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African Fermented Food Condiments: Microbiology Impacts on Their Nutritional Values

Nurudeen Ayode Olasupo and Princewill Chimezie Okorie

Abstract

Fermented food flavoring condiments are products usually derived from the fermentative activities of microorganisms on vegetable proteins of legumes or oil seeds. Africa is a continent that is endowed with many fermented food condiments. These condiments, apart from their flavoring properties, serve as a cheap source of plant protein to the populace, especially the rural dweller whose staple foods are mainly carbohydrate based. The production dynamics of these condiments vary from country to country. However, the microbial interplay during their production and their nutritional qualities appear to be same. This chapter seeks to evaluate the range of substrates employed in the production of fermented condiments of African origin, the microbial interplay in their production and their nutritional values.

Keywords: microbiology, nutrition, fermentation, African fermented condiments

1. Introduction

Fermented foods constitute a significant component of African diets. There are many fermented foods known in Africa. These foods are classified into five major categories based on the substrate from which they are derived [1] and they include fermented food condiments among others.

Condiment is defined as a spice, sauce or other food preparation that is added to food to impart a particular flavor or enhance its taste (example salt). Fermented food flavoring condiments are products usually derived from the fermentative activities of microorganisms on vegetable proteins of legumes or oil seeds origin [2, 3]. They include *iru* from Africa locust bean, *ugba* from African oil bean seed and *ogiri* from melon seeds among others. These fermented food condiments are known to be good sources of proteins and vitamins [1, 4].

The use of fermented vegetable proteins as seasonings is wide spread in Africa, especially among the rural dwellers. In West Africa, some of the common fermented vegetable condiments include *iru* or *dawadawa* from locust bean (*Parkia biglobosa*) (**Figure 1**), *ogiri* from melon seeds (*Citrullus vulgaris*) (**Figure 2**), *daddawa* from soybean (*Glycine max*), *soumbala* from soybean (*Glycine max*) (**Figure 3**), *ugba* from African oil bean seed (*Pentaclethra macrophylla*) (**Figure 4**) and *owoh* from



a



b

Figure 1.
Unfermented seeds of African locust bean (a) and fermented seeds of African locust bean (b) (iru/ dawadawa/ Afitin/Sonru/soumbala). Source: [31].



a



b

Figure 2.
Unfermented melon seeds (a) and fermented melon seeds (b) (ogiri). Source: [22].



Figure 3.
Sombala (in balls) and the seeds used for their preparation. Source: [11].



Figure 4.
African oil bean seeds (a) and fermented slices of the oil bean cotyledon (b) ugba. Source: [57].

cotton seeds (*Gossypium hirsutum*). **Table 1** presents a comprehensive list of fermented food condiments of African origin.

These fermented condiments bear different names according to the country or region of the continent from which they are produced. African locust bean tree (*Parkia biglobosa*), for instance, is one of the most common plants whose seeds are used as protein source condiment after fermentation. It is consumed by various socioethnic groups in the West African subregion, and it bears different names across the region. It is popularly known as *afitin/sonru/iru* in Benin [5–7], *iru/dawadawa* in Nigeria [8, 9], *sombala* in Burkina Faso [10, 11] and *netetu* in Senegal [12].

Raw material	Product	Country	Reference
Soy bean	<i>Dawadawa</i>	Nigeria	[19]
	<i>Soumbala</i>	Burkina Faso	[11]
	<i>Tempeh</i>	Ghana	[19]
Melon seed	<i>Ogiri</i>	Nigeria	[23]
Castor oil seed	<i>Ogiri igbo</i>	Nigeria	[26]
Fluted pumpkin seed	<i>Ogiri ugu</i>	Nigeria	[27]
African locust bean	<i>Dawadawa/iru</i>	Nigeria	[17]
	<i>Afitin/Sonru</i>	Benin	[5]
	<i>Soumbala</i>	Burkina Faso	[10]
	<i>Netetu</i>	Senegal	[12]
African oil bean seed	<i>Ugba</i>	Nigeria	[38]
African yam bean	<i>Ogiri</i>	Nigeria	[38]
Cotton seed	<i>Owoh</i>	Nigeria	[95]
Bambara groundnut	<i>Ogiri okpei</i>	Nigeria	[31]
<i>Prosopis africana</i> seed	<i>Okpehe</i>	Nigeria	[28]
Roselle plant	<i>Bikalga</i>	Burkina Faso	[14]
	<i>Dawadawa botso</i>	Niger	[14]
	<i>Furundu</i>	Sudan	[14]
	<i>Mbuja</i>	Cameroon	[14]
Fish	<i>Lanhouin</i>	Benin	[15]

Table 1.
Common fermented food condiments of African origin.

The Roselle plant (*Hibiscus sabdariffa* L.) is another herbal shrub whose seeds are rich in protein, oil and dietary fiber [13]. The seeds of this plant are widely used in alkaline fermentation for the production of food condiment popularly known as *bikalga* (Burkina Faso), *dawadawa botso* (Niger), *datou* (Mali), *furundu* (Sudan) and *mbuja* (Cameroon) [14].

