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Current Status of Alkaline Fermented Foods and Seasoning Agents of Africa

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Abstract

Fermented foods and seasoning agents play central roles in the food and nutrition security of nations across the world, but particularly so in Africa, Asia, South America and Oceania. As several people across the world gravitate back to “eating natural,” there is a new emphasis on these fermented foods and seasoning agents which are also critical cultural foods in countries and societies where they are important. The result is the growth in demand for these products beyond what the traditional kitchen technologies is able to cope with. In Africa, many of the seasoning agents are products of alkaline fermentation of legume seeds, pulses and in some cases animal proteins and sea foods. There is an upswing in the popularity of these seasoning agents and around them, new cottage industries are growing, as against the kitchen technology that sustained them through the ages. This chapter will explore the state of biotechnological developments around these foods and seasoning agents and point the way to good manufacturing practice and industrial development and the need to grow this value chain that has helped to sustain societies through ages.

Keywords: alkaline fermentation, African seasoning agents, fermented foods, *okpeye*, *dawadawa*, *ugba*, *ogiri*, *soumbala*

1. Introduction

Fermented foods are products of edible or inedible raw materials that have undergone desirable physico-chemical and biochemical modifications through the activities of microorganisms and/ or their metabolites, but in which the weight of the microorganism (relative to substrate) in the food is small [1]. A distinct group of fermented foods is the traditional alkaline fermented products often used as food condiments/ seasoning agents [2]. Fermented foods and seasoning agents play central roles in the food and nutrition security of many nations, but particularly so in Africa, Asia, South America and Oceania [3]. As several people across the world gravitate back to “eating natural,” there is a new emphasis on fermented foods and seasoning agents which are also critical cultural foods in countries and societies where they are important. In Africa, many of the seasoning agents are products of fermentation of legume seeds, a process that causes an increase, to alkaline regions, in pH of the product. This results from microbial degradation of seed proteins to peptides and amino acids and finally to ammonia [3, 4]. Fermentation of raw materials such as fish, legumes and plant oil seeds for the production of

food condiments with desirable organoleptic properties and enhanced nutritional values has historically been a popular practice in Africa, particularly in West and Central Africa. Currently, there is an upswing in the popularity of these seasoning agents, and around them new cottage industries are growing, as against the kitchen technology that sustained them through the ages [3]. This resurgence in alkaline fermented foods are results of a better understanding of fermentation processes, as well as increased knowledge of the nutritional, and health-promoting benefits of fermented foods [5]. This chapter will explore the state of biotechnological developments around these foods and seasoning agents and point the way to good manufacturing practice and industrial and market development.

1.1 The beginning of fermented foods

The art of food fermentation dates back to prehistoric times and are the oldest methods for producing new foods from existing substrates, and of prolonging the shelf life of foods [3, 6]. Historically, fermentation has been used to modify the composition of foods without any scientific knowledge of the processes or benefits, and this art has been practiced for thousands of years [7–9]. As at 2000–4000 BC, the Egyptians were producing alcoholic beverages [6]. According to records [10, 11], fermentation has been in practice also in Sudan, (1500 BC) and Mexico, (2000 BC). Despite advances in biotechnology and efforts towards industrialization of the traditional fermentations, uncontrolled traditional techniques/ kitchen technologies are still predominantly used for the processing of alkaline African fermented foods and seasonings.

Modern food technology practices such as the use of good manufacturing practice (GMP) protocols, as well as new innovations like the use of starter cultures in controlled fermentations continue to play little or no role in the developing countries. The disposition to understanding traditional food processing is now beginning to gain some ground in developing countries. It is essential to recognize the significance of biotechnology-based innovations and applications in food processing in order to ensure quality and safety of products [12]. More recently, process techniques used in traditional fermented foods are being redefined and diversified through the use of molecular biology-based tools, enabling fermentation technology around these processes to evolve towards sustainable commercialization and industrialization. This lift from artisanal production has stimulated new interests in food research, such that today a lot of scientific works [13–26] have been devoted to these fermented foods. With modern biotechnology new and better methods for processing foods under GMP are developing.

2. Fermentation processes

Across cultures, a variety of traditional techniques are used for producing fermented foods and seasoning agents. The techniques differ based on microorganisms, raw material and fermentation conditions [27, 28]. Basically, processes involved in food product development by fermentation are of four types (**Figure 1**), viz.: alcoholic, lactic acid, acetic acid and alkaline fermentation [6, 27, 29].

Alcoholic fermentation is mainly performed by yeasts leading to the production of ethanol. Products include wine, beer, other alcoholic beverages and bread. Lactic acid fermentation is driven by lactic acid bacteria (LAB), which produce organic acid and other compounds in various foods. Acetic acid fermentation is carried out by the acetic acid bacteria which convert alcohol to acetic acid under aerobic process as in vinegar. Alkaline fermentation usually takes place during the fermentation of

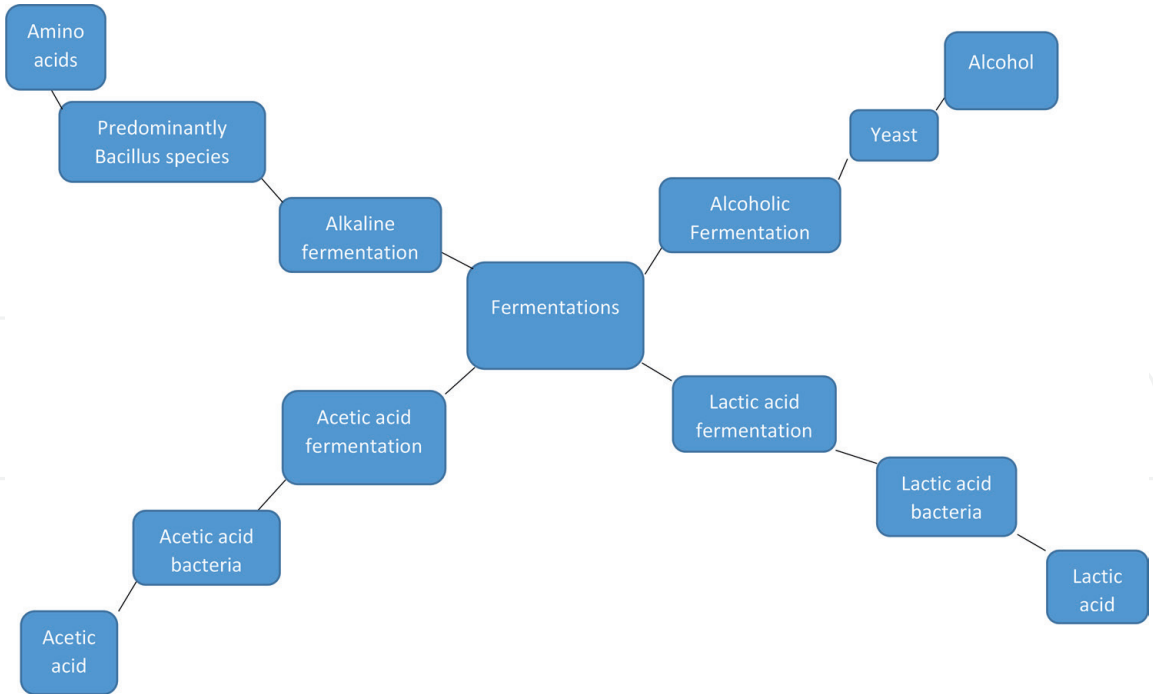


Figure 1.
An illustration of the various types of fermentations, based on microorganisms, fermentation condition and end product. Source: Anal [27].

Food group/class	Substrate	Derived product	Country
Starchy foods	Root tubers		
	Cassava	Garri, akpu, loi-loi	Nigeria
		lafun/aribo	Nigeria
			Nigeria
		Kokobebe	Nigeria
	Cereal-based		
	Maize	Ogi/akamu	Nigeria
		Kito	Tanzania
		Mawe	Nigeria (Benin)
		Njera	Ethiopia
		Mahewu	South Africa, Kenya
	Uji		
	Millet	Kenkey/banku	Ghana
		Ogi/akamu	Nigeria
		Uji	Uganda, Tanzania
	Sorghum	Busa	Egypt
		Nasha	Sudan
		Kisra	Sudan
		Bogobe	Botswana
		Uji	Uganda, Tanzania

Food group/class	Substrate	Derived product	Country
Alcoholic and non-alcoholic beverages	Cereal	<i>Burukutu/pito/otika</i>	Nigeria
	Palm sap	<i>Ngwo/nkwuenu</i>	Nigeria
	Grape	<i>Pique</i>	Mexico
	Cane sugar	<i>Sake</i>	Japan
		<i>Tape</i>	Indonesia
Animal-based product	Milk	<i>Nono</i>	Nigeria
	Beef tripe	<i>Afo-nama</i>	Nigeria
	Milk	<i>Warankasi</i>	Nigeria
Fish/sea food product	Fish	<i>Azu-okpo</i>	Nigeria
	Crab	<i>Nshiko</i>	Nigeria
	Cray fish/shrimp	<i>Upuni/oporo</i>	Nigeria
	Fish	<i>Garum</i>	Europe
	Fish	<i>Suan yu</i>	China
	Fish (herring)	<i>Surstromming</i>	Sweden
Plant based alkaline product (seasoning agents)	Refer to (Table 2)	Refer to (Table 2)	Refer to (Table 2)

Sources: [4, 30–37].

Table 1.
The main classes of fermented foods based on the substrate from which they were derived.

fish, legumes and other plant seeds (raw materials with high protein content, and in which principal metabolic processes center around protein degradation) to produce seasoning agents including *dawadawa* from Locust bean and *ugba* from oil bean and several related products.

Fermented foods can be classified in different ways based on the type of substrate, microorganisms involved in the fermentation and even the processing methods. Based on the substrate or raw material from which they are manufactured [30], foods derived by fermentation can be classified into five main categories namely: 1. Starchy foods such as root tubers (cassava), examples: *garri*, *akpu*, *lafun*, cereals (maize, sorghum, millet). 2. Alcoholic and non-alcoholic beverages (palm wine) *ngwo*, *nkwu enu*, *kunu-zaki*, 3. Animal protein based products (milk) example *nono*, *warankasi* 4. Fish/ sea food based foods examples *azu-okpo*, *garum* 5. Plant-seed and legume based products (seasoning agents), including *daddawa*, *iru* and *netetu* among others. **Table 1** presents the main classes of fermented foods based on the substrate from which they were derived.

