

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

185,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



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

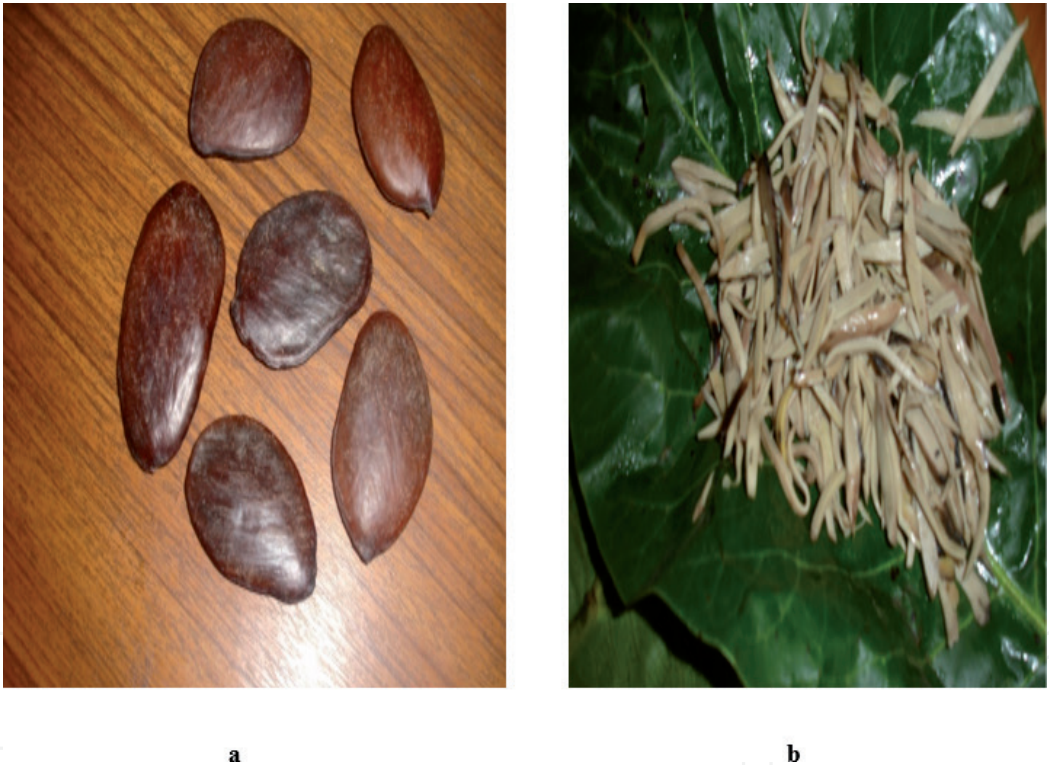


Figure 4.
African oil bean seeds (a) and fermented slices of the oil bean cotyledon (b) ugba. Source: [57].

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], *soubala* 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*)