Even within a country, the names of these condiments vary from one part to another. The origin of such names, however, could be attributed to a number of factors which include (a) the region or area of manufacture of the condiment, (b) the type of legume or oil seed used and (c) the spelling according to the region or area. In Nigeria, for instance, the Yorubas of the Southwestern Nigeria locally call fermented condiments *iru*, the Hausas of the Northern part call it *dawadawa* and the Ibos of the Eastern part call it *ogiri* [1]. *Owoh*, on the other hand, is a popular name for fermented condiments among the Urhobos and Itsekiris in the Niger Delta region, while the Igala and Idoma people of the Middle Belt region call it *okpiye* [3].

The conventional substrates for these condiments production are diverse but are mainly legumes and oil seeds. *Lanhouin* is, however, a fish-based condiment, which is common in Benin [15]. *Lanhouin* is used as a taste- and flavor-enhancing condiment in some main dishes such as vegetable, slimy vegetable and tomato sauces. One condiment can be produced from more than one raw material. For instance, in Nigeria, *dawadawa* and *iru* are locally produced from three materials: African locust bean (*Parkia biglobosa*), soybean (*Glycine max*) or Bambara groundnut (*Vigna subterranea*) [16–21]. *Ogiri* is traditionally prepared by fermenting melon seeds (*Citrullus vulgaris*) and fluted pumpkin (*Telfairia occidentalis*) or castor oil seed (*Ricinus communis*) [22–27]. *Owoh* is produced from fermented seeds of the cotton plant (*Gossypium hirsutum*) or African yam bean (*Sphenostylis stenocarpa*)

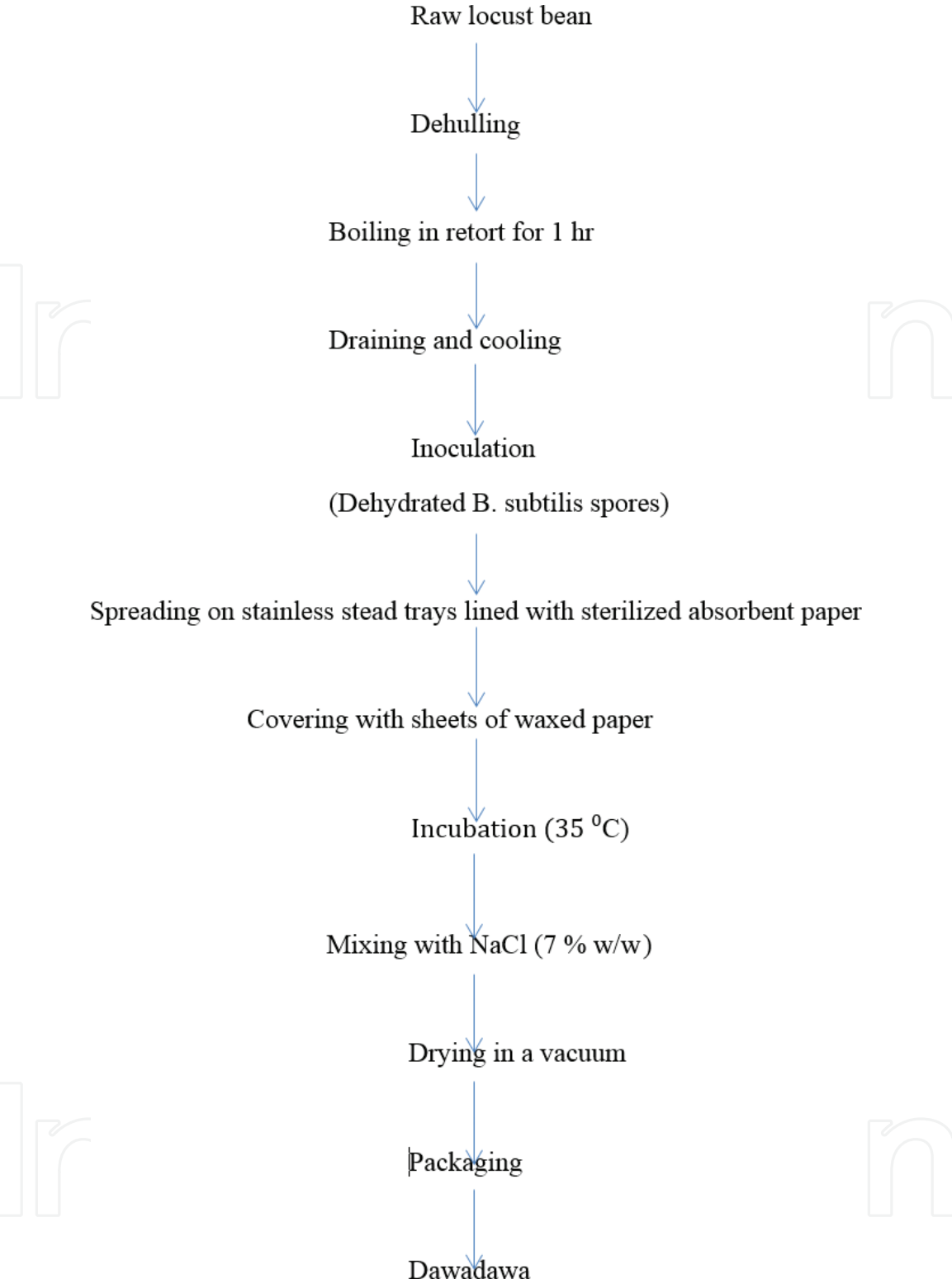


Figure 5.
Flowchart for the preparation of dawadawa. Source: [31].