3. Diversity of alkaline fermented foods and seasoning agents

Alkaline fermentation mainly relate to the fermentation of legumes (soy bean), protein rich oil seeds (African oil bean) and fish to produce condiments. During these processes, there is always an increase in pH up to 8 and above. The increase in pH has been attributed to the metabolic activities of the microbes that break-down the protein of the raw material into peptides, amino acids and ammonia [2]. A diversity of alkaline fermented foods including seasoning agents are available world-wide, particularly in countries in Africa and Asia where these products are an integral part of the cultural diets of the native communities [2, 3, 12, 31]. They are

prepared from a wide range of raw materials including soybean, African locust bean and various species of fish [32]. Most of these are highly priced seasoning agents prepared by solid state fermentations in which *Bacillus* species are the key organisms. **Table 2** shows some common alkaline seasoning agents that are key players in traditional food systems across the world, particularly in Africa and Asia. Some

Raw material	Product local name	Distribution/ country	State of development	References
Soy-bean (<i>Glycine max</i>)	<i>Daddawa</i>	West Africa, Nigeria	A, B	[15, 19]
	<i>Soy-dawadawa</i>	Ghana	A, B	[3, 16, 20]
	<i>Kinema</i>	India	A, B	[14, 41, 42]
	<i>Hawaijar</i>	India	A, B	[43–45]
	<i>Aakhune</i>	India	A, B	[27]
	<i>Bekang</i>	India	A, B	[27]
	<i>Peruyaana</i>	India	A, B	[27]
	<i>Tungrymbai</i>	India	A, B	[27]
	<i>Thua-nao</i>	Asia, Thailand	A, B, C	[27, 45–47]
	<i>Natto</i>	Asia, Japan	A–D	[27, 48]
	<i>Douchi</i>	China, Taiwan	A, B	[75, 76]
	<i>Chungkukjang or jeonkukjang or cheonggukjang</i>	Korea	A, B	[27, 50, 51]
	<i>Meju</i>	Korea	A, B	[52]
	<i>Miso</i>	Japan	A–C	[45, 53, 54]
	<i>Shoyu</i>	Japan, Korea, China	A, B	[54]
	<i>Tauco</i>	Indonesia	A, B	[55]
African locust bean (<i>Parkia biglobosa</i>)	<i>Tempe</i>	Indonesia (origin), The Netherlands, Japan, USA	A–D	[45, 56, 57]
	<i>Yandou</i>	China	A, B	[45, 58, 59]
	<i>Soumbala</i>	Burkina-Faso	A, B, C	[3, 60]
	<i>Afitin/sonru/</i>	Mali, Côte d’Ivoire and Guinea, Nigeria (Benin)	A, B	[24, 27, 38, 61]
	<i>Netetu</i>	Senegal	A, B	[62]
Mesquite (<i>Prosopis africana</i>)	<i>Kinda</i>	Sierra Leone	A, B	[63]
	<i>Dawadawa/iru</i>	West Africa (Nigeria)	A, B	[3, 24, 60, 61]
	<i>Okpehe/okpeye/okpiye</i>	West Africa/middle belt and southern Nigeria	A–C	[3, 22]
Castor oil/fluted pumpkin/melon	<i>Kpaye/afiyo</i>	Northern Nigeria	A, B	[64, 65]
	<i>Ogiri</i>	West Africa/ Eastern Nigeria	A, B	[4, 15, 24, 66]
African oil bean (<i>Pentaclethra macrophylla</i>)	<i>Ugba/Ukpaka</i>	West Africa/ Southern Nigeria	A–C	[4, 67]

Raw material	Product local name	Distribution/ country	State of development	References
Roselle (<i>Hibiscus sabdariffa</i>)	<i>Bikalga</i>	Burkina-Faso	A–C	[68, 79]
	<i>Daton</i>	Mali		[68]
	<i>Furandu</i>	Sudan		[2]
	<i>Mbuja</i>	Cameroon		[2]
<i>Cathormion altissimum</i>	<i>Oso</i>	West Africa/ Nigeria	A, B	[69, 70]
Saman tree (<i>Albizia saman</i>)	<i>Aisa</i>	Nigeria	A, B	[21]
African yam bean	<i>Owoh</i>	Nigeria	A, B	[21, 71, 72]
Cotton seed (<i>Gossypium hirsitium</i>)	<i>Owoh</i>	Nigeria	A, B	[2, 73]
Leaves of Cassia	<i>Kawal</i>	Sudan	A, B	[45, 74]

State of development is based on published information. Product may not be in the market. Key: A: Microorganisms involved are known, B: Roles of organisms known or inferred, C: Starter Cultures have been developed or suggested, D: Pilot or improved technologies or industrial plant (s) available.

Table 2.
Some of the plant-based alkaline fermented seasoning agents.

of these are described briefly to show state of the art and current application of modern technology (biotechnology) to the production processes.

Fermented condiments are cherished by consumers due to their peculiar organoleptic properties, nutritional and health significance as well as durability. The seasoning agents are characteristically used in small quantities to flavor traditional dishes, but their unique aroma eventually become central to the properties of those foods [9]. The quality of fermented foods is influenced by the starting raw material, microbiota as well as the processing methods [6]. The starting raw material for producing a particular seasoning can vary. For instance, *ogiri* is traditionally produced from any of three substrates namely: castor oil seeds, fluted pumpkin seeds (*Telfairia vulgaris*) and melon seeds. Given the diversity of raw materials from which comparable products are obtained, it is clear that the basis for uniformity in flavor characteristics relate considerably to the biochemical and physiological features of the microorganisms that drive the process. In different parts of the world, and even within the same region or country, the same fermented product may be known by different local names. For instance, in Nigeria *dawadawa /iru* is the traditional name for a fermented seasoning from African locust bean [33] while *netetu* is used in Senegal to refer to a food condiment from the same substrate [34] and *soumbala* is the traditional name used in Burkina-Faso [35].

3.1 Traditional plant-based alkaline fermented seasoning agents

Among the various substrates used for preparation of traditional fermented seasonings, soy beans is the most popular because of its wide spread distribution across the globe and importance as a rich source of plant protein [36]. In East and Southeast Asia and in West Africa, a wide range of alkaline fermented seasonings are produced from soy bean [27]. These include West African *dawadawa*, Japanese *natto* and Thai *thua nao*. Soy bean can be fermented by either bacteria or fungi. For bacteria-based soy bean products, *Bacillus* species (predominantly *B. subtilis*) are the predominant microorganisms. Fungi-based soy bean products are produced

using filamentous mold (Mostly *Aspergillus*, *Mucor*, *Rhizopus*) [27]. The other common substrates used to prepare alkaline fermented products in Africa include African locust bean (*dawadawa*, *iru*, *kinda*, *soumbala*), African mesquite seeds (*Okpeye/ okpehe/ kpaye/ afiyo*) and African oil bean (*ugba*).

Apart from these popular legumes and oil seeds, other less popular and less utilized legumes and vegetables are also used for production of alkaline condiments in Africa. These include *Albizia saman* seeds for production of aisa [22], cotton seeds (*Gossypium hirsutum*) for used production of *owoh* [2] and *Hibiscus sabdariffa* for production of bikalga [37].

3.1.1 Dawadawa

Dawadawa is probably the most popular and commercially successful traditional seasoning agent in West and Central African Savannah where it is known by different ethnic names [38, 39]. *Dawadawa* is processed from the solid substrate fermentation of cotyledons of locust bean (*Parkia biglobosa*). It is widely consumed as a food seasoning in the Northern and some part of Southern Nigeria [3, 15]. The traditional process may vary slightly depending on the processor and locality. In perhaps the most popular process (**Figure 2**) the basic steps include boiling of

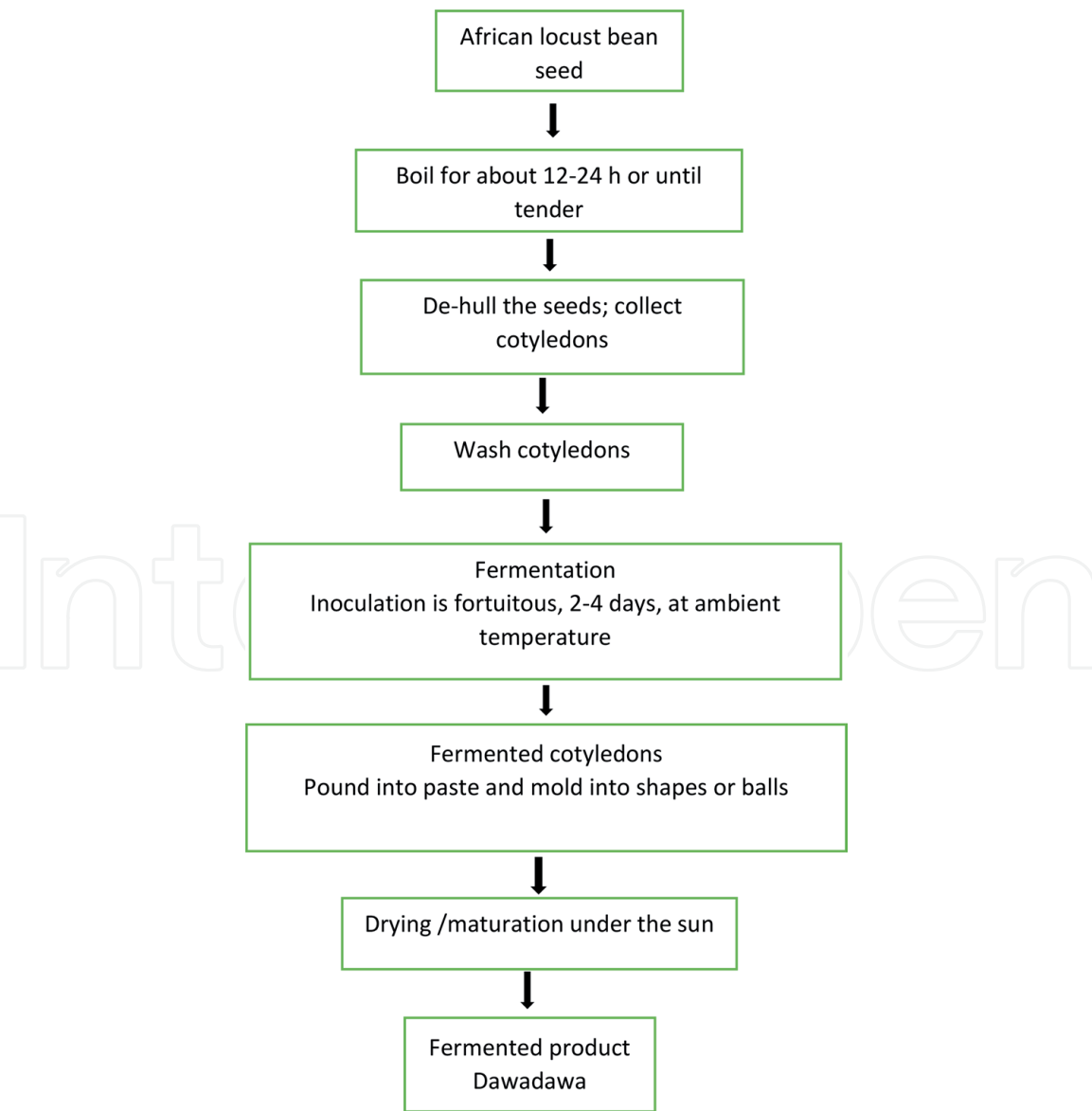


Figure 2.
Flow chart for the traditional method of producing dawadawa.