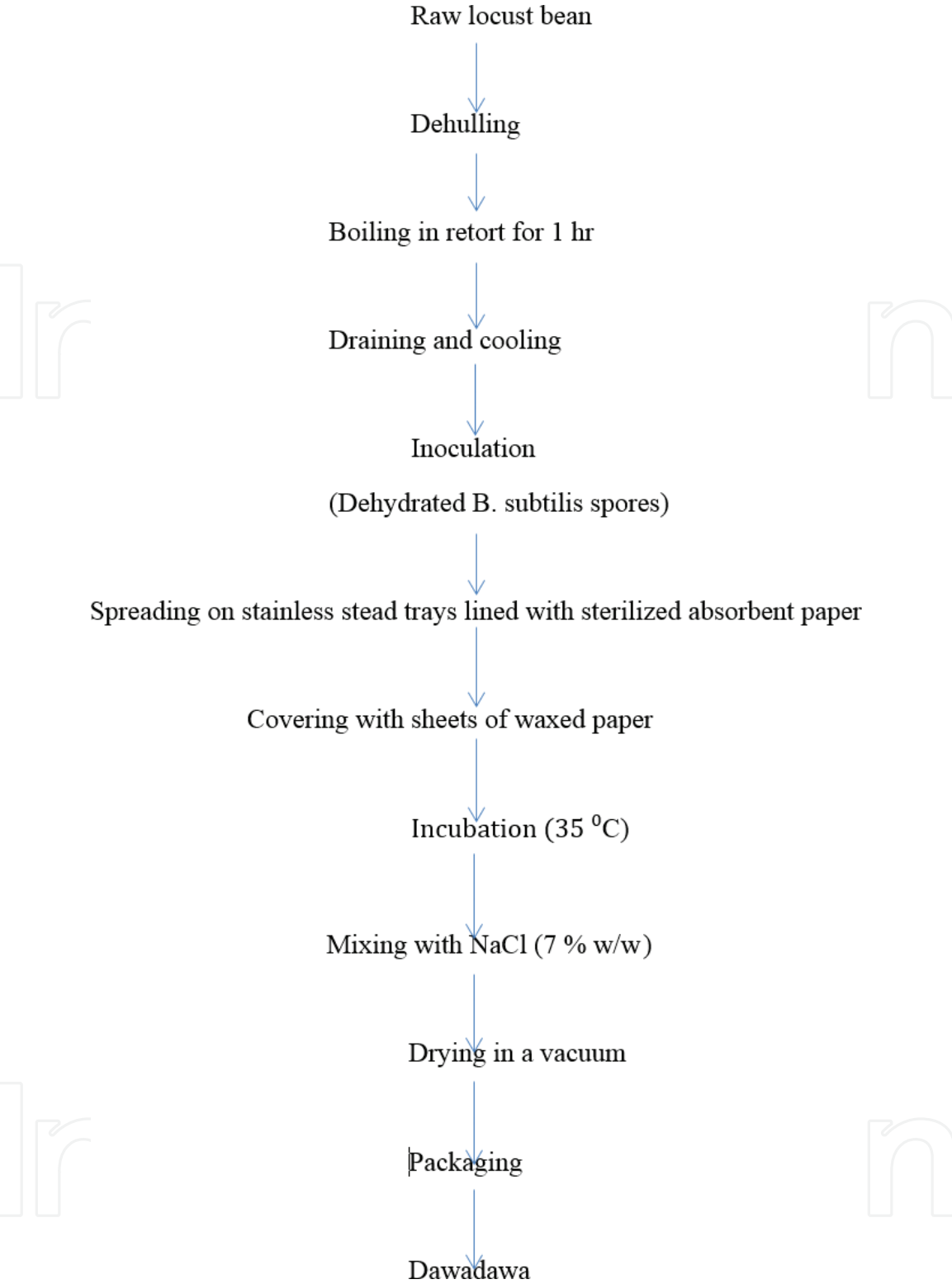


Figure 5.
Flowchart for the preparation of dawadawa. Source: [31].

[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

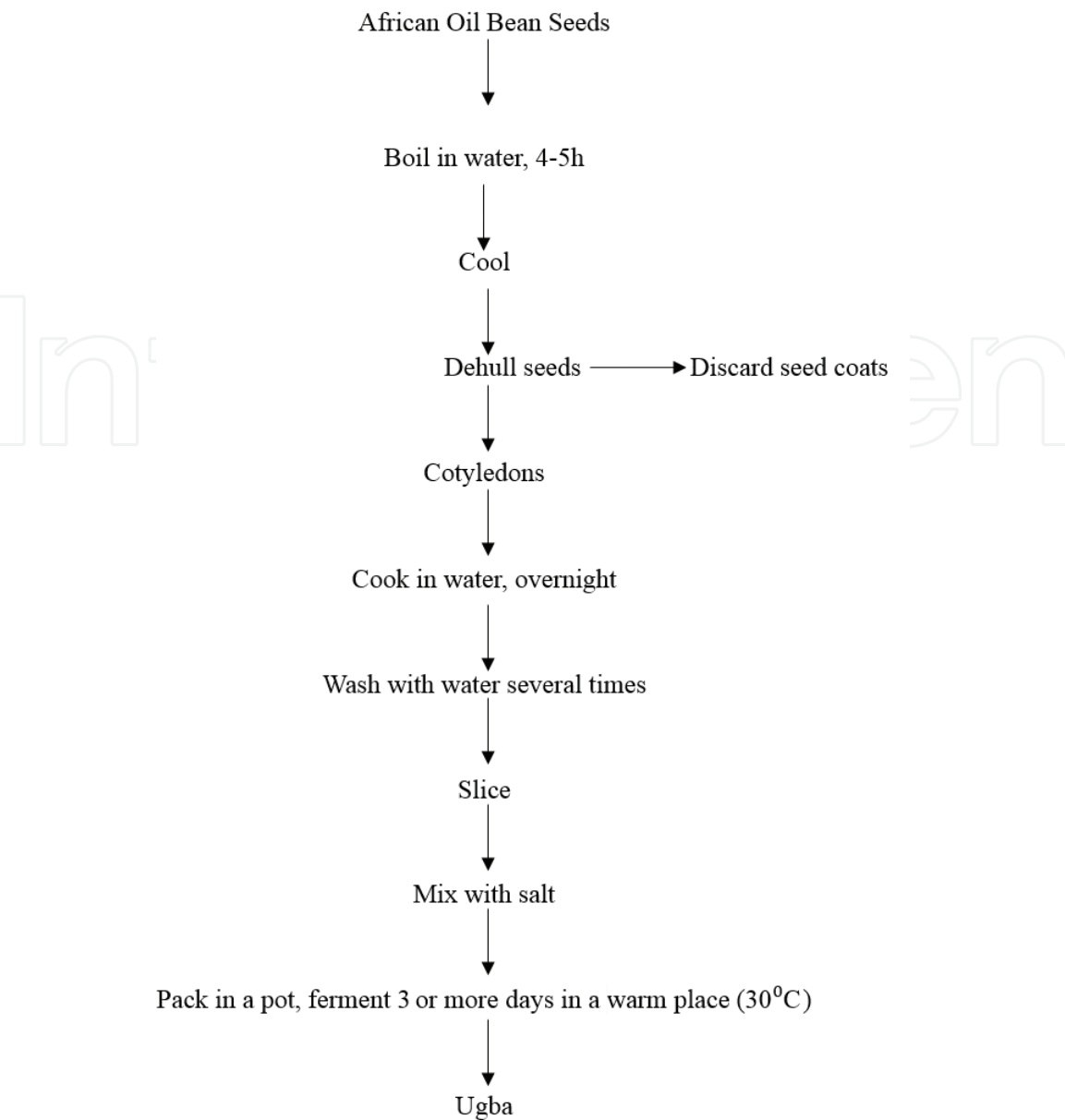


Figure 6.
Flowchart for the preparation of ugba. Source: [97].