[28–30]. On the other hand, *okpiye* is prepared from the seeds of *Prosopis africana* [31–33]. Almost any edible plant material can be subjected to fermentation to produce condiment.

Fermented food condiments play very important role in the diet of many Africans. They are used to enhance the flavor of many dishes including soups and sauces [6, 34]. These fermented food condiments are also known to be good sources of protein and vitamins [1, 4]. Apart from the flavoring attributes, they contribute to the protein intake of the consumers. The significance of this fact is better appreciated when you realize that most of the meals in many parts of West, Central, and

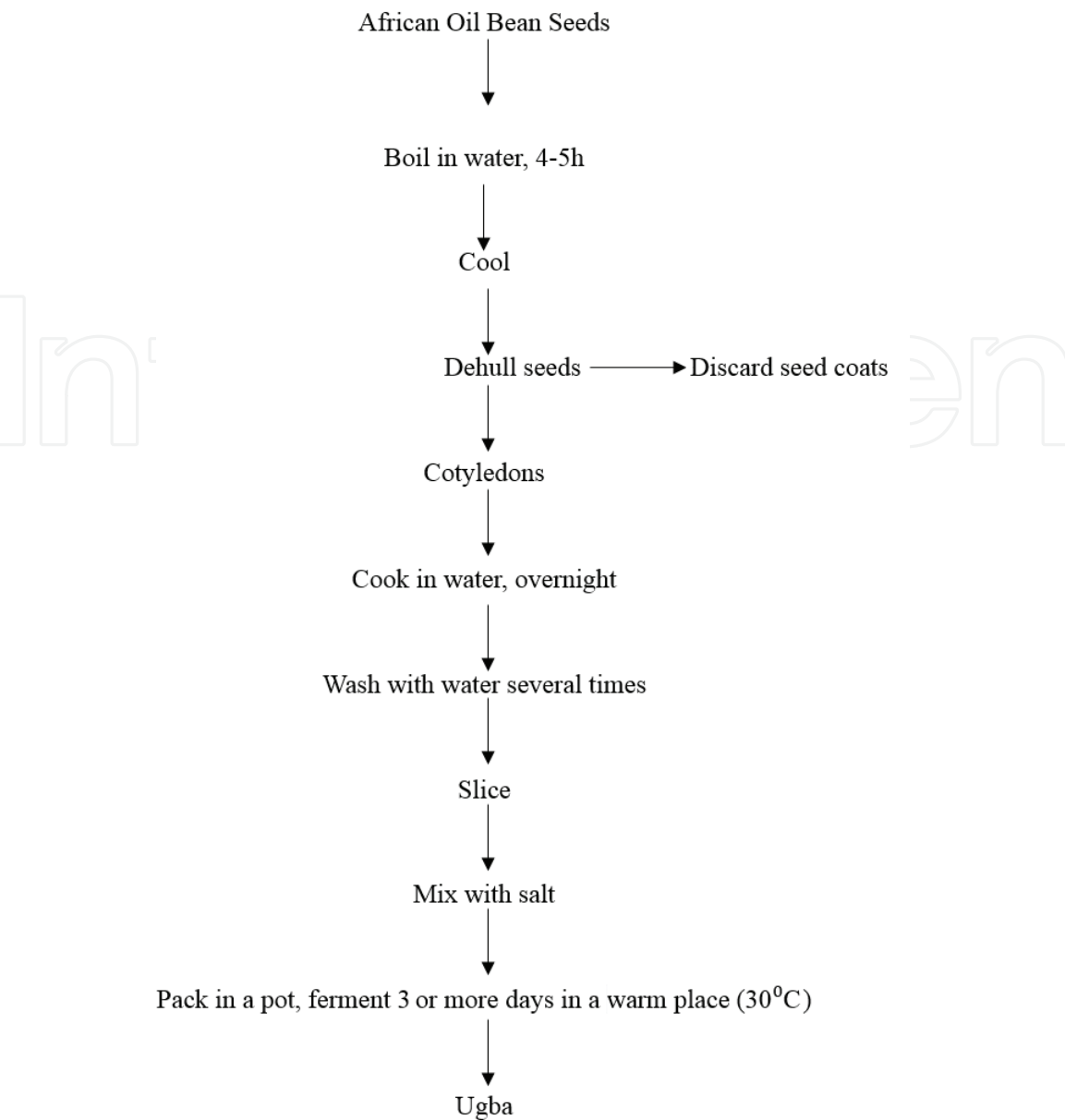


Figure 6.
Flowchart for the preparation of ugba. Source: [97].

Southern Africa are made of starchy roots and grains and have to be taken with soups to which these condiments are an essential input [3].