the locust bean seeds for 12–24 h, followed by manual de-hulling to remove the seed coat. The de-hulled cotyledons are collected and washed thoroughly and then boiled again for 1 h. The cotyledons are placed in jute bags or wrapped with banana leaves and allowed to ferment for 2–4 days at ambient temperature. During fermentation, the pH increases from near neutral to 8.1 or higher due to the breakdown of protein to amino acids and ammonia. As with other traditional processes, inoculation is usually fortuitous from production environment and equipment used or (rarely by back slopping). Microorganisms that drive the process are predominantly species of *Bacillus* [14, 40]. Other associated organisms include *Staphylococcus* [41], but the roles of these minor populations are contentious. At the end the product is sticky, with pungent odor and covered with mucilaginous grayish layer.

Dawadawa is the most scientifically studied traditional seasoning in West Africa. Several studies designed to improve the traditional process of have been published [41, 42]. **Figure 3** shows a modified procedure for *dawadawa* production [43]. Although, many African alkaline seasoning agents are still produced by the old-aged traditional cottage and kitchen processes, the preparation of some condiments like *dawadawa* has achieved pilot commercial status and is now considerably carried out on large scale by

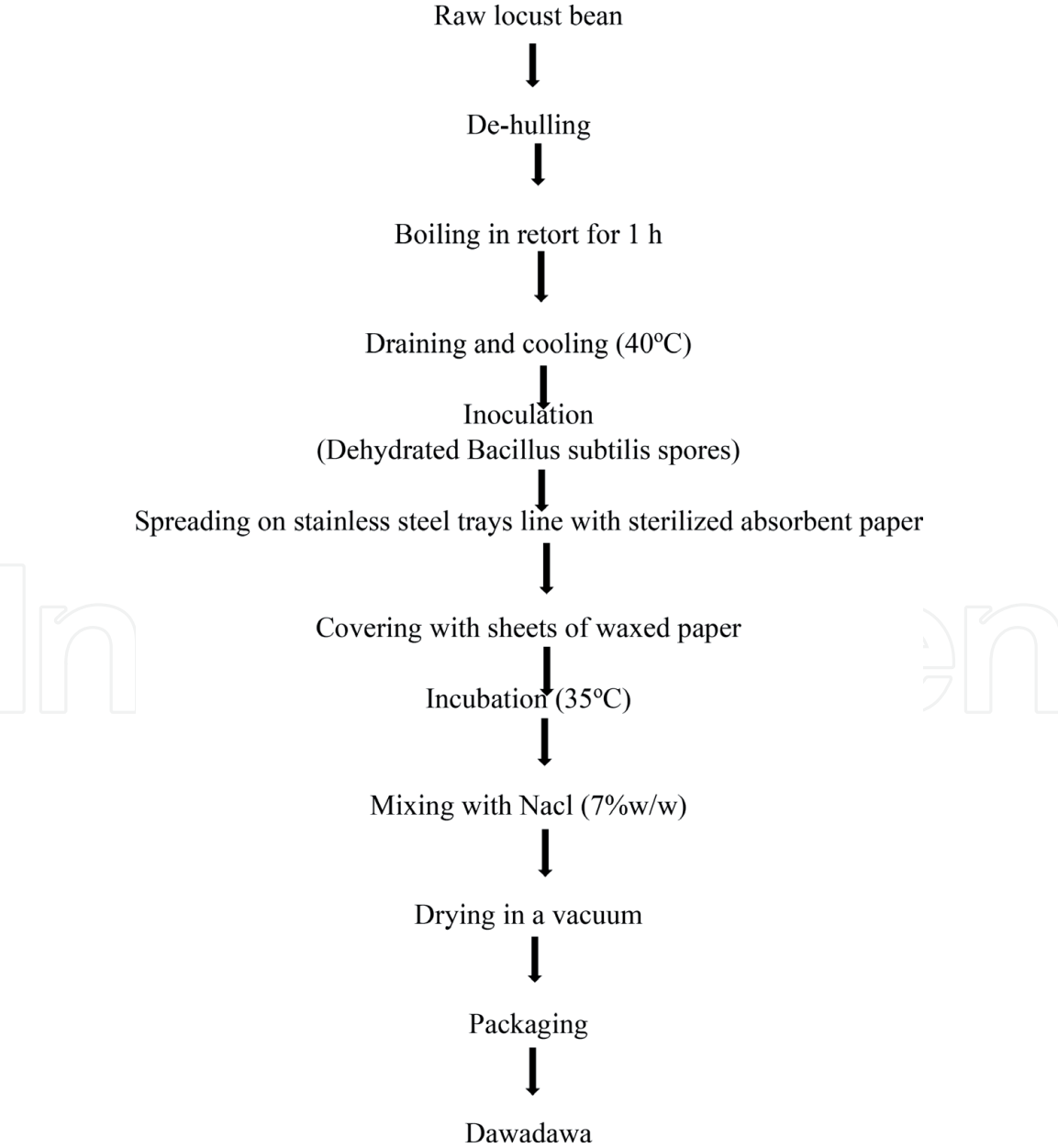


Figure 3.
Flow chart for the modern production of dawadawa. Source: [15, 31, 38].

entrepreneurs [29]. In Nigeria and some other parts of West Africa, *dawadawa* cubes are available in the markets [43] with improved quality, durability and packaging. These are produced using reasonably reproducible protocol and are marketed under various brand names. However, the most significant achievement towards improving the traditional fermentation technology is that the mechanism of flavor production during the fermentation, as well as flavor components generated in *dawadawa* have been studied by international food manufacturers and used as basis for the development of flavors from legumes hydrolysis for bouillon-type products [44].

3.1.2 Soumbala

Soumbala is a traditional condiment popular in Burkina Faso and other countries in West and Central Africa. It is also known by different names by different local communities [45]. Similar to *dawadawa*, it is prepared by solid state alkaline fermentation of African locust beans. It contributes significantly to protein nutrition of the consumers. The traditional process for preparing *soumbala* is uncontrolled and similar to *dawadawa* with minor variations based on ethnic preferences. The principal microorganisms involved in the fermentation of *soumbala* are *Bacillus* spp. [34]. The ability of *Bacillus* species involved in *soumbala* fermentation to inhibit undesirable bacteria including *Bacillus cereus* and *E. coli* has been reported [46–48].

3.1.3 Okpeye

Okpeye, much like *dawadawa* is a traditional seasoning produced by solid substrate alkaline fermentation of *Prosopis africana* (African mesquite) seeds. *P. africana* grows across the African Savannah and rain forest regions, but is mostly used as source of seasoning in the middle belt and parts of the Southeastern Nigeria [3]. Like *dawadawa*, the household technology used for producing *okpeye* can also vary between cultures. Perhaps, the most common procedure for preparation of *okpeye*, as practiced in parts of Southeastern Nigeria is as described (**Figure 4**) [9]. The process involves boiling of the mesquite seeds for 12–24 h to cook the seeds, soften the seed coat and ease the de-hulling process. This is followed by de-hulling in a very laborious manual process. The cotyledons are washed thoroughly, drained and reheated (dry heat) in a pot lined with the leaves of *Alchornea cordifolia* popularly known as (*akwukwo okpeye*) by the native people. Other leaves such as banana leaves may be used when the conventional leaves are unavailable. The cotyledons are spread to a few cm depth in a shallow raffia basket already lined with leaves of *Alchornea cordifolia*, covered with more leaves and weighted with pebbles. This solid substrate fermentation arrangement is then placed outside under the sun in the day time and inside the house in the night (avoiding precipitation and moisture for the duration of the process). Fermentation proceeds for 4 days at uncontrolled temperature which varies from less than 30°C at night to over 37°C in the afternoons during very sunny days. At the end of this stage the fermented cotyledons now dark brown in color with strong ammonia-like smell are ground into a smooth paste and molded into different shapes and sizes. At this moment the product may be used but for more desirable quality, it is usually sun dried for a variable length of time at the end of which the product becomes hard and black with a more mellow and preferable aroma. The dried condiment is resistant to spoilage by microorganisms and has a very long shelf life with occasional re-drying under the sun [3]. **Figure 5** shows the stages in the traditional process of *okpeye* production. During the natural process the pH increases from an initial of 6.0–6.2 in the boiled unfermented substrate to 8.0–8.8 (sometimes pH of 9.0–9.2 may be achieved) in the fermented product [49]. In our laboratory a diversity of microorganisms were established to be involved in