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

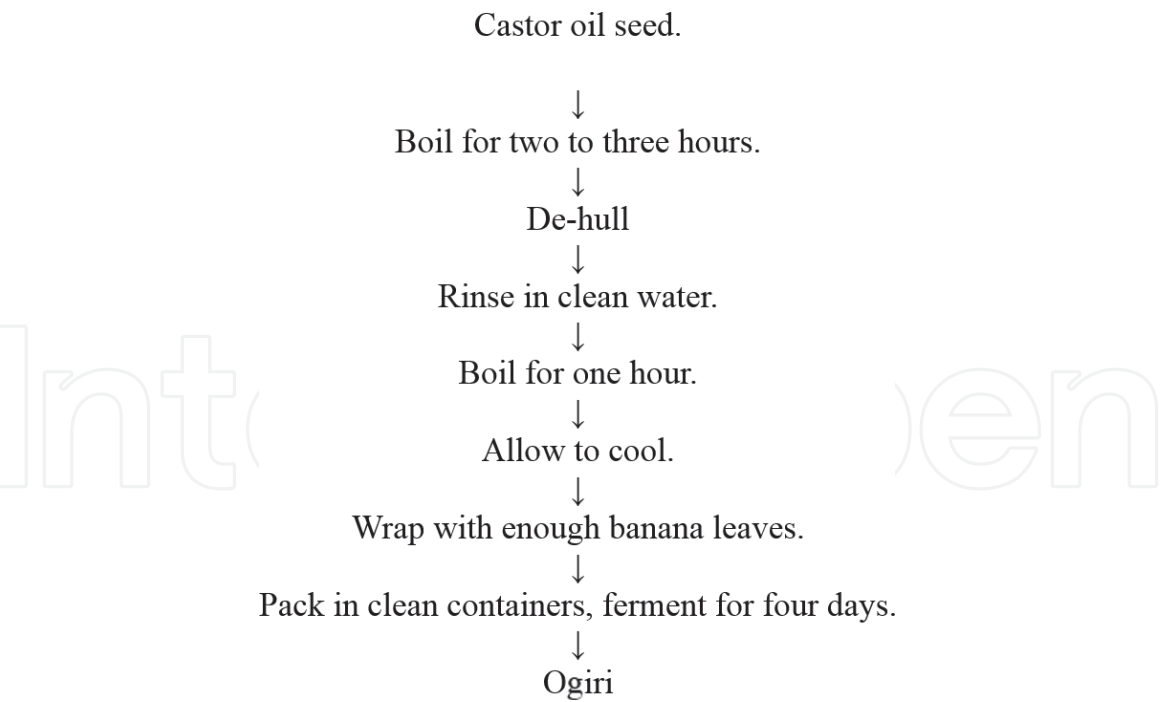


Figure 7.
Flowchart for the preparation of ogiri. Source: [98].

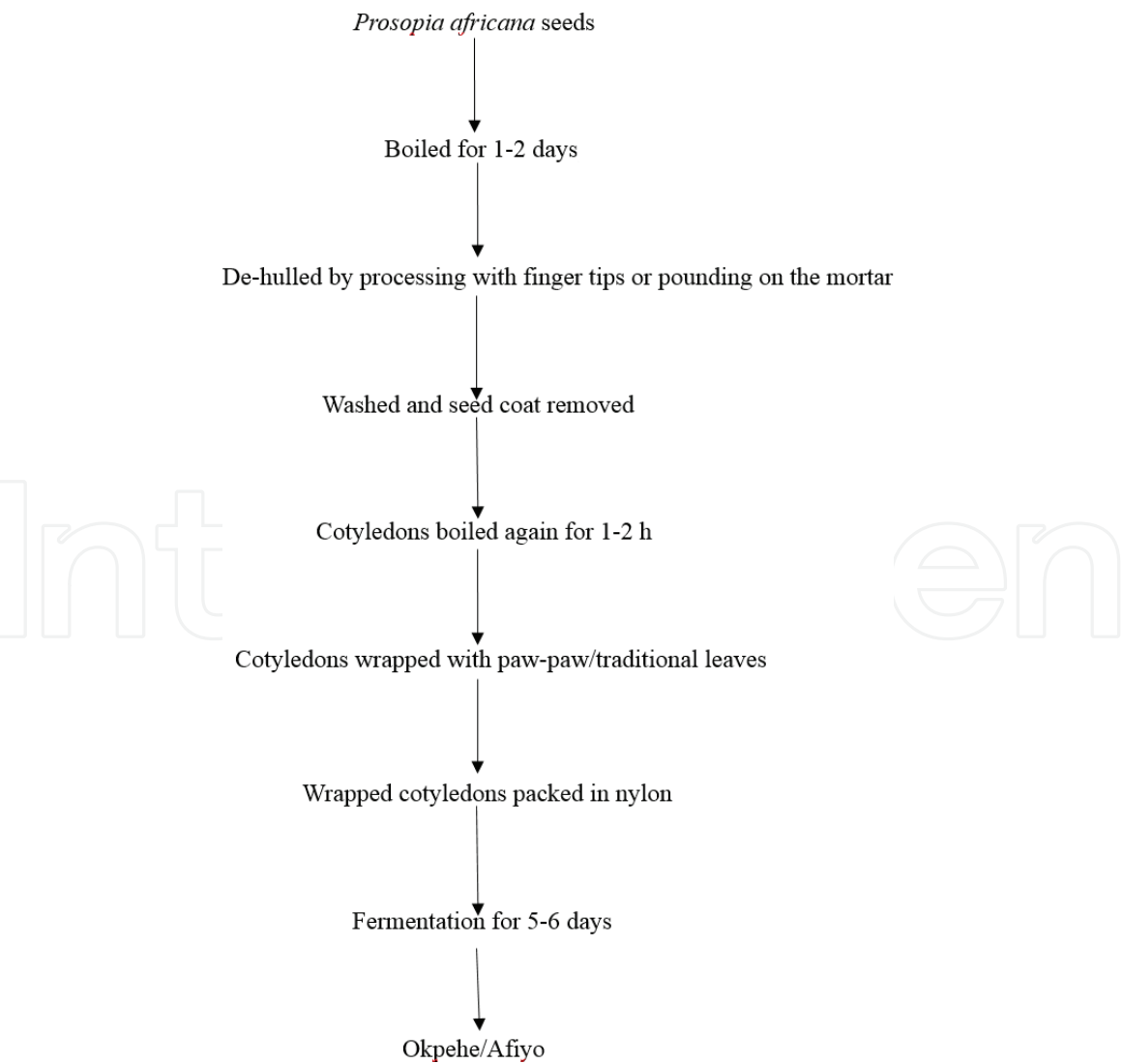


Figure 8.
Flowchart for the preparation of okpehe. Source: [43].