The traditional methods of preparation of these condiments are generally very laborious, time and energy consuming and are usually carried out with rudimentary utensils. The essential steps in the preparation of these condiments are similar with minor differences occurring from one condiment to another and among different localities [30]. In Benin Republic, for instance, *ikpiru* and *yanyanku* are two additives used for traditional alkaline fermentation of African locust bean (*Parkia biglobosa*) to obtain the popular *afitin/sonru/iru* condiment [35]. These additives are, however, not involved in the production of the same condiment in the other neighboring countries. The basic steps in the production of these condiments involve shelling/decorticating and dehulling of the seeds, the seeds are washed and wrapped in several layers of leaves and left to ferment. In some other methods, the seeds are spread in calabashes that are stacked together and wrapped in several jute bags and left to ferment. These conditions create low oxygen tension and help to maintain the optimum conditions of temperature and humidity necessary for the fermentation process. The fermentation time varies from one product to another

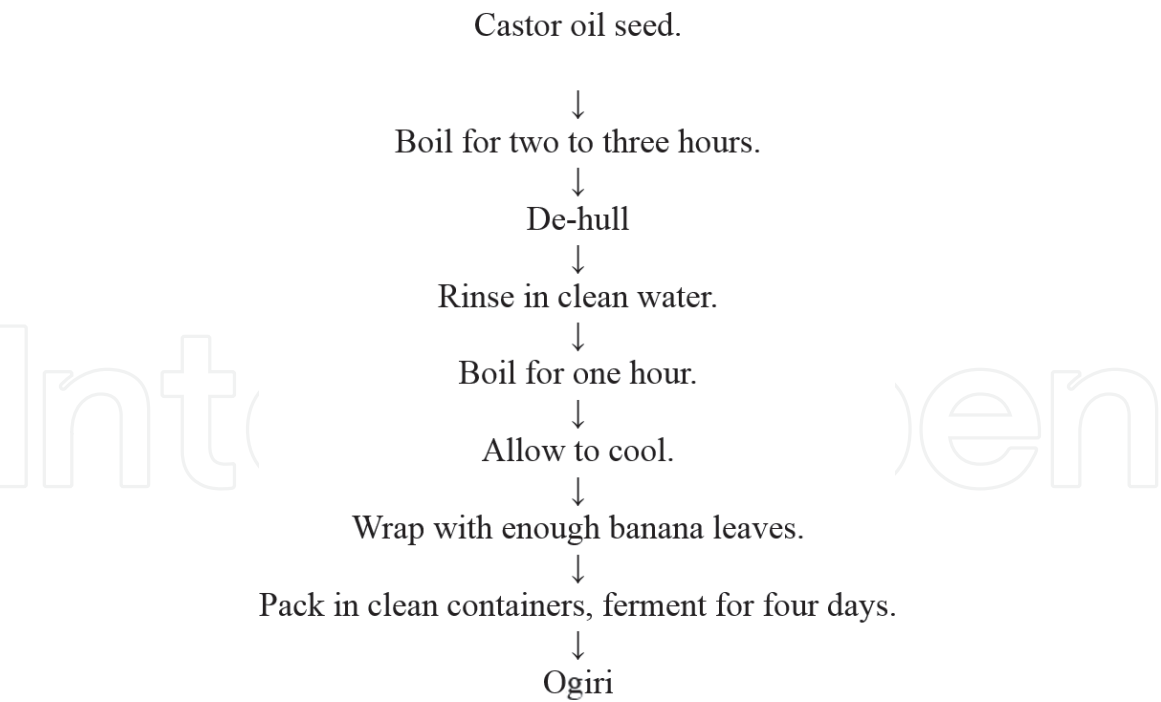


Figure 7.
Flowchart for the preparation of ogiri. Source: [98].