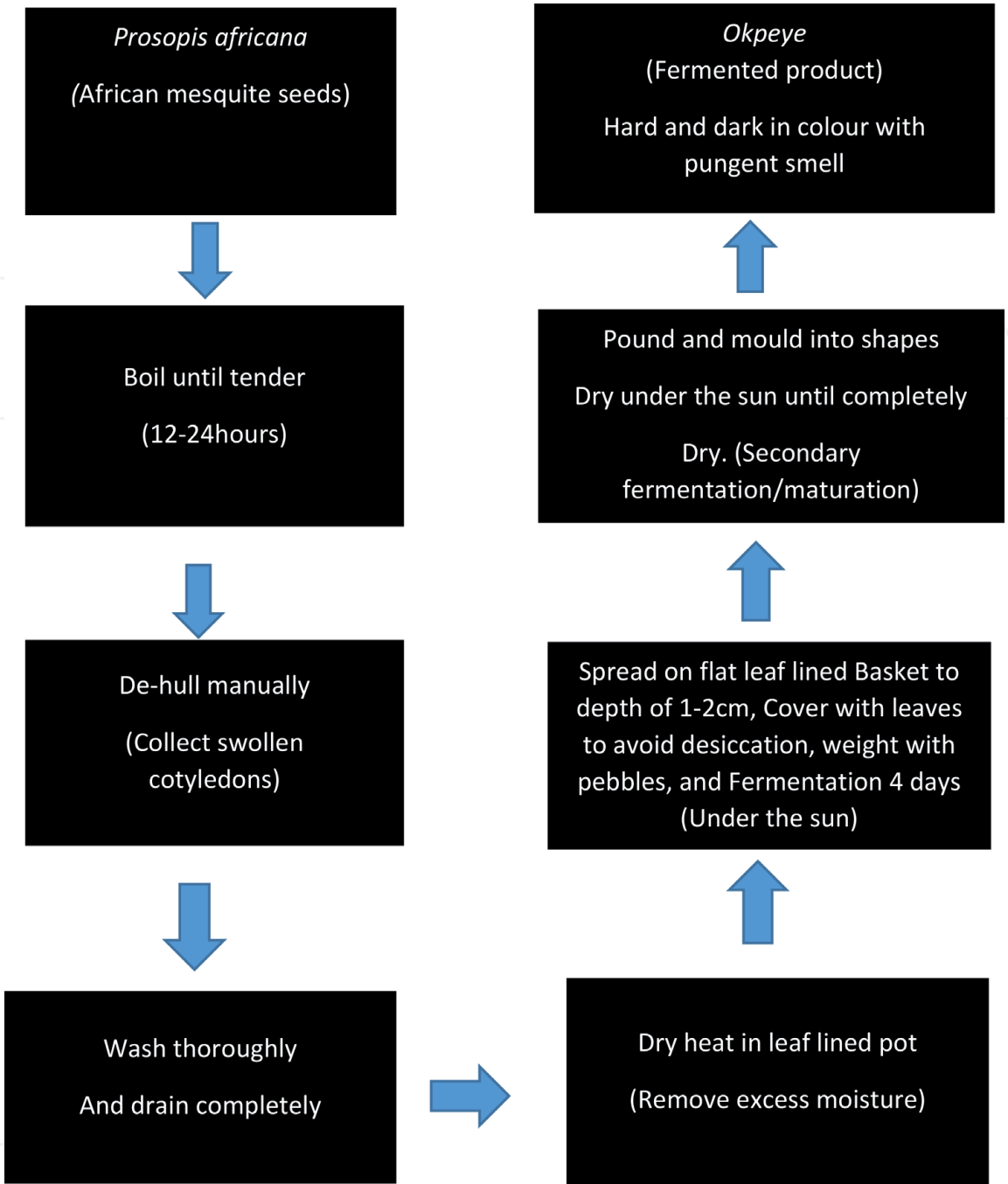


Figure 4.
Traditional process for the production of okpeye.

the primary fermentation. However, only species and strains of *Bacillus* were shown to be principal drivers of the process. Their populations increased significantly and persisted until the end. The organisms include *B. subtilis*, *B. velezensis*, and *B. amyloliquefaciens*. Other *Bacillus* species isolated include *B. licheniformis*, *B. anthracis*, *B. thuringiensis* and *B. cereus*. Apart from *Bacillus* species other bacteria that also participated in the fermentation especially at the early stages include *Enterobacter* sp., *Proteus mirabilis*, *Pseudomonas* sp., *Micrococcus* sp. and *Staphylococcus* sp. [49]. As in similar processes, these organisms are transient, incapable of producing condiments in pure culture and their roles in the process remain unclear.

3.1.4 Ugba

Ugba is a Nigerian-based condiment prepared by the solid state alkaline fermentation of seeds of the African oil bean (*Pentaclethra macrophylla*). It is also known



Figure 5. Steps in the traditional fermentation of *P. africana* seeds to produce okpeye. (A) Seeds before boiling; (B) boiled seeds; (C) de-hulled seeds before fermentation; (D) de-hulled cotyledons spread on leaf lined basket; (E) fermentation taking place outside under the sun; (F) fermented cotyledons; (G) ground paste; (H) molded seasoning undergoing drying under the sun; (I) dried okpeye seasoning. Source: [89].

as *ukpaka* by the Igbos in the Southeastern part of Nigeria where it is most popular. *Ugba* is consumed as a delicacy, appetizer or used as a flavoring agent in various traditional dishes. Prepared in different ways, *ugba* is an important food product for various traditional ceremonies [9]. The production, like other traditional processes, is still carried out in various homes on small scale under uncontrolled condition resulting in products that are non-uniform in quality.

The basic procedures (**Figure 6**) involve boiling of oil bean seeds for 12 h or more, removing the seed coat and slicing the cotyledons into thin slices. The slices are then soaked in water overnight, washed thoroughly and wrapped with fresh leaves for fermentation to take place. Fermentation is usually done at ambient temperature and the duration varies depending on the intended use. Fermentation can last as short as 3 days or up to 5 days. **Figure 7** shows African oil bean seeds, fermented slices of oil bean cotyledons and fermented product (*ugba*) packaged in different ways.

Microbiological and biochemical changes that take place during the traditional process have been studied extensively [50, 51]. A diverse group of microorganisms were reported to participate in the traditional fermentation of African oil bean, with *Bacillus cereus* dominating the process [50]. Over 30 different organic compounds of varying molecular weights and volatility including alcohols, organic acids, ketone, aldehydes, hydrocarbons amines and esters have been shown to contribute to the flavor of the final product [51]. The specific contributions of these various molecules remain to be established as also their flavor threshold in the product.

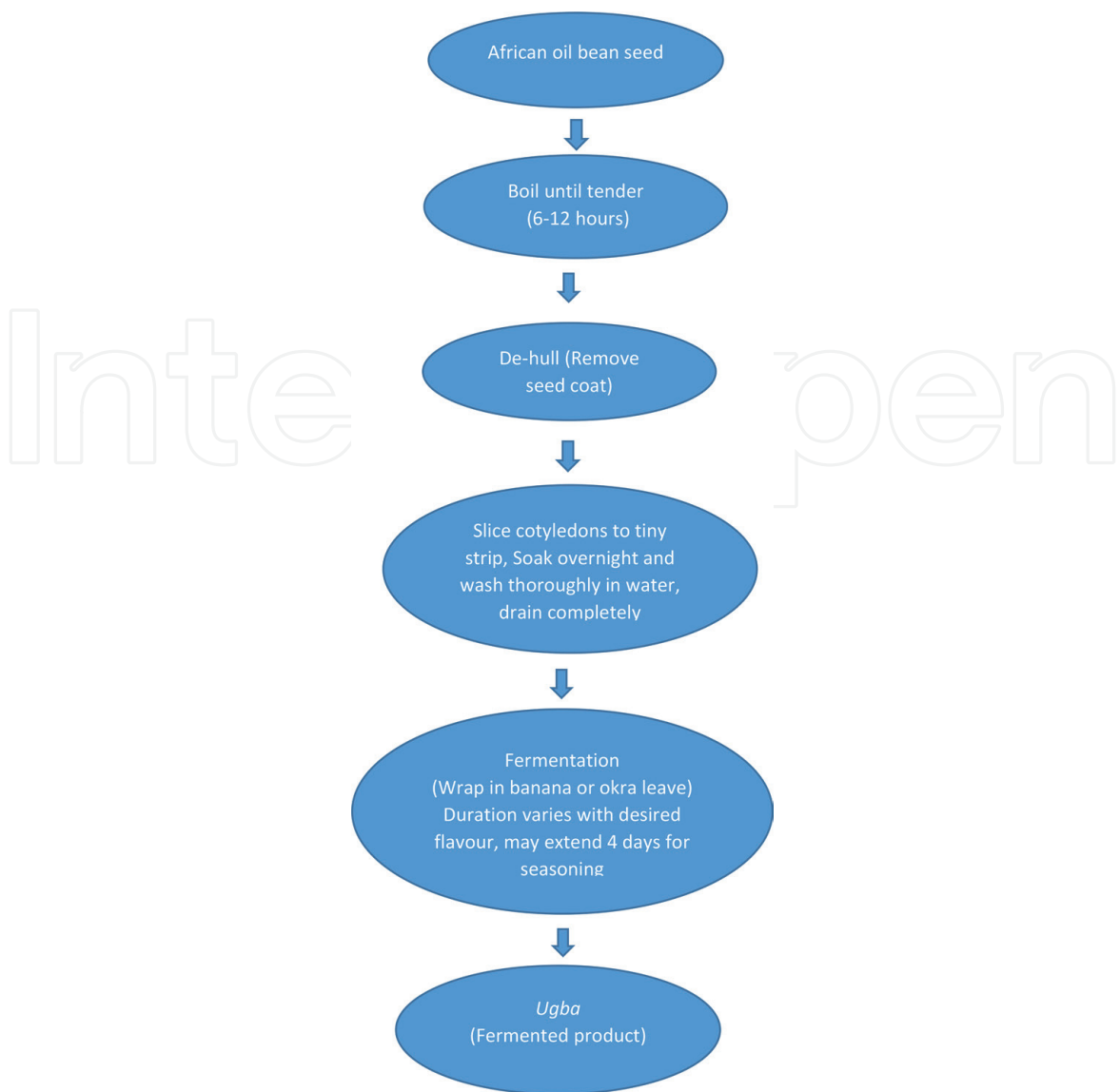


Figure 6.
Flow chart for the traditional production of ugba.

