteolytic activity. The nomadic Fulani has, since ancient times, processed milk into a soft cheese known as warankasi in Nigeria or woagachi in the Republic of Benin as a means of preserving excess milk. Warankasi is a good source of animal protein and is used to replace meat or fish, or in combination with them, in various food recipes. Its low lactose content makes it an acceptable food to many people who suffer from lactose intolerance associated with milk consumption in African and Asian population due to low levels of intestinal β-galactosidase (lactase).

The traditional West African cheese-making process was developed (presumably empirically) by the nomadic Fulani and is based on the milk-coagulating properties of juice from the leaves of the sodom apple plant [*Calotropis procera* (Ait.)]. The juice, obtained by crushing sodom apple leaves, is mixed with cows' milk gently heated in a pot over a wood fire (Fig. 5). Following coagulation, the loose curd pieces are poured into small raffia baskets and allowed to drain. In the Republic of Benin, the cheese may be further processed by sun drying and coloring with extracts from threshed sorghum ears or other plant materials that impart a reddish color to the cheese (Fig. 6). The unit operations of traditional cheese-making are similar to those of industrial cheese-making and consist of milk setting, cutting or breaking of the curd, cooking of the curd and draining or dipping (13, 44). The process is very unhygienic; there are numerous opportunities for product contamination and there are no quality standards. Consequently, the quality of the product is highly variable and often very poor.

Starting with pasteurized milk and applying scientific knowledge of the biochemical properties of sodom apple proteinases, an improved cheese-making procedure based on the traditional process has been developed (10, 15, 16). Vegetable rennet prepared by precipitating the milk clotting proteinases in sodom apple leaves with ammonium sulfate is used as coagulant (14). This allows better control of the coagulation process and reduces product contamination. Following coagulation, the curd pieces are drained in stainless steel hoops instead of raffia baskets, salted and pressed in a hydraulic press to reduce the moisture content and extend the shelf life (Fig. 7). Cheese yields and recovery of milk components (95.6 % for fat, 85.5 % for protein) were very good when the improved cheese-making process using sodom apple rennet as coagulant was compared with a laboratory cheese-making procedure using calf rennet (15).

Figure 5. Addition of juice from crushed sodom apple leaves to milk in traditional West African cheese-making

Figure 6. Retailing of warankasi in Benin Republic (courtesy of M. Egounlety)

RAW MILK (4.7 kg)

↓

PASTEURIZE (72°C FOR 16 SEC OR 63°C FOR 30 MIN)
AND COOL

↓

ADD 1.8 mM $CaCl_2$ AND MIX THOROUGHLY AT 40°C

↓

ADD 7 mL PARTIALLY PURIFIED VEGETABLE RENNET
AND STIR FOR 2 MINUTES

↓

HEAT GENTLY AT THE RATE OF 1.5-2°C PER MINUTE
UNTIL CURD FORMATION AT ABOUT 75°C

↓

MAINTAIN AT 75°C FOR 30 MINUTES

↓

COOK CURD PIECES WITH GENTLE STIRRING
BY INCREASING TEMPERATURE TO 80°C FOR 10 MINUTES

↓

DRAIN FOR 1 HOUR IN STAINLESS STEEL HOOPS

↓

PRESS OVERNIGHT AT 120 kPa

↓

IMPROVED WARANKASI

Figure 7. Outline of an improved process for the production of warankasi

PRODUCTION OF KILISHI AND OTHER PROCESSED MEATS

Suya (tsire or balangu), banda (kundi) and kilishi are the most important traditional processed meats in Nigeria and other West African countries including Chad, Niger and Mali where they provide valuable animal protein in the diets of the people. Banda is a salted, smoke-dried meat product made from chunks of cheap, low quality meat from various types of livestock including donkeys, asses, horses, camel, buffalo and wild life (41). The meat chunks are pre-cooked before smoking/kiln drying or sun drying. The traditional smoking kiln for banda is usually an open-top, 50-gallon oil drum fitted with layers of wire mesh that hold the product, and fired from the bottom. Banda is a poor quality product, stone-hard and dark in color. Unlike banda, suya and kilishi are made by roasting spiced, salted slices/strips of meat (usually beef). Kilishi is different from suya in that a two-stage sun-drying process precedes roasting. Consequently, kilishi has a lower moisture content (6-14 %) than suya (25-35 %) and a longer shelf life. A variety of spices and other dried ingredients are used in kilishi processing including ginger (*Zingiber officinale*), chillies (*Capsicum frutescens*), melegueta pepper (*Aframomum melegueta*), onion (*Allium cepa*), *Piper guineense*, *Thonningia sanguinea*, *Fagara santhoxyloides* and defatted peanut (*Arachis hypogea*) cake powder. Kilishi consists of about 46% meat and about 54% non-meat ingredients, with defatted peanut powder accounting for about 35% of the ingredient formulation (36). Other traditional processed meat products in Nigeria include ndariko and jirge (41). Ndariko is made by sun drying long strips of meat with or without the addition of salt and spices. Jirge, like ndariko, is prepared by sun drying meat strips; but the meat for jirge is first cut into chunks and allowed to ferment to develop the desired sour taste before sun drying.

A major source of concern, from a public health standpoint, as revealed by consumer surveys, is the unhygienic conditions under which meat products are often processed and retailed in Nigeria and other West African countries (34). For products such as suya and kilishi, the spices used in their processing are potentially sources of microbial contamination. Microbial populations including coliforms exceeding acceptable limits for ready-to-eat meat products and the presence of a wide spectrum of pathogenic bacteria have been reported in retail suya (35). Consequently, research efforts have been directed at improving the quality, wholesomeness, safety and shelf life of traditional processed meats through the upgrading of the traditional technology and the control of microbial contamination (33, 17). A model pilot plant for improved processing of kilishi has been established in Benin City, Nigeria under an International Development Partnerships (IDP) collaborative research project between Wilberforce University, USA and the University of Benin, Nigeria funded by the United States Agency for International Development (USAID)/the United Negro College Fund Special Programs (UNCFSP) and the Raw Materials Research and Development Council of Nigeria (Fig. 8). The pilot plant uses improved technology involving cabinet (tray) drying and vacuum packaging and has clearly demonstrated the benefits arising from upgrading traditional food processing technologies in terms of improved product quality, shelf life, consumer acceptance, export potential and income generation (3).

Figure 8. Slicing of beef in kilishi pilot plant (courtesy of J. O. Igene & H. A. Agboola)

CONCLUSION

The critical role that food science and technology plays in national development cannot be overemphasized in West African countries where high post-harvest losses, arising largely from limited food preservation capacity, is a major factor constraining food and nutrition security. Seasonal food shortages and nutritional deficiency diseases are still a major concern. While the large food multinationals play a unique role in promoting industrial development in West Africa through employment generation, value-added processing and training of skilled manpower, their impact is felt greatest in the urban areas. Small-scale food industries that involve lower capital investment and that rely on traditional food processing technologies are crucial to rural development in West Africa. By generating employment opportunities in the rural areas, small-scale food industries reduce rural-urban migration and the associated social problems. They are vital to reducing post-harvest food losses and increasing food availability. While a lot still has to be done in upgrading traditional West African food processing technologies, some successes have been achieved including the mechanization of gari processing, the production of instant yam flour, the production of soy ogi, the industrial production of dawadawa, and the upgrading of the kilishi process and the West African cheese-making process.

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