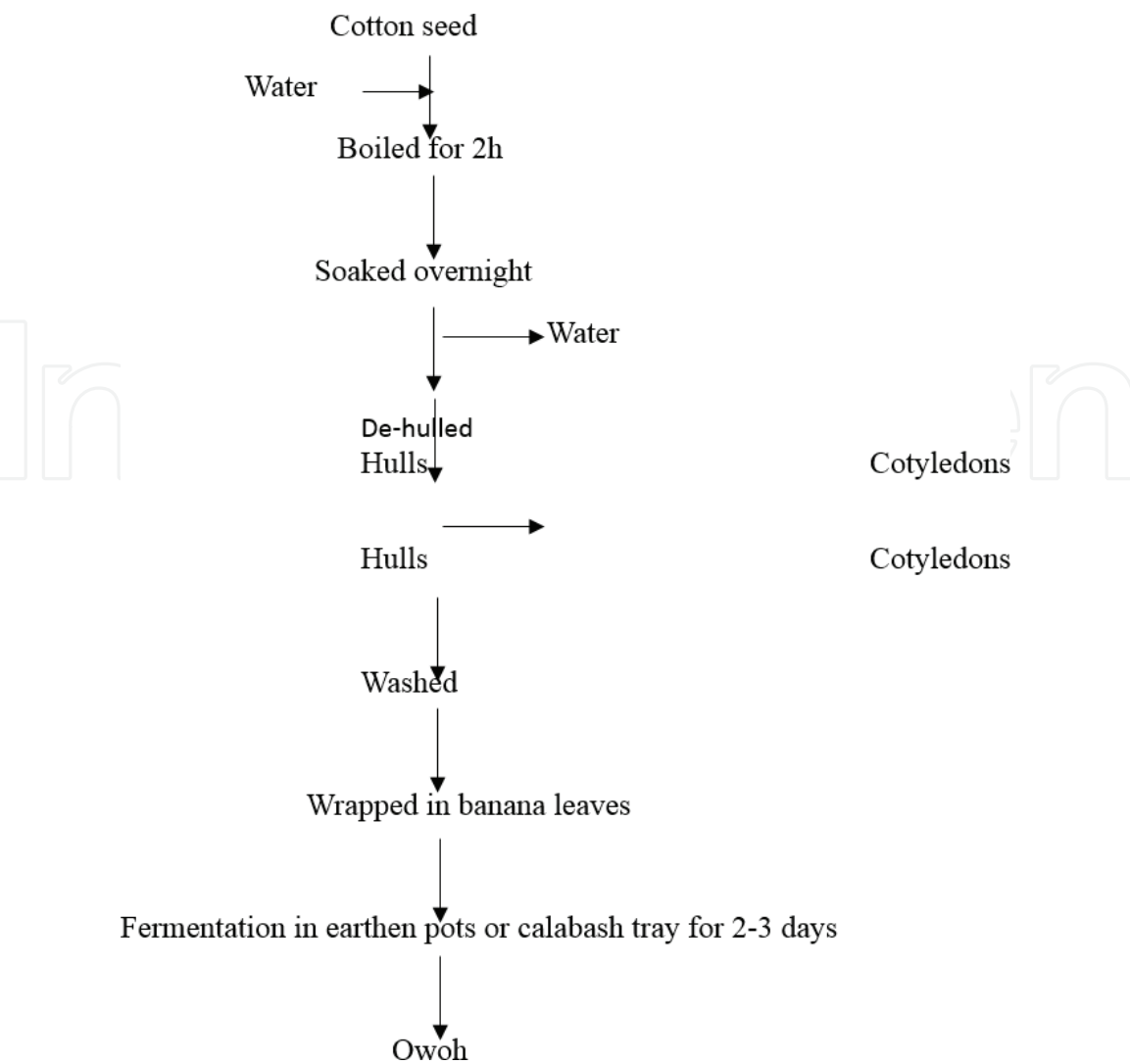


Figure 9.
Flowchart for the preparation of owoh. Source: [28].

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.