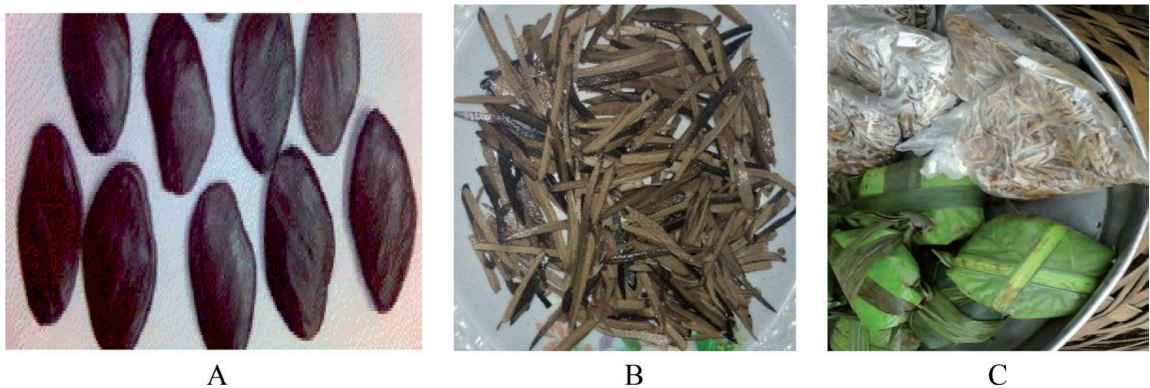


Figure 7.
African oil bean seeds (A), fermented slices of oil bean cotyledons (B) and fermented oil seeds cotyledons (ugba) packaged in polythene bags or wrapped with local leaves.

3.1.5 Ogiri

Ogiri is a popular African fermented seasoning, traditionally prepared by the solid state alkaline fermentation of castor oil seeds (*Ricinus communis*). Depending on locality, season and availability it may also obtained by fermenting melon seeds

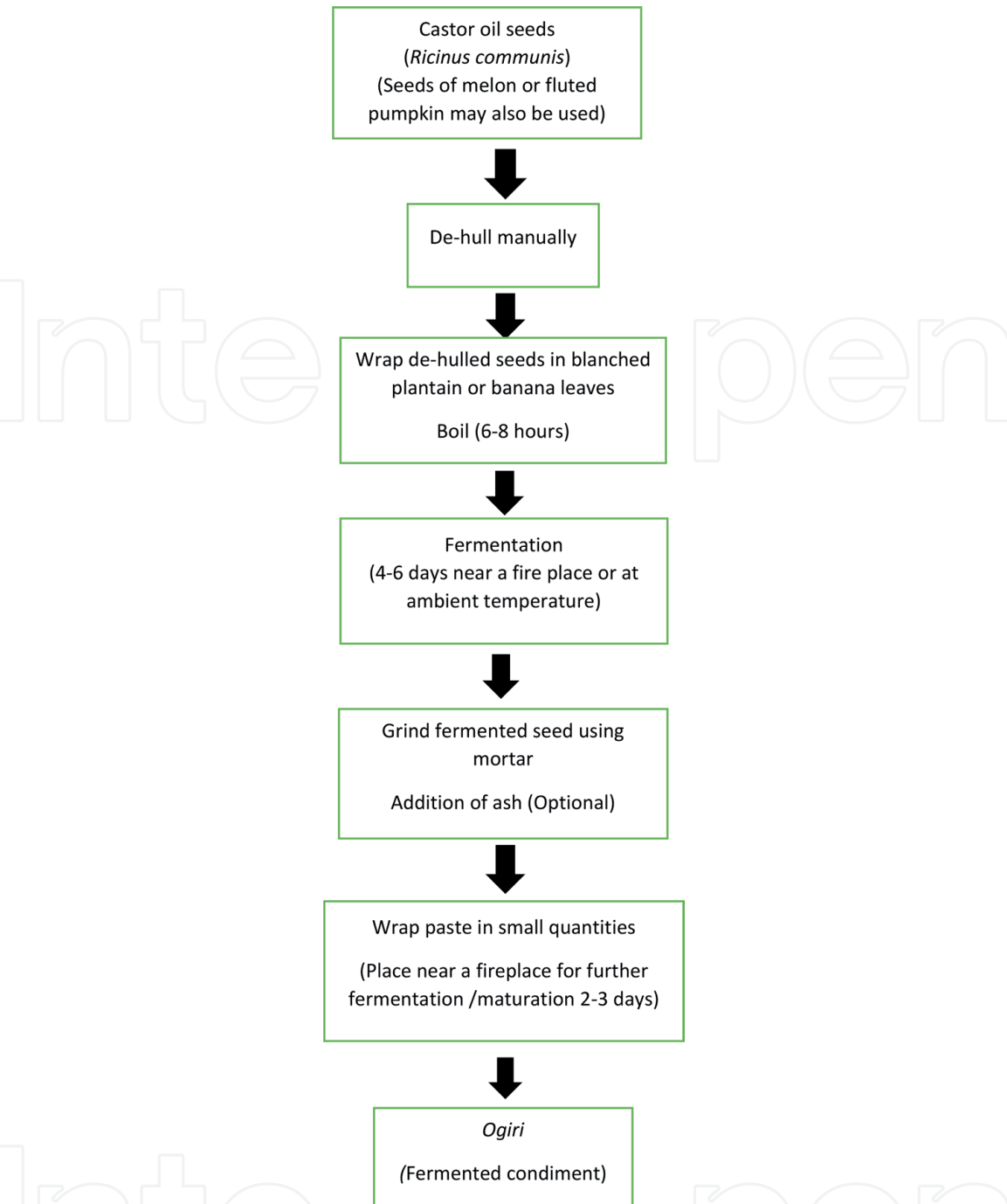


Figure 8.
Flow chart for the traditional production of Ogiri.

(*Citrullus vulgaris*) and fluted pumpkin seeds (*Telfairia occidentalis*). Ogiri is used in flavoring many traditional soups. In fact, it is regarded as an indispensable seasoning in the preparation of specialized soups which are highly cherished and extensively consumed by the Igbo ethnic group in the Southeastern Nigeria. Like many indigenous fermented products, production of *ogiri* is still by the traditional family-village art done on a small-scale cottage level. Details of the traditional process may vary between cultures. For production of *ogiri* (**Figure 8**) the shelled seeds of castor oil are wrapped in blanched banana leaves and boiled for about 8 hours until the seeds are properly cooked. The wrapped seeds are then placed near the fireplace to ferment for 4–6 days depending on the intensity of the fire. On completion of this stage, the fermented seeds which are now sticky and strong smelling are ground on a grinding stone or mortar into a fine paste which is divided into small portions and packaged in blanched banana leaves (**Figure 9**). The packs are placed



Figure 9.
Fermented castor oil seed (Ogiri) condiment (A) and fermented castor oil seeds (Ogiri) condiment wrapped with local leaves (B).

near the fireplace or in a warm place to ferment further for 1–2 days. At this stage the fermented condiment is ready to use or sale and it has a characteristic strong pungent flavor. *Bacillus* strains mainly *B. subtilis* and *B. licheniformis* have been reported as the predominant fermenting microorganisms. The pH of the fermented product is alkaline (>8.0) [4, 23, 24].

3.2 Less common legume-based alkaline fermented seasoning agents of Africa

3.2.1 Aisa

Aisa is a Nigerian seasoning agent processed from the solid state alkaline fermentation of *Albizia saman* (Jacq) F. Mull popularly known as monkey pod, rain tree or saman tree [2, 21]. *Albizia saman* is one of the uncommon and under-exploited legumes in the sub-Saharan regions. Like other traditional fermented seasonings, *aisa* is used to flavor various traditional dishes and soups. The production process is similar to dawadawa. The basic method involves boiling of the saman seeds until tender, followed by manual de-hulling. The cotyledons are washed and boiled again for 1–2 h, and washed in water. The cotyledons are wrapped in clean fresh leaves (banana or paw-paw) in bundles. The wrapped bundles are placed in calabashes and allowed to ferment for 1–7 days at ambient temperature. At the end of fermentation, the product is dark brown, sticky mash covered with mucilaginous coat and possessing a strong ammoniacal smell. *Bacillus* species are reported as the predominant micro flora responsible for *aisa* fermentation [21]. Other organisms that have also been reported to take part in the process include *Escherichia coli*, *Klebsiella*, *Enterobacter*, *Proteus* and *Staphylococcus* species.

3.2.2 Owoh

Owoh is another African fermented seasoning whose substrate is under-utilized. It is made by the solid state alkaline (pH 8.8 and above) fermentation of cotton seeds (*Gossypium hirsutum*) [2]. *Owoh* is mainly used as a seasoning in the