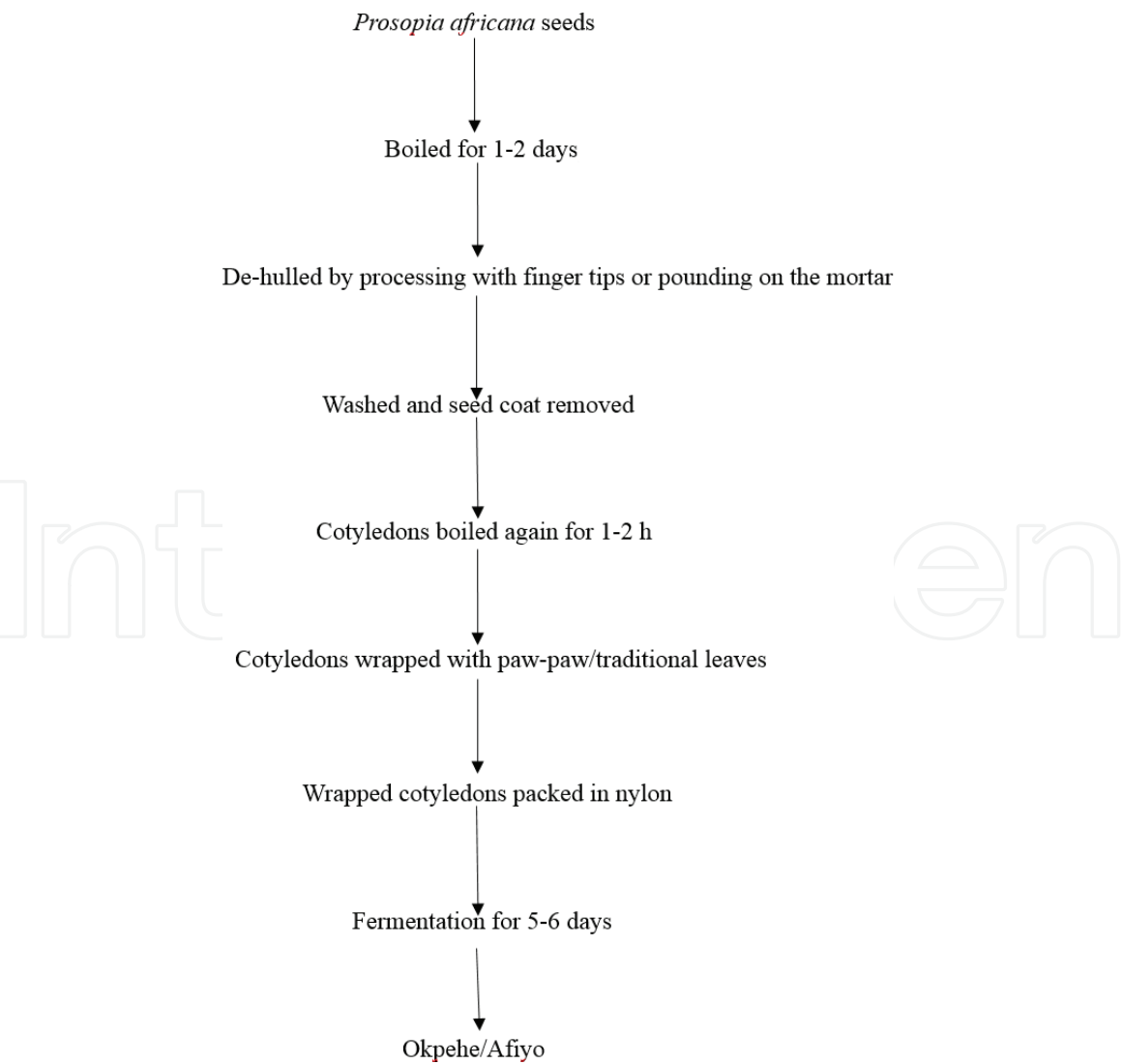


Figure 8.
Flowchart for the preparation of okpehe. Source: [43].