Author details

Nurudeen Ayoade Olasupo^{1*} and Princewill Chimezie Okorie²

1 Department of Microbiology, Faculty of Science, Lagos State University, Lagos, Nigeria

2 Department of Biotechnology, Federal Institute of Industrial Research Oshodi, Lagos, Nigeria

*Address all correspondence to: naolasupo@yahoo.com

IntechOpen

© 2019 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Olasupo NA. Fermentation biotechnology of traditional foods of Africa. In: Shetty K, Pometto A, Paliyath G, Levi RE, editors. Food Biotechnology. 2nd ed., revised and expanded ed. Boca Raton, New York: CRC Press, Taylor and Francis Group; 2006. pp. 1705-1739
- [2] Isu NR, Ofuya CO. Improvement of the traditional processing and fermentation of African oil bean (*Pentaclethra macrophylla* Benth) seeds into a food snack ugba. International Journal of Food Microbiology. 2000;**59**:235-239. DOI: 10.1016/S0168-1605(00)00318-4
- [3] Olasupo NA, Obayori OS, Odunfa SA. Ethnic African fermented foods. In: Tamang JP, editor. Fermented Foods and Beverages of the World. Boca Raton, London, New York: CRC Press, Taylor and Francis Group; 2010. pp. 323-352
- [4] Okechukwu RI, Ewelike N, Ukaoma AA, Emejulu AA, Azuwiki CO. Changes in the nutrient composition of the African oil bean meal “ugba” (*Pentaclethra macrophylla* Benth) subjected to solid state natural fermentation. Journal of Applied Bioscience. 2012;**51**:3591-3595
- [5] Azokpota P, Hounhouigan DJ, Annan N, Nago MC, Jakobsen M. Diversity of volatile compounds of Afitin, iru and sonru, three fermented food condiments from Benin. Western Journal of Microbiology and Biotechnology. 2008;**24**:879-885
- [6] Azokpota P, Hounhouigan DJ, Nago MC, Jakobsen M. Esterase and protease activities of *Bacillus* spp. from afitin, iru and sonru: Three African locust bean (*Parkia biglobosa*) condiments from Benin. African Journal of Biotechnology. 2006;**5**(3):265-272
- [7] Hongbété F. Valorisation de la technologie du Afitin: Amélioration de la fermentation et mis au point d'exhausteur de goût. Thèse d'ingénieur agronome. Bénin: Faculté des Sciences Agronomiques, Université d'Abomey-Calavi; 2001. 75p
- [8] Ajayi OA, Akinrinde IM, Akinwunmi OO. Towards the development of shelf stable 'iru' (*Parkia biglobosa*) condiment bouillon cubes using corn, cassava and potato starch extracts as binders. Nigerian Food Journal. 2015;**33**:67-72. DOI: 10.1016/j.nifo.2015.04.006
- [9] Daramola B, Fasominu OA, Oje OJ, Makanju OO. Influence of dietary supplementation on biotransformation of locust beans (*Parkia biglobosa*) to condiment. African Journal of Biotechnology. 2009;**8**:1116-1120
- [10] Diawara B, Sawadogo L, Amoa-Awua WKA, Jakobsen M. Quality system for the production of soumbala. The HACCP System for Traditional African Fermented Foods: Soumbala. Taastrup; 1998. ISBN 87= 90737=00=8 WAITRO Danish Technological Institute
- [11] Ouoba LII, Rechinger KB, Diawara B, Traore AS, Jakobsen M. Degradation of proteins during the fermentation of African locust bean (*Parkia biglobosa*) by strains of *Bacillus subtilis* and *Bacillus pumilus* for production of soumbala. Journal of Applied Microbiology. 2003;**94**:396-402. DOI: 10.1046/j.1365-2672.2003.01845.x
- [12] Ndir B, Lognay G, Wathelet B, Cornelius C, Marlier M, Thonart P. Composition chimique du nététu, condiment alimentaire produit par fermentation des graines du caroubier africain *Parkia biglobosa* (Jacq.) Benth. Biotechnology, Agronomy and Social Environment. 2000;**4**(2):101-105
- [13] Ismail A, Ikram MKE, Nazri MSH. Roselle (*Hibiscus sabdariffa* L.) seeds—Nutritional composition,

protein quality and health benefits.
Food Science. 2008;2(1):1-16

[14] Parkouda C, Nielsen DS, Azokpota P, Ouob LII, Amoa-Awua WK, Thorsen L, et al. The microbiology of alkaline fermentation of indigenous seeds used as food condiments in Africa and Asia. *Critical Review in Microbiology*. 2009;35(1):139-156

[15] Kindossi JM, Anihouvi VB, Vieira-Dalodé G, Akissoé NH, Jacobs A, Dlamini N, et al. Production, consumption, and quality attributes of Lanhouin, a fish-based condiment from West Africa. *Food Chain*. 2012;2(1):117-130

[16] Campbell-platt G. African locust bean (*Parkia* species) and its West African fermented food products, Dawadawa. *Ecology and Food Nutrition*. 1980;9:123-132

[17] Odunfa SA. Microorganisms associated with fermentation of African locust bean (*Parkia filicoidea*) during iru preparation. *Journal of Plant Foods*. 1981a;91:219-223

[18] Antai SP, Ibrahim MH. Microorganisms associated with African locust bean (*Parkia filicoidea*) fermentation for dawadawa production. *Journal of Applied Biotechnology*. 1986;61:145-148

[19] Popoola TOS, Akueshi CO. Microorganisms associated with the fermentation of soybean for the production of soybean daddawa (as condiment). *Nigerian Food Journal*. 1984;283:194-196

[20] Ogbadu CO, Okagbue RN. Bacterial fermentation of soybean for dawadawa production. *Journal of Applied Bacteriology*. 1988;65:353-356. DOI: 10.1111/j.1365-2672.1988.tb01902

[21] Barimalaa IS, Achinewhu SC, Yibatima I, Amadi EN. Studies on the solid substrate fermentation of bambara

groundnut (*Vigna subterranea* (L) Verdc). *Journal of Science, Food and Agriculture*. 1989;66:443-446

[22] Ogundana SK. The production of ogiri a Nigerian fermented food condiment. *Lebensmittel Wissenschaft und Technologie*. 1981;13:334-336

[23] Odunfa SA. Microbiology and amino acid composition of ogiri—A food from fermented melon seeds. *Die Nahrung*. 1981;25:811-816

[24] Odibo FJC, Umeh AI. Microbiology of the fermentation of *Teliferia rosopsis* seeds for ogiri production. *MIRCEN Journal of Applied Microbiology and Biotechnology*. 1989;5:217-222

[25] Anosike EO, Egwuatu CK. Biochemical changes during the fermentation of castor oil (*Ricinus communis*) seeds for use as a seasoning agent. *Plant Foods for Human Nutrition*. 1981;30:181-184

[26] Odunfa SA. African fermented foods. In: Wood BJB, editor. *Microbiology of Fermented Foods*. Vol. 2. London/New York, NY: Elsevier Applied Science; 1985. pp. 155-191

[27] Barber L, Achinewhu SC, Ibiama EM. The microbiology of ogiri production from castor seed (*Ricinus communis*). *Food Microbiology*. 1988;5:177-182