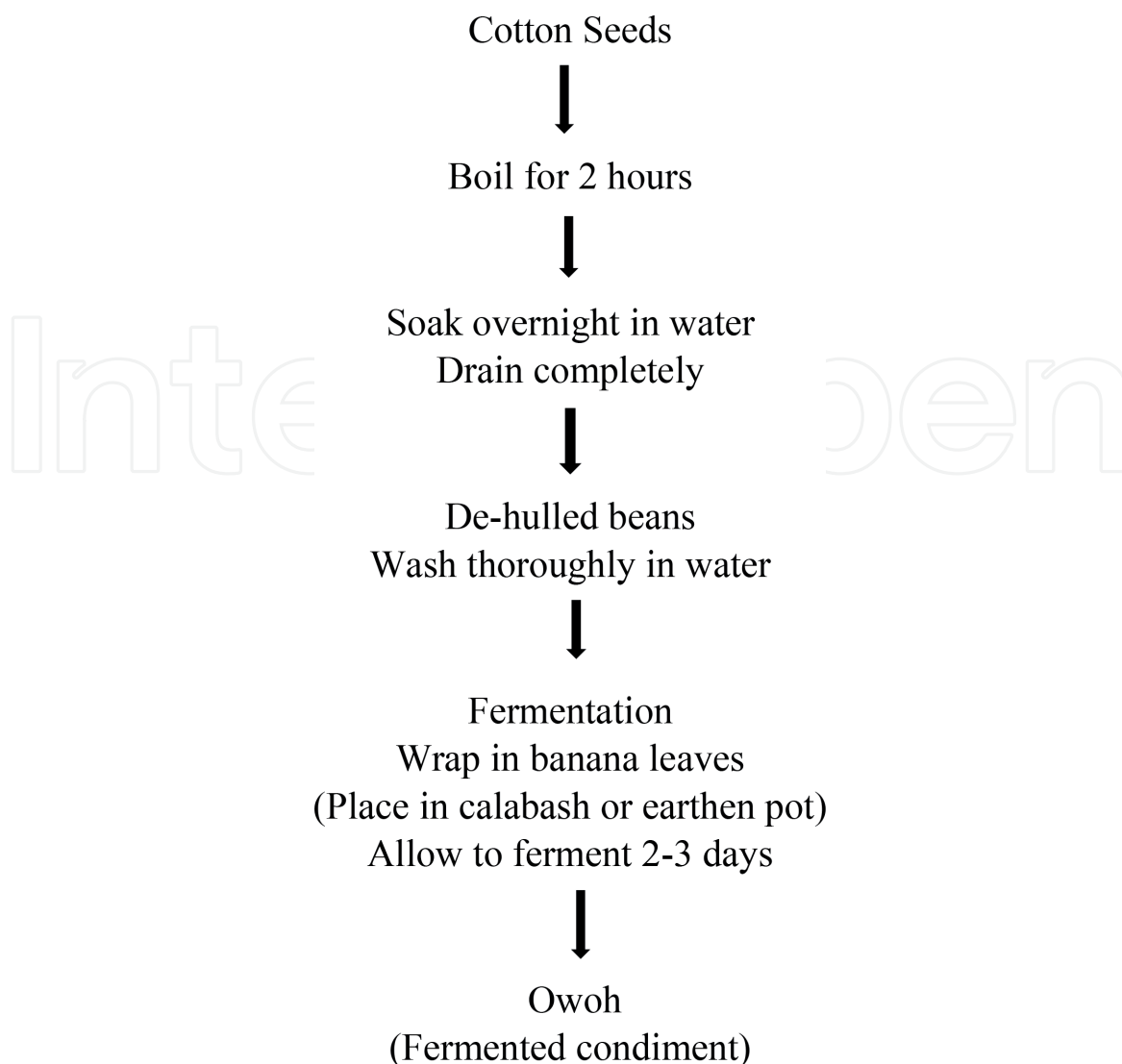


Figure 10.
Traditional process for the production of Owoh.

mid-Western Nigeria. The raw seeds are toxic and inedible. The traditional process (**Figure 10**) involves boiling of cotton seeds until they are properly cooked and become tender. The seed coats are removed manually. The cotyledons are then washed, wrapped in banana leaves and boiled again for 1–2 h. The wraps are removed from water and placed in calabashes or earthen pots, and then covered with jute sacks and placed in a warm location (often beside the fire place) to ferment. Fermentation is done at ambient temperature for 2–3 days. At the end of the fermentation, the mash is ground and molded into balls. The product may be used at this point, but preferably it is sun dried to extend the shelf life and also to develop more desirable aroma [52]. The major fermentative organisms are reported to be *Bacillus* species including *B. subtilis*, *B. licheniformis*, and *B. pumilus*.

3.2.3 Bikalga

Bikalga is an African alkaline fermented condiment made from *Hibiscus sabdariffa*. It is widely used to flavor various traditional dishes in Burkina Faso [37]. It is known by different ethnic names in different parts of African. In Niger it is known as *dawadawa bosto*, *datou* in Mali, *furundu* in Sudan and *mbuja* in Cameroon. The predominant organisms involved in the fermentation of *Hibiscus sabdariffa* are *Bacillus* spp. notably *B. subtilis* subsp. *subtilis* and *B. licheniformis*.

3.3 Fish-based fermented products used as condiment in Africa

Like oil seeds, fermentation of fish is an essential part of socio-economic life of many communities in Africa particularly in Ghana, Egypt and Nigeria. Owing to the rapid deterioration of fish, fermentation offers an easy and cost effective way of preserving it. In the tropical countries fish fermentation usually involves the use of high concentration of salt combined with drying [53, 54]. Duration of fermentation is from a few days to weeks. Fish can be fermented whole or in parts. As in many traditional processes, fermentation of fish is carried out on small scale in homes [55, 56]. As with other traditional processes, uncontrolled nature and lack of hygiene practices are the major challenges to product quality and safety. The most popular fermented fish products used as condiments in Africa include *Lanhouin*, *Momone* and *Feseekh* [56]. **Table 3** presents the common fermented fish-based condiments of Africa and some other regions of the World.

Substrate	Product local name	Nature of product	Region/ country	Microorganism	Reference
Cassava fish (<i>Pseudotolithus senegalensis</i>)	<i>Lanhouin</i>	Condiment	West Africa	<i>Bacillus</i> , <i>Staphylococcus</i> , <i>Corynebacterium</i> , <i>Pseudomonas</i> , <i>Micrococcus</i> , <i>Streptococcus</i> , <i>Achromobacterium</i> , <i>Alcaligenes</i>	[37]
Cat fish, barracuda, sea bream and African jack mackerel (<i>Caranx hippos</i>)	<i>Momoni</i>	Condiment	West Africa (Ghana)	<i>Micrococcus</i> , <i>Streptococcus</i> , <i>Pediococcus</i>	[37]
<i>Alestes baremoze</i> (Pebbly fish), <i>Hydrocynus</i> sp. (Tiger fish)	<i>Feseekh</i>	Sauce	Egypt	Not known	[37, 95]
Fish	<i>Azu-okpo</i>	Condiment	Nigeria	Not known	[31]
Shrimp, salt	<i>Belacan</i> (<i>Blacan</i>)	Condiment	Malaysia	<i>Bacillus</i> , <i>Pediococcus</i> , <i>Lactobacillus</i> , <i>Micrococcus</i> , <i>Sarcina</i> , <i>Clostridium</i> , <i>Brevibacterium</i> , <i>Flavobacterium</i> , <i>Corynebacterium</i>	[45, 96]
Fish shrimp	<i>Bakasang</i>	Condiment	Indonesia	<i>Micrococcus</i> , <i>Streptococcus</i> , <i>Pediococcus</i> sp. <i>Pseudomonas</i> , <i>Enterobacter</i> , <i>Moraxella</i> , <i>Staphylococcus</i> <i>Lactobacillus</i>	[37, 45, 97]
Marine fish salt, sugar	<i>Budu</i>	Condiment	Thailand, Malaysia	<i>Micrococcus luteus</i> , <i>Staphylococcus arlettae</i> , <i>Pediococcus halophilus</i> , <i>Staphylococcus aureus</i> , <i>S. epidermidis</i> , <i>Bacillus subtilis</i> , <i>B. laterosporus</i> , <i>Proteus</i> sp., <i>Micrococcus</i> sp., <i>Sarcina</i> sp., <i>Corynebacterium</i> sp.	[37, 45, 98]

Substrate	Product local name	Nature of product	Region/ country	Microorganism	Reference
Finger size fish (<i>Esomus danricus</i>)	<i>Hentak</i>	Condiment	India	<i>Lactococcus lactis</i> , <i>L. plantarum</i> , <i>L. fructosus</i> , <i>L. amylophilus</i> , <i>L. coryniformis</i> , <i>Enterobacter faecium</i> , <i>Bacillus subtilis</i> , <i>B. pumilus</i> , <i>Micrococcus</i> sp., <i>Candida</i> sp., <i>Saccharomyopsis</i> sp.	[45, 99]
Sardine, salt	<i>Jeotgal</i>	Condiment	Korea	<i>Staphylococcus</i> , <i>Bacillus</i> sp., <i>Micrococcus</i> sp.	[45, 100]
Shell fish	<i>Gulbi</i>	Condiment	Korea	<i>Bacillus licheniformis</i> , <i>Staphylococcus</i> sp., <i>Aspergillus</i> sp., <i>Candida</i> sp.	[45, 101]
Marine fish	<i>Nuoc mam</i>	Condiment	Vietnam	<i>Bacillus</i> sp., <i>Pseudomonas</i> sp., <i>Micrococcus</i> sp., <i>Staphylococcus</i> sp., <i>Halococcus</i> sp., <i>Halobacterium salinarum</i> , <i>H. cutirubrum</i>	[45, 102]

Table 3.
Some common fermented fish products used as condiment in Africa and other continents of the world.

3.3.1 *Lanhouin*

Lanhouin is a traditional fermented salted fish condiment in West Africa, prepared from whole cassava fish (*Pseudotolithus senegalensis*). It is added as a flavoring to many traditional dishes especially soups [55, 56]. The traditional preparation of *lanhouin* involve scaling of the fresh fish and removing of the gut, followed by soaking in salted water for 8–11 h to allow ripening. The quantity of salt added varies between 20 and 35% depending on the size of the fish. Fermentation takes place naturally for about 2–9 days. On completion of fermentation, the product is washed in water to remove excess salt and then dried under the sun for 2–4 days. The fermented fish product has characteristic strong smell. The predominant microorganisms involved in the traditional process of *lanhouin* are members of the *Bacillus* species. Other bacteria such as *Staphylococcus*, *Corynebacterium*, *Pseudomonas*, *Micrococcus*, *Streptococcus*, *Achromobacter*, *Alcaligenes* were also reported to take part in the process although their roles are not clearly established.

3.3.2 *Momoni*

Momoni is another type of fermented fish from West Africa. It is particularly common in Ghana. Different types of fresh fish such as catfish, barracuda, sea bream and African jack mackerel (*Caranx hippos*) are used as substrate to prepare *momoni* [57]. *Momoni* is prepared traditionally based on the experience of the processor. During preparation, the scales and gut are removed. The gill and the gut regions are heavily salted (up to 30% salt may be used). Fermentation lasts for 1–5 days. Afterwards, the fermented product is washed in brine and cut into parts, followed by sun drying for a few hours [58]. Like *lanhouin*, *momoni* is widely used as flavor intensifier to prepare traditional dishes. The main organisms associated with *momoni* production are *Bacillus* species and lactic acid bacteria (LAB). Other bacteria and fungi are also reported to be associated with the process.

3.3.3 Feseekh

Feseekh is a fermented fish product from Egypt. It is popularly served as an appetizer, but in some occasions such as during feasts it may be the main meal. Unlike *lanhouin* and *momoni*, *feseekh* is fermented without drying. The type of fish used for preparing *feseekh* are *Alestes baremoze* (Pebbly fish), and *Hydrocyrus* sp. (Tiger fish) [59]. The quantity of salt added during fermentation may vary from 20 to 30%. *Feseekh* is processed at a temperature of about 18–20°C for about 60 days and the product can be stored up to 3 months. Microorganisms involved in the fermentation have not yet been fully characterized.