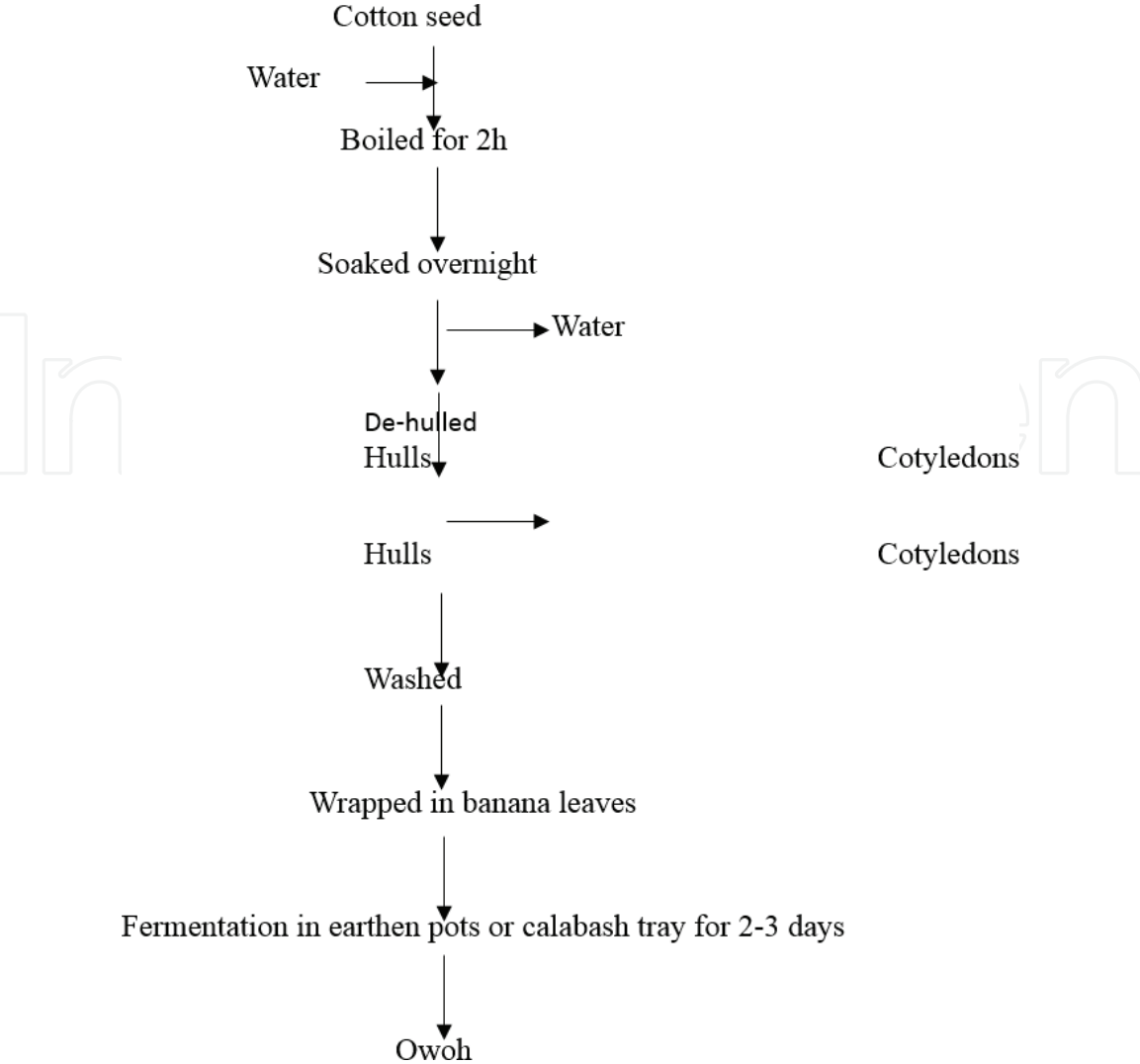


Figure 9.
Flowchart for the preparation of owoh. Source: [28].

and from one processor to another. Generally, it ranges from 48 to 120 h (2–5 days). **Figures 5–9** show the flowcharts for the fermentation of African locust bean seeds, African oil bean seeds, castor oil seeds, *Prosopis africana* seeds and cotton seeds, respectively, into various food condiments.

2. Microbiology of African fermented condiments

The microbiota in any fermenting food matrix is a function of the hygienic status of the production environment, the utensil and the raw material used and the handlers. The traditional fermentation method employed in the processing of most fermented African condiments is by chance inoculation [2, 30, 36]. The microbial interaction during their production is, therefore, determined by the microbiological status of the raw material, utensils, handlers and production environment. These factors vary from one community to the other and from one processor to another. The microbial interplay in the fermenting mash, therefore, may also vary from one processing community to the other and from one processor to another and even from one batch of production to another (**Table 2**). During fermentation of these condiments, the microorganisms use the nutritional components of the substrates, converting them into products that contribute to the chemical composition and taste of the final product [30, 37].

Food	Area of production/ consumption	Raw material	Microorganisms
Dawadawa or iru	Most of West Africa especially northern African parts	African locust bean (<i>Parkia biglobosa</i>) Soybean (<i>Glycine max.</i>)	<i>Bacillus subtilis</i> <i>B. licheniformis</i>
Ogiri	Southwestern Nigeria	Melon (<i>Citrullus vulgaris</i>)	<i>Bacillus</i> sp.(predominant), <i>Proteus</i> , <i>Pediococcus</i>
Ogiri-nwan	Southwestern Nigeria	Fluted pumpkin bean (<i>Telfairia occidentalis</i>)	<i>Bacillus</i> sp. (proteolytic)
Ogiri-igbo (ogiri-agbor)	Southeastern Nigeria	Castor oil seed (<i>Ricinus communis</i>)	Various <i>Bacillus</i> species: <i>B. subtilis</i> , <i>B. megaterium</i> , <i>B. firmus</i>
Ogiri-saro (<i>sigda</i>)	Sierra Leone, Sudan	Sesame seed (<i>Sesamum indicum</i>)	<i>Bacillus</i> sp.
Ogiri-okpei/Okpehe	Middle belt Nigeria	Mesquite (<i>Prosopis africana</i>)	<i>Bacillus</i> sp.
Ugba (<i>apara</i>)	Eastern Nigeria	African oil bean (<i>Pentaclethra macrophylla</i>)	<i>Bacillus subtilis</i> <i>Micrococcus</i> sp.
Owoh	Midwestern Nigeria	Cotton seeds (<i>Gossypium hirsutum</i>)	<i>Bacillus</i> sp.
Bakalga	Niger, Mali, Sudan, Burkina Faso	Kartade red sorrel (<i>Hibiscus sabdariffa</i>)	<i>Bacillus subtilis</i>

Source: [3].

Table 2.
Some important fermented vegetable foods of Africa and their fermenting organisms.

The major fermenting microorganisms involved in the fermentation process of most vegetable protein (fermented condiments) have been identified as proteolytic *Bacillus* species, e.g., *B. subtilis*, *B. megaterium*, *B. circulans* [2, 30, 33, 38]. *Bacillus subtilis*, however, appears to be the most predominant of all the *Bacillus* species. The endospores of these bacilli are believed to be associated with the cotyledons of these seeds from the onset of the fermentation process.

Proteolysis is the major biochemical activity taking place during the fermentation of most fermented food condiments that are of plant origin [39, 40]. Proteolytic activity has been found to steadily increase with increase in the fermentation period during the production of these food condiments [39, 41]. Due to the high level of hydrolytic enzyme production by *Bacillus* species, all the species have been reported to have one or more enzymatic hydrolytic properties during legume fermentation [42, 43]. However, it appears that *Bacillus subtilis* is the most adapted and dominant species. *Bacillus subtilis* produces high levels of protease, amylase and polyglutamic acid (responsible for mucilage production that is common in fermented vegetable protein) [43].