[28] Sanni AI, Ogbonna DN. The production of owoh—A Nigerian fermented seasoning agent from cotton seed (*Gossypium hirsitium*). *Food Microbiology*. 1991;8:223-229

[29] Sanni AI, Ogbonna DN. Biochemical studies on owoh—A Nigerian fermented soup condiment from cotton seed. *Food Microbiology*. 1992;9:177-183

[30] Sanni AI, Onilude AA, Fadahunsi IF, Ogubanwo ST, Afolabi RO. Selection of starter cultures for the production

of ugba, a fermented soup condiment. European Food Research Technology. 2002;**215**:176-180. DOI: 10.1007/s00217-002-0520-3

[31] Achi OK. Microorganisms associated with natural fermentation of Prosopis Africana seed for the production of okpehe. Plant Foods for Human Nutrition. 1992;**42**:304-309

[32] Odibo FJC, Ugwu DA, Ekeoha DC. Microorganisms associated with the fermentation of Prosopis seeds for ogiri-okpei production. Journal of Food Science Technology. 1992;**29**:306-307

[33] Sanni AI. Biochemical changes during production of okpehe—A Nigerian fermented food condiment. Chemical Microbiological Technology Lebensmittel. 1993;**15**:97-100

[34] Gutierrez ML, Maizi P, Nago CM, Hounhouigan J. Production et commercialisation de l'Afitin dans la région d'Abomey-Bohicon au Bénin. CERN, CNEARC, CIRAD Librairie du CIRAD; 2000. 124 p

[35] Agbobatinkpo PB, Dabade SD, Laleye F, Akissoe N, Azokpota P, Hounhouigan JD. Softening effect of Ikpiru and Yanyanku, two traditional additives used for the fermentation of African Locust Bean (*Parkia biglobosa*) seeds in Benin. International Journal of Biology and Chemical Science. 2012;**6**(3):1281-1292

[36] Ogueke CC, Anosike F, Owuamanam CI. Prediction of amino nitrogen during ugba (*Pentaclethra macrophylla*) production under different fermentation variables: A response surface approach. Nigerian Food Journal. 2015;**33**(1):61-66

[37] Njoku HO, Okemadu CP. Biochemical changes during the natural fermentation of the African oil bean for the production of ugba. Journal of Food Science and Agriculture.

1989;**49**:457-465. DOI: 10.1002/jsfa.2740490408

[38] Obeta JAN. A note on the microorganisms associated with the fermentation of seeds of African oil bean (*Pentaclethra macrophylla*). Journal of Applied Biotechnology. 1983;**54**:433-435

[39] Odunfa SA, Oyewole OB. Identification of *Bacillus* species from iru. a fermented African locust bean product. Journal of Basic Microbiology. 1986;**26**:101-108. DOI: 10.1002/jobm.3620260212

[40] Ghosh D, Chattora DK, Chattopadhyay P. Studies on changes in microstructure and proteolysis in cow and soy milk curd during fermentation using lactic cultures for improving protein bioavailability. Journal of Food Science Technology. 2013;**50**:979-985

[41] Ogueke CC, Aririatu LE. Microbial and organoleptic changes associated with ugba stored at ambient temperature. Nigerian Food Journal. 2004;**22**:133-140

[42] Aderibigbe EY, Schink B, Odunfa SA. Extracellular proteinases of *Bacillus* sp isolated from African locust bean, iru. Food Microbiology. 1990;**7**:281-293. DOI: 10.1016/0740-0020(90)90033-E

[43] Oguntinyinbo FA, Sanni AI, Franz CMAP, Holzapfel WH. *In-vitro* fermentation studies for selection and evaluation of *Bacillus* strains as starter cultures for production of okpehe, a traditional African fermented condiment. International Journal of Food Microbiology. 2007;**113**:208-218

[44] Isu NR, Njoku HO. An evaluation of the microflora associated with fermented African oil bean (*Pentaclethra macrophylla* Benth) seeds during ugba production. Plant Foods for Human Nutrition. 1997;**51**:145-157