4. Significance of food fermentation to rural communities and economies

The significance of fermented foods including seasoning agents in human nutrition, particularly among rural populations is now better appreciated. As a result research efforts are being intensified towards better understanding of the processes as well as to achieve commercialization of these foods. Fermented foods including those derived from alkaline fermentation are critical components of the human diets world-wide. Currently, it is estimated that fermentation derived foods, beverages and condiments contributes about a third of the human diets and food supply world-wide [60]. These foods are particularly important in the cultures and food ecology of the developing nations such as Africa where they have been reported to contribute more than half the calorie, ensuring the food security of millions [61]. In the recent times, the awareness of the nutritional values and health benefits associated with eating fermented products has made them indispensable as part of food system and has also led to their being classified as functional foods.

In some African countries especially Nigeria, fermented foods are valuable in the nutrition of infants and school-age children. In the rural communities, *akamu*, a fermented cereal based product is an important weaning food as well as breakfast meal. Indigenous fermentation technologies help to reduce the problem of food insecurity in the world [27]. In this regard, fermentation increases food availability by providing different types of products in a diversity of flavors, aroma and texture. Food fermentation as an enterprise is particularly useful in the economy and socio-cultural lives of many communities. The nutritional and socio-economic values, health benefits and functional attributes of fermented foods have been widely documented [62–73]. Many of the substrates used for producing fermented foods contain naturally occurring toxins and anti-nutrients and only become edible following detoxification through fermentation. It also increases the bioavailability of key nutrients such as essential amino acids while enriching the sensory quality and functional properties of foods [74, 75].

5. Traditional fermentation techniques

The techniques of traditional fermentation can be solid-state or submerged culture. In solid state fermentation, the microorganisms grow on solid substrate containing little or no free moisture, but enough to sustain metabolic activity of the organisms. This technique is used in the production of all the alkaline fermented seasoning agents discussed earlier. Submerged fermentation is performed on a liquid substrate or a solid substrate immersed in a solution to form a suspension or slurry. These types of fermentations are seen in most commercial processes such as those employed for the production of alcoholic beverages and several other high-volume products.

5.1 Impact of process techniques on food quality

In the past, fermented foods were important only in the regions or places of manufacture. However, due to increasing demand, urbanization and industrialization, some of the fermented products such as soy sauce, and Japanese natto are becoming globally popular [76]. The challenge though is that the majority of the indigenous fermented foods and condiments are manufactured under conditions devoid of good manufacturing practices (GMPs) and good hygiene practices (GHPs) [22]. Often, hazard analysis and critical control point principles (HACCPs) are not observed during their production and unit operations are not clearly defined. This is inconsistent with modern food practices and may hinder the adoption of such products into the international markets [77]. Obviously, the uncontrolled nature of process techniques of traditional fermentation can have fundamental impact on the quality and safety of products. In the traditional setting, fermentation associated variables such as pH, DO, temperature, inoculum and moisture are not regulated. The variation in the fermentation conditions has frequently affected product quality, resulting in products that are non-uniform in quality between successive batches. Likewise, differences in processing techniques adopted by various processors which depend so much on personal knowledge, experience and expertise of the food handler and processor can also cause variation in product quality. Besides, the equipment used in the processing of traditional alkaline fermented seasonings such as fresh leaves, jute bag, local basket and calabash are substandard and they fall short of standard food hygiene protocol. Product consistency and safety of traditional fermented foods often arise fortuitously, from the physiological pressures imposed by the microbial selection rather than by processor actions.

In any food industry, maintaining proper hygiene in the production environment should be priority [3]. Although traditional fermentations often achieved the desired products, there is need to integrate modern GMPs in the production of these valuable constituents of traditional diets. Another significant challenge in traditional fermentation that can lead to poor and inconsistent product quality is the participation of undesirable microbial strains in the process [78]. Most traditional alkaline fermentations rely on chance inoculation that encourage the participation of several species of microorganisms, including desirable and undesirable strains as against modern industrial technologies that make use of a single or defined selected strains (starter culture) to effect the desired change in the substrate. Although substrate modification and environmental condition may be tailored to favor the growth of the desired organisms, total reliance on process conditions to guarantee product/consumer safety may not always result in desirable outcomes. Besides, the contribution of the transient populations to the final product flavor and quality remain unknown. It is necessary therefore to migrate these traditional processes to modern, biotechnology-based food processing to eliminate process failures, some of which can result in consumer risks. Consumer safety and product quality can be best ensured by strict compliance with GMP.

6. Modern approach to food fermentation in Africa

In recent times, scientific knowledge and modern food processing technologies have found application in food fermentation particularly in Asia and South America. The result is that many traditional kitchen technologies used in the manufacturing of fermented foods in the past are now modified [79]. The same may not be said (to the same degree) of traditional fermentation in Africa, where products

are still mostly produced through kitchen technologies and village art that rely on illiterate processors. However, gradually the technology of alkaline fermented foods and products derived from other fermentations is evolving to a better and more commercial status. Progressively, traditional fermentation processes are being refined and diversified through the application of molecular biology and microbial technology (MT) such as the use of improved raw materials, starter/protective culture, process optimization/ control including the use of modern packaging. This shift from artisanal production to scientific industrial one has generated new areas of study for industrialists and food scientists and new small scale industries. Innovations and recent developments in the production of alkaline fermented foods in Africa and other regions of the world will be approached at four levels namely: Raw material development, the use of starter culture, modified fermentation processes (process optimization), and product presentation (packaging).

6.1 Raw material development

High quality raw materials should be sourced and tested in order to select the more appropriate variety for use in fermentation. Agricultural procedures that encourage increased production of the improved varieties should be adopted. The use of improved and homogenous substrate for production of fermented foods will go a long way in solving the problem of product variability. The various raw materials (legumes and oil seeds) used for producing alkaline fermented foods are seasonal crops and are not readily available round the year. In order to overcome the current challenges of periodic or non-availability of raw materials, the use of irregularly available raw materials are being replaced wholly or partially with more abundant substrates in the production of various fermented products [3, 19]. In instances, the conventional substrate for production of ogiri an African alkaline fermented seasoning agent is castor oil seed [80]. However, when the main substrate is unavailable, alternative materials such as melon seed and fluted pumpkin seeds are used for the production [81]. Similarly, a related food condiment *owoh* can be produced from African yam bean [82] and cotton seeds [52]. In many cases, such as with oil bean and African mesquite, the seeds for producing fermented seasonings are produced by wild forest trees that are not yet domesticated. The availability of these crops is being threatened by deforestation and urbanization. For sustainability and also to overcome the bottleneck associated with the non-domestication of these crops, Agricultural and forestry management should put in place policies intended to secure the availability of these raw materials in order to ensure long-term supply [3]. This is without prejudice to the biochemical prospect of producing the product using more readily available alternatives by exploiting the versatility of fermenting microorganisms.

6.2 The use of starter culture

Literature on the use of starter cultures for the production of alkaline fermented foods including seasoning agents abound (**Table 4**). Modern researches on fermented foods have begun to adopt new approaches that focus on understanding the profile and the role of associated microorganisms in alkaline fermentations. Food researchers recognize that metabolic activities of microorganisms involved in a process have considerable impact on quality attributes of the final product such as color, flavor, texture and aroma as well as nutritional quality. Equipped with this knowledge, approaches used for characterizing the microorganisms in fermented foods have evolved to a better status. Many different techniques have been adopted to study the diversity of micro flora of fermented foods and their

Microorganism	Product	References
<i>Bacillus subtilis</i> B7 and B15	<i>Soumbala</i>	[85, 87, 88]
<i>B. subtilis</i> , <i>B. subtilis</i> kk-2:B ₁₀	<i>Kinema</i>	[134]
<i>B. subtilis</i> mm-4:B12	<i>Ugba</i>	[72]
<i>B. subtilis</i>	<i>Okpehe</i>	[22]
<i>B. subtilis</i> 24BP, <i>B. subtilis</i> fpdp2	<i>Soy-dawadawa</i>	[19, 20]
<i>B. subtilis</i> TISTRO(BIOTEC7123)	<i>Thuo nao</i>	[135]
<i>Lactobacillus plantarum</i> 120 <i>L. plantarum</i> 145 <i>Pediococcus pentosaceus</i>	<i>Shan yu</i>	[36]
<i>L. plantarum</i> <i>Pediococcus acidilactici</i> <i>P. pentosaceus</i>	<i>Som-fug</i>	[136]
<i>Lactobacillus plantarum</i> <i>L. helveticus</i> <i>Lactococcus lactis</i> subsp. <i>lactis</i>	Mackerel mince	[137]

Table 4.
Bacillus strains and lactic acid bacteria (LAB) suggested as potential starter cultures for production of fermented condiment.

possible roles. This may be grouped into two: cultural/physiological methods and molecular methods [83]. Molecular techniques are of great importance in studying the microbial profiles, succession and functionality in traditional fermented foods. PCR-based methods and gene sequencing are now used for proper characterization of micro-biota including pathogens in fermented foods. Functional genomics is a useful tool in improving traditional process as this enables comparisons of traits of microorganisms involve in food fermentation and enables selection of organisms with desirable traits as potential starter cultures.

“Omics” is the acronym that has arisen from the study of functional genomics and comprises transcriptomics, proteomics and metabolomics. The introduction of “Omics” technologies offer better and clearer understanding of microbial populations in food processes and provide good opportunity for process standardization. These have been applied in the study of some traditional fermented foods such as *kimchi* a Korean fermented product. Another novel approach in food fermentation technology is the application of ultrasonic waves in the production of fermented foods [6]. The use of ultrasound has been reported as an important tool for measuring changes in chemical composition during fermentation and to enhance process efficiency and rate of production by improving mass transfer, cell permeability and removal of undesirable organisms.

Recent developments allow the establishment of starters, resulting in the evolution of kitchen technology to more optimized/controlled fermentation. The microorganisms used as starter cultures in food processing are selected based on food substrate, with the objective of achieving objective and reproducible bio-modification.

In the efforts towards commercialization and upgrading of African alkaline fermented foods to industrial level, different species of microorganism have been studied and screened **Table 3** [15]. Pure cultures of *B. subtilis* var. *natto* is used in the commercial preparation of Japanese *natto* [84, 85]. Species of *B. subtilis* have been studied and demonstrated as potential starters for *soumbala* [46–48]. Similarly, strains of *Bacillus* species have been screened and suggested as starters by researchers from Nigeria. These include *B. subtilis* mm: B₁₂, for *ugba* [52] and

B. subtilis for *okpehe* [54]. The use of *B. subtilis* fpdp2, *B. subtilis* 24BP2 for soy dawadawa production has been demonstrated [19, 20], while strains of *B. subtilis* KK-2:B10 and *B. subtilis* GK have been used as starter cultures for *kinema* production and a starter for *thua-nao* (*B. subtilis* TISTRO (BIOTECHC7123)) has been reported [86, 87].