Protein has been identified as one of the major components of the legumes and oil bean seeds used for the fermentation of these condiments [38]. Metabolic and enzymatic hydrolytic activities of the *Bacillus* species serve to break down the protein into amino acids [39, 40, 43–46]. An increase in the population of *Bacillus* species from the beginning of the fermentation process till the end had been reported [41]. Microorganisms belonging to other groups of bacteria are also associated with the fermentation of these condiments. They include species of *Escherichia*, *Proteus*, *Pediococcus*, *Micrococcus*, *Staphylococcus*, *Streptococcus*, *Alcaligenes*, *Pseudomonas*, *Corynebacterium* and *Enterococcus* [17, 18, 20, 37, 41, 47–49]. *Staphylococcus* and

Micrococcus species are very active at the early stage of the fermentation process. They multiply rapidly within 24 h of fermentation and then decrease as fermentation progresses [41]. Their role in the fermentation process is, however, lower compared to that played by the *Bacillus* species. Species of *Escherichia*, *Proteus* and *Pediococcus* generally play a minor role in the fermentation process [38, 50, 51].

Besides proteolysis, other biochemical changes mediated by microorganisms during the production of these condiments include production of flavor-enhancing compounds, production of vitamins and essential fatty acids and degradation of indigestible oligosaccharides responsible for flatus factors [45]. A significant increase in vitamins, such as thiamine and riboflavin, has been observed in these condiments, which is possibly due to riboflavin synthase associated with the *Bacillus subtilis* [45]. A reduction in the content of flatus factors [stachyose, raffinose and melibiose] in fermented condiments of African origin has been reported [52]. The reduction is as a result of sucrase activities of the *Bacillus* group and possibly by the α -galactosidase activities of other microorganisms in the fermenting mash [39, 53].

Members of the *Enterobacteriaceae* have also been associated with the ecology of fermenting plant protein especially at the early stages of production [31, 54]. These species do not survive until the end of the fermentation, presumably because of the modified environment [41]. It is evident that production of these fermented condiments is initially mediated by a diverse microbial flora, which eventually becomes Gram-positive flora (a reflection of many African fermented foods) [26].

The identification of these organisms have been based on phenotypic approach with its inherent shortcomings, especially its inability to isolate and identify viable, but unculturable, microorganisms. Unculturable, yet viable, microorganisms are known to be in most food matrix [55, 56]. In a recent study [57] on the processing methods and safety of a fermented food condiment in Nigeria (*ugba*), the author deployed both phenotypic and molecular tools in his study. New bacterial species of *Arthrobacter*, *Empedobacter*, *Providencia*, *Brevibacterium*, *Elizabethkingia*, *Acinetobacter*, *Burkholderiales*, *Proteobacterium*, *Wautersiella*, *Dysgonomonas*, *Zymomonas* and *Flavobacterium* were uniquely identified by the clone library technique employed. The study, therefore, underscores the need to deploy molecular techniques in the evaluation of the microbiology of these African fermented food condiments. It is possible that the microbial structure reported for these products could be wider than is currently recorded.

3. Nutritional properties

Fermentation has generally been observed to improve the nutritional qualities and safety of fermented food products [58–63]. Proximate analyses of most fermented vegetable protein of African origin have shown that these condiments are rich sources of protein, essential amino acids, vitamins and minerals. These components have been found to increase during the fermentation of these condiments [4, 63–65].

The substrates for the fermentation of these condiments harbor diverse microorganisms from the environment [66–68]. These microorganisms transform the chemical constituents of the raw materials during fermentation. The transformation has the following advantages: [i] enhance nutritive value of the products; [ii] enrich bland diets with improved flavor and texture; [iii] preserve perishable foods; [iv] fortify products with essential amino acids, health promoting bioactive compounds, vitamins and minerals; [v] degrade undesirable compounds and antinutritional factors; [vi] impart antioxidant and antimicrobial properties; [vii] improve digestibility and [viii] stimulate probiotic functions. Fermentation of these

products also results in a lower proportion of dry matter in the food products, and the concentration of the vitamins, minerals and protein appears to increase when measured on dry weight basis [4, 63–65, 69, 70].

A large percentage of Africa’s population live below poverty line with diets that are poor in protein and other essential nutrients [3, 71]. Fermented food condiments have been found to be rich in proteins and other essential nutrients and, therefore, serve as supplements for these nutrients outside their usage as flavoring agents [72–75] (**Table 3**). *Bikalga*, for instance, is a popular fermented food condiment in Benin Republic, which is considered as an excellent source of protein with essential amino acids. It also contains lipids, carbohydrates, essential fatty acids and vitamins [11, 76]. Many families often use *Bikalga* as a meat substitute. Most African fermented food condiments are used to improve nutritional values of foods as well as their sensory properties and as taste enhancer [70].

Generally, a significant increase in the soluble fraction of amino nitrogen of a food is observed during fermentation [77]. Investigation by Niba [78] showed that protein quality in grain cereals is improved during fermentation due to depletion of trypsin inhibitors, which increases the digestibility of various amino acids.