- [45] Odunfa SA. Dawadawa. In: Raddy NR, Pierson MD, Salunkhe DK, editors. Legume Based Fermented Foods. Boca Raton, FL: CRC Press; 1986. pp. 173-189
- [46] Wang J, Fung DY. Alkaline fermented foods. A review with emphasis on pidan fermentation. *Critical Review in Microbiology*. 1996;**22**:101-138
- [47] Eze VC, Onwuakor CE, Ukeka E. Proximate composition, biochemical and microbiological changes associated with fermenting African oil bean (*Pentaclethra macrophylla* Benth) seeds. *American Journal of Microbiology*. 2014;**2**:674-681
- [48] Ogbulie TE, Nsofor CA, Nze FC. Bacteria species associated with ugba (*Pentaclethra macrophylla* Benth) produced traditionally and in the laboratory and the effect of fermentation on product of oligosaccharide hydrolysis. *Nigerian Food Journal*. 2014;**32**(2):73-80
- [49] Anyanwu NCJ, Okonkwo OL, Iheanacho CN, Ajide B. Microbiological and nutritional qualities of fermented ugba (*Pentaclethra macrophylla* Benth) sold in Mbaise, Imo state, Nigeria. *Annual Research Review in Biology*. 2016;**9**(4):1-8. DOI: 10.9734/ARRB/2016/23610
- [50] Odunfa SA. Biochemical changes in fermenting African locust bean (*Parkia biglobosa*) during iru fermentation. *Journal of Food Technology*. 1985;**20**:295-303. DOI: 10.1111/j.1365-2621.1985.tb00379.
- [51] Odunfa SA, Komolafe OB. Nutritional characteristics of *Staphylococcus* species from fermenting African locust bean (*Parkia biglobosa*). *Die Nahrung*. 1989;**33**:607-615
- [52] Sarkar PK, Morrison E, Tinggi U, Somerset SM, Craven GS. B-group vitamin and mineral contents of soybeans during kinema production. *Journal of Science Food and Agriculture*. 1998;**78**:498-502
- [53] Aderibigbe EY, Odunfa SA. Growth and extracellular enzyme production by strains of *Bacillus* species isolated from fermenting African locust bean, iru. *Journal of Applied Bacteriology*. 1990;**69**:662-671. DOI: 10.1111/j.1365-2672.1990.tb01560
- [54] Mulyowidarso RK, Fleet GH, Buckle KA. The microbial ecology of soybean soaking for tempe production. *International Journal of Food Microbiology*. 1989;**8**:35-46. DOI: 10.1016/0168-1605(89)90078-0
- [55] Davey HM, Kell DB. Flow cytometry and cell sorting of heterogeneous microbial populations: The importance of single cell analyses. *Microbiological Review*. 1996;**60**:641-696
- [56] Gunasekera TS, Dorasch MR, Slado MB, Veal DA. Specific detection of *Pseudomonas* spp in milk by fluorescent in situ hybridization using ribosomal RNA directed probes. *Journal of Applied Microbiology*. 2003;**94**:936-945
- [57] Okorie PC. Studies on the processing methods and safety of ugba: An indigenous Nigerian fermented condiment [PhD thesis]. Ojo, Lagos, Nigeria: Lagos State University; 2018
- [58] Anukam KC, Reid G. African traditional fermented foods and probiotics. *Journal of Medicine and Food*. 2009;**12**:1177-1184
- [59] Chelule PK, Mbongwa HP, Carries S, Gqaleni N. Lactic acid fermentation improves the quality of mahewu, a traditional South African maize-based porridge. *Food Chemistry*. 2010;**122**(3):656-661
- [60] Charles MAP, Franz M, Huch JMM, Hikmate A, Nabil B, Gregor R, et al. African fermented foods and

- probiotics. International Journal of Food Microbiology. 2014;**6**:248-256
- [61] Chen P, Li C, Li X, Li J, Chu R, Wang H. Higher dietary folate intake reduces the breast cancer risk: A systematic review and meta-analysis. British Journal of Cancer. 2014;**110**:2327-2338
- [62] Reid G, Nduti N, Sybesma W, Kort R, Kollmann TR, Adam R, et al. Harnessing microbiome and probiotic research in sub-Saharan Africa: Recommendations from an African Workshop. Microbiome. 2014;**2**:12
- [63] Chung SK, Mee SL, Se IO, Sang CP. Discovery of novel sources of vitamin B12 in traditional Korean foods from nutritional surveys of centenarians. Current Gerontology Geriatrics Research. 2010;**2010**(3):374897. DOI: 10.1155/2010/374897
- [64] Makanjuola OM, Ajayi A. Effect of natural fermentation on the nutritive value and mineral composition of African locust beans. Pakistan Journal of Nutrition. 2012;**11**(1):11-13
- [65] Tofalo R, Schirone M, Perpetuini G, Angelozzi G, Suzzi G, Corsetti A. Microbiological and chemical profiles of naturally fermented table olives and brines from different Italian cultivars. International Journal of Biotechnology. 2012;**102**:121-131. DOI: 10.1007/s10482-012-9719-x
- [66] Daeschel MA, Anderson RE, Fleming HP. Microbial ecology of fermenting plant materials. FEMS Microbiological Review. 1987;**46**:357-367. DOI: 10.1111/j.1574-6968.1987.tb02472
- [67] Ouba LII, Diawara B, Moa-Awua WK, Traore AS, Moller PL. Genotyping of starter cultures of *Bacillus subtilis* and *Bacillus pumilus* for fermentation of African locust bean (*Parkia biglobosa*) to produce Soumbala. International Journal of Food Microbiology. 2004;**90**:197-205
- [68] Ling J, Wu Q, Xu Y, Fan W. Interactions between *Bacillus licheniformis* and *Saccharomyces cerevisiae* in the fermentation of soy-sauce flavor liquor. Microbiology China. 2013;**40**:2014-2021
- [69] Adams MR. Topical aspect of fermented foods. Trends in Food Science & Technology. 1990;**1**:141-144. DOI: 10.1016/0924-2244(90)90111-B
- [70] Savadogo A, Tapi A, Chollet M, Wathelet B, Traoré AS, Jacques PH. Identification of surfactin producing strains in Soumbala and Bikalga fermented condiments using polymerase chain reaction and matrix assisted laser desorption/ionization-mass spectrometry methods. International Journal of Food Microbiology. 2011;**151**:299-306. DOI: 10.1016/j.ijfoodmicro.2011.09.022
- [71] Oguntoyinbo FA. Safety challenges associated with traditional foods of West Africa. Food Review International. 2014;**30**:338-358. DOI: 10.1080/87559129.2014.940086
- [72] Mbadiwe EI. Nutritional evaluation of seeds of *Pentaclethra macrophylla*. Plant Foods for Human Nutrition. 1978;**28**:261-269
- [73] Mba AV, Njike MC, Oyenuga VA. Proximate chemical composition and amino acid content of Nigerian oil seeds. Journal of Food Science and Agriculture. 1974;**25**:1547-1553. DOI: 10.1002/jsfa.2740251216
- [74] Odoemelam SA. Proximate composition and selected physicochemical properties of the seeds of African oil bean (*Pentaclethra macrophylla*). Pakistan Journal of Nutrition. 2005;**4**:382-383. DOI: 10.3923/pjn.2005.382.383