Besides, other bacteria such as lactic acid bacteria (LAB) have also been used as starter cultures for fermented foods including fermented fish [88–91]. A combination of *Lactobacillus plantarum*, *Pediococcus acidilactici*, and *P. pentosaceus* was used as starter for the production of *som-fug*, a Thai fermented fish product [89]. *Suan yu*, a fermented fish product from China has been produced using defined strains of *L. plantarum* 120, *L. plantarum* 145, and *P. pentosaceus* 220 as mixed starter cultures, and this resulted in reduction of the fermentation time and enhanced quality [92]. Likewise, combined cultures of *L. plantarum*, *Lactococcus lactis* subsp. *lactis* and *L. helveticus* have been used for the production of fermented mackerel mince [93]. Lactic acid bacteria have been used as starter cultures to initiate the fermentation of cassava for garri production [94]. Sanni and coworkers [95] used antimicrobial producing strains of LAB to control spoilage organisms during production of *ogi*. Mixed cultures of LAB and yeast were also used as starter culture for ‘*gowe*’ production [96, 97].

Apart from bacteria, fungal starter cultures have been applied in the production of fermented foods. A combination of *Aspergillus* and *Actinomucor* has been used to produce *surimi*, fish-based fermented product [98, 99]. Similarly fermentation of silver cap fish using fungal starter cultures has been reported [100]. The nutritional benefits and organoleptic properties of four commercially available mold starters in fermented fish paste have been documented [101]. Despite successful applications and demonstrated beneficial roles of various starter cultures in food fermentations, their use in commercial traditional food productions is still limited and a subject of controversy. However, the prospect for commercializing the production of starter cultures for use in production of traditional foods and seasoning agents look promising.

6.3 Modified fermentation process (process optimization and control)

The uncontrolled nature of traditional fermentations is a major hindrance to the scaling up of indigenous food fermentations [76]. Optimization may only be possible when the roles of process variables such as duration of fermentation pH, temperature, inoculum-substrate ratio, DO and mass transfer and pretreatment are understood and controlled [16, 22, 35, 42]. An improved method of producing an African fermented condiment (Dawadawa) from locust beans has been reported to reduce fermentation time and cost of energy [42]. Also, in Burkina-Faso, a novel de-hulling machine introduced in the production of *soumbala* resulted in decrease in the boiling and de-hulling time by 75%, corresponding to an appreciable saving in energy cost and time [102].

In Uganda, pasteurization and refrigeration were used to increase the shelf life and safety of *obushera* a fermented cereal-based beverage [103]. Mechanization and modernization of the various labor intense unit operations in traditional fermented foods can result in significant improvement in the processes and increase the economics of production of these important food products besides enhancing reproducibility of process. Equipment used in traditional process remain rudimentary and process modernization and improvement based on those can constitute a great challenge as these may be difficult to replicate. The development of bioreactors will enhance performance and improve productivity. Research on-going in our laboratory is working towards developing a solid-state bioreactor for use in a trial scale-up of *okpeye* process and other related seasoning agents. Although many African alkaline fermented foods are still manufactured by the traditional family art, the

manufacture of some such as *dawadawa*, and *soumbala* have been improved and elevated to pilot status [43]. More recently, due to increasing demand and awareness about natural healthy diets, some traditional alkaline fermented foods have evolved from their place of manufacture onto trans-border food markets [76, 104]. Of particular interest are two Asian fermented foods kimchi (fermented vegetable product) from Korea and natto (fermented soy bean product) from Japan which have penetrated markets beyond Asia [15, 76]. The production and marketing of tempe, an Asian fermented product has crossed borders and extended to the United States where about over 16 companies are involved in production [12].

6.4 Product presentation (packaging)

Packaging is an integral part of GMPs in foods. It provides environmental condition for storage, handling and long shelf life of product. It also minimizes post-process contamination and protects against microbial spoilage including undesirable change in sensory properties as well as consumer abuse. The shelf life of processed foods can be extended by aseptic and adequate packaging. Inadequate packaging and poor presentation of product are among the challenges mitigating the global development and consumer appeal of fermented products in Africa and other developing regions [105]. Unlike modern food industries that use attractive and esthetic packaging that increases consumer appeal, all sorts of wrapping materials are used for packaging traditional fermented products in Africa [3]. On account of this, indigenous fermented foods are often considered as food for the poor [105]. The adoption of modern esthetic packaging and adequate presentation are crucial steps to overcome the challenges of kitchen technology and also for commercialization and industrialization of fermented foods and condiments. These will help to minimize the problems of post process contamination and increase consumer confidence.

The application of these basic food-control strategies in the production of fermented foods will move these products beyond the local markets. Besides the challenges of unattractive packaging, some local fermented products such as *dawadawa* and *okpeye* are not packaged at all. These are displayed at points of sale often in open non-sterile bowls and local baskets which may lead to post-production contamination [3].

7. Conclusion and the way forward

Although, the economic and food security importance of African fermented foods and seasonings remain outstanding, their continued availability in the near future in a rapidly urbanized and global setting cannot be guaranteed on the basis of the present household technologies and practices. Today, with surge in the demand for “natural” foods, there is resurgence in demand across board for traditional foods which have also somehow become synonymous with the natural foods. The surge in demand for these traditional fermented products is not matched by supply and the trend can only get worse on the basis of kitchen technologies and traditional raw materials supply. Therefore, if we are to continue to enjoy these valuable components of our cultural diets, there has to be a way to manufacture those using sustainable modern technologies and GMPs. It is a challenge to industrialists, food scientists and researchers to ensure that knowledge generated through research are used to bring new ideas and innovations in the area of food fermentation and value chain. It has been observed that much of the research findings from scientists, particularly in the developing countries, end up in the journals and never make it to the market. There is an urgent need to address and bridge this research-to-market gap. It is hoped that through research innovations, many fermented foods can be developed on the basis

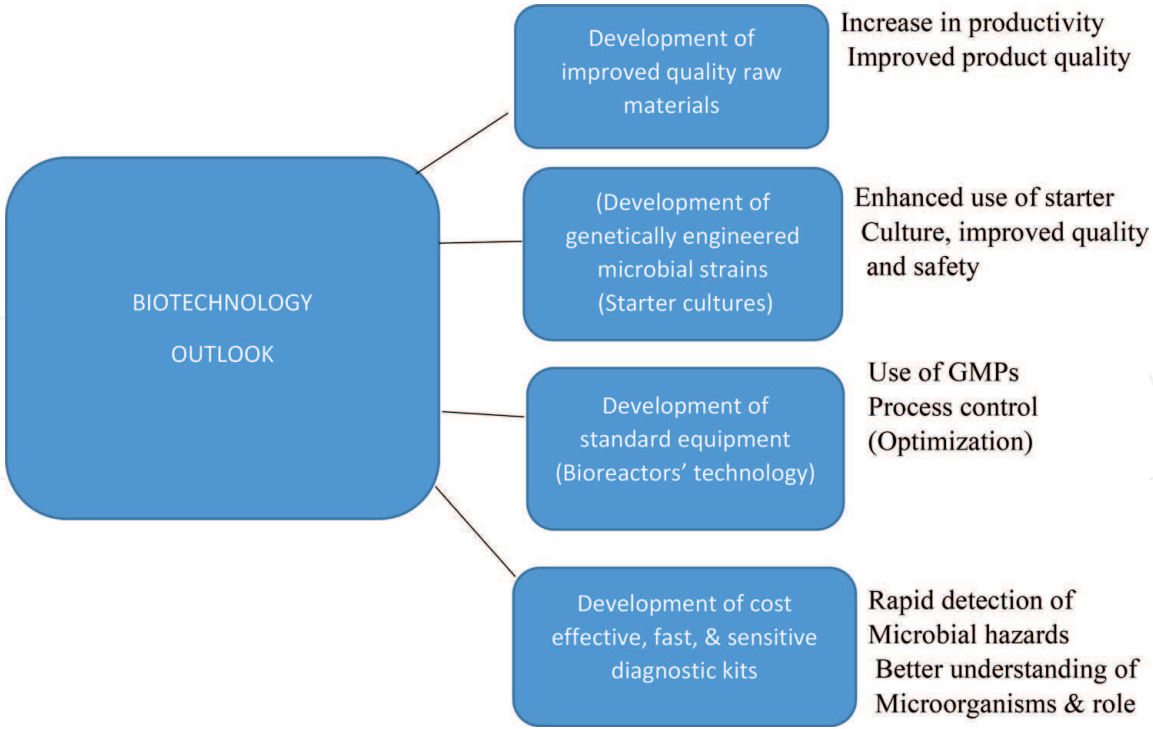


Figure 11.
Schematic presentation of prospects of biotechnology in commercialization and industrialization of fermentation process.

of good manufacturing practices (GMPs) to be able to achieve sustainable commercial marketability in the coming years. Currently, the disposition to understand traditional fermentation processes and their applications for industrialization is gaining ground in Africa and other developing regions. It is essential to recognize the critical role of microbial technology and significance of molecular biology-based applications in food processing in order to ensure quality and safety.

Recent understanding in the methods of processing fermented foods through application of scientific information has helped to improve quality of traditional foods in many ways. Microbial technology has played a key role in this aspect, being helpful for production of functional foods, bio-preservation and sensory improvement of fermented foods. With the application of sophisticated technologies including genomics and proteomics, commercialization and industrialization of fermented foods look promising. **Figure 11** illustrates prospects of biotechnology in commercialization and industrialization of fermentation process. Future research will have to look at the use of improved raw materials as fermentation substrates, development and use of standard inoculums (starter cultures), and application of process control and defined unit operation, use of GMP and HACCP protocols by food processors, and use of adequate and esthetic packaging materials. These will eliminate challenges associated with food safety, achieve uniformity and reproducibility in products, enhance consumer confidence and increase product marketability across borders. A major breakthrough in the years ahead will target the evolution of viable small and medium fermentation enterprises around traditional alkaline fermented foods and other related products in Africa and other parts of the world.

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