Fermentation markedly improves the digestibility, nutritive value and flavor of raw seeds [79–81]. Studies on the effect of fermentation on the nutrient content of some unfermented leguminous seeds (locust beans and oil bean seeds) showed that protein and fat increased when fermented, whereas the quantity of carbohydrates decreased [82]. Increased levels of the amino acids were also reported except for arginine, leucine and phenylalanine. Similar results have been reported for other seed legumes [26, 52]. The organisms involved in the fermentation processes, especially *Bacillus* sp., produce proteolytic enzymes, which hydrolyze proteins to amino acids and peptides [18, 23, 26, 50, 83–85]. *Bacillus* strains obtained from fermenting African oil bean seed and locust beans have been found to produce glutamic acid and extracellular proteinases, which play active role in the fermentation process of these seeds [42, 86].

The proximate composition of some fermented vegetable protein (FVP) and their raw materials indicate that the major components are protein and fat (**Table 3**). The most significant reaction/change in the fermentation of proteins is their hydrolysis to free amino acids and other soluble nitrogen compounds. The amino acids produced vary, depending on the type of seed [fermenting substrate]. The peptides and amino acids are important in the evolution of the flavor of the condiments. Glutamic acid, an important flavoring component, has been observed in the fermentation of *ugba*, *iru* and *dawadawa* [87].

The major component of the carbohydrate content of legumes is starch, raffinose, melibiose and stachyose [26, 50]. During fermentation, these oligosaccharides

Proximate composition (%)						
Condiments	Moisture	Ash	Crude fiber	Crude protein	Carbohydrate	Fat
<i>Iru/Dawadawa</i>	52.0 ± 5.0	3.6 ± 0.1	4.0 ± 0.1	32.9 ± 0.1	16.3 ± 0.8	24.2 ± 0.1
<i>Ogiri</i>	44.1 ± 0.8	3.0 ± 0.0	15.6 ± 0.4	19.9 ± 0.8	25.2 ± 1.2	—
<i>Owoh</i>	46.6	2.21	6.01	16.37	14.06	20.76
<i>Ugba</i>	34.4	1.11	2.93	7.13	17.48	19.72
<i>Okpehe</i>	9.46	4.84	2.99	36.88	47.18	11.35

Source: Adapted from [4, 64, 99].

Table 3.
Proximate composition of some African fermented condiments.

Mineral composition (mg/100 g)								
Condiments	P	K	Na	Ca	Mg	Zn	Fe	Mn
Iru	80.00	205.00	—	9.01	35.00	—	3.31	—
Ogiri	91.17	1075.00	369.36	78.60	58.72	1.17	14.50	1.15
Owoh	—	464.50	416.50	246.0	150.0	119.7	16.0	—
Ugba	291.02	110.39	172.06	208.92	334.98	9.23	42.46	26.87
Okpehe	—	183.1	—	45.3	—	14.2	10.2	4.2
Source: Adapted from [4, 64, 99].								

Table 4.
Mineral composition of some African fermented condiments.

are hydrolyzed to simple digestible sugars [88]. Assay of the fermenting mash of African oil bean seed and African locust bean showed activities of α - and β -galactosidases and sucrase [89], with α - and β -galactosidases being the highest. Other enzymes present are galactanase, glucosidases and fructofuranosidases and polygalacturonases. These enzymes are produced by *Bacillus* species, *Staphylococcus* species and lactic acid bacteria, the latter group producing α -galactosidase, and they play very active role in the hydrolysis of these oligosaccharides. The nutritional significance of hydrolysis of oligosaccharides is evident in the drastic reduction of the level of indigestible carbohydrates, which cause flatulence [89].

Oil constitutes a major component of the legumes and oil seeds, but lipolytic activities are minimal during the production of most African fermented food condiments. Low lipolytic activities were detected during *ugba* and *dawadawa* production. The lipolytic activities are attributed to *Staphylococcus* species in the fermentation medium [39, 90]. During fermentation, the free fatty acid fractions [FFA] are reduced from 0.6 to 0.1% w/w in the fermented seeds. No significant differences were observed between the fatty acid content of the raw seeds and the fermented seeds; the major components are palmitic acid, stearic acid, oleic acid and linoleic acid [91].

Many reports confirm that vitamin levels are higher in fermented vegetable protein foods than in the raw materials, especially for riboflavin, thiamine, niacin, vitamin C and folic acid [1, 89]. Food condiments made from vegetable proteins may be a good source of certain B vitamins, but they are found to be deficient in ascorbate and some fat-soluble vitamins, which are lost during fermentation. Fermentation significantly increases the content of thiamine, riboflavin and niacin in the African oil bean [92]. Similar changes were observed during the fermentation of melon seed and fluted pumpkin seed [93, 94].

Calcium, phosphorus and potassium have been observed to increase when African oil bean seed and African yam bean were fermented for condiment production [95, 96]. Similar observation has been made on other fermented condiments (**Table 4**). It is evident that most fermented food condiments of African origin are good sources of essential nutrients and could be used to produce complementary food supplements and macronutrients in fermented legumes and therefore enhance food quality. However, issues of quality inconsistency, poor keeping quality and safety observed with these products must be addressed.

4. Conclusion

Fermented condiments constitute an important part of diet of most Africans. These condiments, apart from their flavoring properties, serve as cheap source

of protein and other essential micronutrients to the consumers. The production process of most of these condiments is still based on spontaneous fermentation process with its inherent shortcomings. There is need, therefore, for more microbiological studies of their production process with the aim of establishing standardized protocols for their production.

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