- [75] Ogueke CC, Nwosu JN, Owuamanam CI, Iwouno JN. Ugba, the fermented African oil bean seeds; its production, chemical composition, preservation, safety and health benefits. *Pakistan Journal of Biological Science*. 2010;**13**:489-496
- [76] Yagoub AG, Mohamed BE, Ahmed AH, El Tinay AH. Study on Furundu, a traditional Sudanese fermented roselle (*Hibiscus sabdariffa*) seed: Effect on in vitro protein digestibility, chemical composition and functional properties of the total proteins. *Journal of Agriculture and Food Chemistry*. 2004;**52**(20):6143-6150
- [77] Sahlin P. Fermentation as a method of food processing, production of organic acid, pH development and microbial growth in fermenting cereals [licenciate thesis]. Lund, Scania, Sweden: Lund Institute of Technology, Lund University; 1999
- [78] Niba LL. The relevance of biotechnology in the development of functional foods for improved nutritional and health quality in developing countries. *African Journal of Biotechnology*. 2003;**2**:631-635
- [79] Kiers JL, Van Laeken AEA, Rombouts FM, Nout MJR. In vitro digestibility of *Bacillus* fermented soybean. *International Journal of Food Microbiology*. 2000;**60**:163-169
- [80] Oboh G. Nutrient and anti-nutritional composition of condiments produced from some fermented underutilized legumes. *Journal of Food Biochemistry*. 2006;**30**:579-588
- [81] Ng'ong'ola-Manani TA, Østlie HM, Mwangwela AM, Wicklund T. Metabolite changes during natural and lactic acid bacteria fermentations in pastes of soybeans and soybean–maize blends. *Food Science and Nutrition*. 2014;**2**(6):768-785
- [82] Eka OU. Effect of fermentation on the nutrient status of locust beans. *Food Chemistry*. 1980;**5**:305-308
- [83] Steinkraus KH. African alkaline fermented foods and their relation to similar foods in other parts of the world. In: Wesby A, Reilly PJA, editors. *Proceedings of a Regional Workshop on Traditional African Foods – Quality and Nutrition*. Stockholm, Sweden: International Foundation for Science; 1991. pp. 87-92
- [84] Addy EOH, Salami LI, Igboeli LC, Remawa HS. Effect of processing on nutrient composition and anti-nutritive substances of African locust bean (*Parkia filicoidea*) and Baobab seed (*Adansonia digitata*). *Plant Foods for Human Nutrition*. 1995;**48**:113-117
- [85] Leejeerajumnean AA, Duckham SC, Owens JD, Ames JM. Volatile compounds of *Bacillus* fermented soybeans. *Journal of Science, Food and Agriculture*. 2001;**81**:525-529
- [86] Ogbadu CO, Okagbue RN, Ahmed AA. Glutamic acid production by *Bacillus* isolates from Nigerian fermented vegetable proteins. *World Journal of Microbiology and Biotechnology*. 1990;**6**:377-382
- [87] Beaumont M. Flavouring composition prepared by fermentation with *Bacillus* species. *International Journal of Food Microbiology*. 2002;**75**:189-196
- [88] Adebayo-Tayo B, Elelu T, Akinola G, Oyinloye I. Screening and production of mannanase by *Bacillus* strains isolated from fermented food condiments. *Food Biotechnology*. 2013;**13**:53-62, in Roman
- [89] Odunfa SA. Carbohydrate changes in fermenting African locust bean (*Parkia filicoidea*) during iru preparation. *Plant Foods for Human Nutrition*. 1983;**32**:3-10

- [90] Ikenebomeh MJ. The solid substrate fermentation of African locust bean (*Parkia filicodex*) [PhD thesis]. Montreal, Quebec, Canada: McGill University; 1982
- [91] Odunfa SA, Adesomoju AA. Effects of fermentation on the free fatty acids of African locust bean during iru production. *Journal of Plant Foods*. 1985;**6**:111-115
- [92] Achjnewhu SC, Ryley J. Effects of fermentation on thiamin, riboflavin and niacin content of melon seed (*Citrullus vulgaris*) and the African oil bean seed (*Pentaclethra macrophylla*). *Food Chemistry*. 1987;**20**:243-252
- [93] Achinewhu SC. The effect of fermentation on carbohydrate and fatty acid composition of the African oil bean (*Pentaclethra macrophylla*) seed. *Food Chemistry*. 1986;**19**:105-116. DOI: 10.1016/0308-8146(86)90104-4
- [94] Achinewhu SC. Some biochemical and nutritional changes during the fermentation of fluted pumpkin (*Telferia occidentale*). *Plant Foods for Human Nutrition*. 1986;**36**:97-106
- [95] Ogbonna DN, Sokari TG, Achinewhu SC. Development of owoh-type product from African yam bean (*Sphenostylis stenocarpa*) seeds by solid state fermentation. *Plant Foods for Human Nutrition*. 2001;**56**:183-194. DOI: 10.1023/A:1011185513717
- [96] Nwokeleme CO, Ugwuanyi JO. Evolution of volatile flavour compounds during fermentation of African oil bean (*Pentaclethra macrophylla* Benth) seed for “ugba” production. *International Journal of Food Science*. 2015;**2015**:706328. DOI: 10.1155/2015/706328
- [97] Odunfa SA, Oyeyiola GF. Microbiological study of the fermentation of ugba: A Nigerian indigenous fermented food flavor. *Journal of Plant Foods*. 1985;**6**:155-163
- [98] Omafuvbe BO, Olumuyiwa SF, Osuntogun B, Adewusi SRA. Chemical and biochemical changes in African locust bean (*Parkia biglobosa*) and melon (*Citrullus vulgaris*) seeds during fermentation to condiments. *Pakistan Journal of Nutrition*. 2004;**3**(3):140-145. DOI: 10.3923/pjn.2004.140.145
- [99] Omafuvbe BO, Abiose SH, Shonukan OO. Fermentation of soybean (*Glycine max*) for soy-daddawa production by starter cultures of *Bacillus*. *Food Microbiology*. 2003;**19**:561-566