Fermentation of Traditional African Cassava Based Foods: Microorganisms Role in Nutritional and Safety Value

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Authors’ contributions

This work was carried out in collaboration between both authors. Author NHH perceive the idea and designed the study wrote the literature on cassava based foods and conclusions to the first draft of the manuscript. Author BC wrote nutritional safety value of cassava and formatted the draft and also chooses the journal for submission. Both authors read, reviewed and approved the final manuscript.

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ABSTRACT

Cassava is a drought-tolerant, crop grown in tropical and subtropical areas. For decades the communities of Africa have developed their process to ferment and use cassava. Ikivunde, Inyang, kivunde, Mokopa, Chikwangue, Meduame-M-bong, Cossette, Gari, Attié, and Agbelima are the main indigenous fermented cassava based food products from east, west and central Africa respectively. Lactic acid bacteria, yeast, and molds are the main microorganism involve in the fermentation of cassava-based food products and contribute to the production of biochemical compounds such as folates, several organic acids, volatiles organics compound, and others compounds. Role of different microorganisms in food preservation, increase in protein content, aroma, flavor enhancement, decreases in anti-nutrients, and cyanogen reduction as the elevated impact of the fermentation process.

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1. INTRODUCTION

Cassava (*Manihot esculent Crantz*) is one of the important root crops known and used as food in many countries of Africa, Latin America, and some Asian countries [1], [2]. Botanically it is a member of the family Euphorbiaceae and classified as *Manihot esculanta* Crantz. Blench [3] explained that cassava is a food plant brought from the New World to Tropical Africa where it does now establish. The utilization of cassava as food for America’s societies began around the 18th century before Christ, now grown widely in several parts of the world especially in the tropical regions, and constitutes a significant proportion of the diet of the population.

In many parts of Western and Central Africa, cassava is being processed into many traditional staple foods. Tefera et al. [4] explained in his report that about 70 percent of cassava production in Africa is used for human consumption. It is playing an important role in solving food insecurity problems in many regions because it has a comparatively high biological efficiency of food energy production. Cassava roots are rich in carbohydrates but have low protein content and potentially toxic due to the presence of cyanogenic glycoside [5], [6]. These glucosides can give rise fatalities if roots are consumed unprocessed. In most African countries' cassava may be processed by boiling, roasting, drying, leaching with cold water, or by fermentation. The boiling or drying process alone may not detoxify cyanogenic glycoside. However, fermentation is a part of the process in which it transforms into a valuable product [7]. During fermentation, roots are softened and there is the disintegration of tissue structure which results in contact of linamarin with linamerase which is located in the cell wall, and subsequent hydrolysis to glucose and cyanohydrins which are easily broken to ketone and HCN [8]. According to Flibert et al. [9] fermentation improves food preservation, nutritional value, energy density, and organoleptic characteristics of foods.

Even though cassava fermented foods have a long history in Africa there is no writing culture in most African countries. Some studies have been conducted on cassava fermented food in Africa, showing some aspects of these foods. This review aims to establish the relationship between cassava fermented food in Africa and microorganism’s role to their nutritional and safety value such as protein enhancement, cyanide reduction, anti-nutrient reduction, and palatability.

2. CASSAVA

Cassava is a major staple food in the developing world providing a basic diet for over half a billion people. It is one of the most drought-tolerant crops capable of growing on marginal soils [2]. There are two major types of cassava namely, the Sweet variety which is higher in sugars and contains fewer cyanide compounds, while the bitter variety contains higher quantities of cyanide compounds (higher than 50 parts per million) [10].

Aloys and Zou [11] explained that cassava has nearly twice the calories than that of potatoes and perhaps one of the highest value calorie food for any tropical starch-rich tubers and roots. The calorie value mainly comes from sucrose which accounts for more than 69% of total sugars. Cassava carries some of the valuable vitamins such as folates, thiamin, pyridoxine, riboflavin, and pantothenic acid [12]. It is one of the chief sources of some essential minerals like zinc, magnesium, copper, iron, manganese and potassium [13]. Cassava is very low in protein than in cereals and pulses and contains toxic cyanogenic glucoside as well as antinutrients like phytate and tannin [14].

2.1 Cassava Fermented Foods in Africa

2.1.1 Pupuru

Pupuru is a traditionally fermented cassava-based food product in southwestern and West African countries [15]. Ray and Sivakumar [16], explained the ways of preparation as peeling of tubers, steeping of peeled tubers in steam water, fermentation of tubers for four to six days, draining of water and grounding between the two palms of the hand and molding into balls with the use of mixed cultures of microorganisms such as *Lactobacillus Plantarum*, *Lactobacillus fermatur*, *Cryptococcus humicola*, *Leuconostoc spp.*, *Corynebacterium pyrogenes* and *Saccharomyces cerevisiae* [17]. After drying dirty outer, most of the balls are scraped off and the inner portion is milled lightly to form a powder and finally eaten with vegetable soup.
2.1.2 Inyanga and Ikivunde

Inyanga is produced by molds fermentation, similar to mokopa and consumed in Burundi. Preparation of Inyange is mentioned somewhere else [11]. Cassava roots are peeled, washed, cut into pieces, and sun-dried for a day. Then heaped together and covered by plantain leaves and left to ferment for five days. At the end of the fermentation, the pieces become soft and covered with microorganisms such as Aspergillus oryzae, Aspergillus fumigatus, Penicillium cryogenic, Rhizopus stolonifera and Mucor spp. [11]. They are then scraped, dried, and pounded in a wooden mortar with a pestle and then sieved to get slightly dark colored flour and made into Inyange (Fig. 1). It is usually eaten with cassava leaves sauce. This is maybe the reason why it is nutritionally higher than ikivunde, but it holds higher anti-nutrients like phytate and tannin [18], [19]. Whereas, in Ikivunde cassava roots used for preparation are sometimes not peeled. The roots of cassava are soaked in a stream or stationary water for at least three days to allow them to ferment until they become soft [11], [9].

2.1.3 Attieke

Attieke is another cassava-based food in Burkina Faso, Béni, Togo, Mali, Senegal [9], [20]. Regarding the process of production, roots of cassava are peeled, cut into pieces, washed three times with fresh water, milled. Assanvo et al. [21], explained that during milling, the cassava product is mixed with about 5%-10% of traditionally prepared inoculums, 10% of water, and about 0.1% palm oil. The inoculated pulp is fermented overnight and pressed for several hours. The pressed pulp is taken from the bags and sieved to obtain granules that are sundried and then cleaned to remove fibers and leftovers. Finally, granules are steamed to produce attieke [22].

2.1.4 Garri

Gari is made from the bitter variety of cassava tubers (Manihot utifissima Pohl; Manihot esculenta Crantz) [23]. It is popular in Nigeria, Republic of Benin, Togo, Ghana, Liberia, and Sierra Leone [24]. The procedure of garri preparation is peeling of cassava roots, and grating into fine pulp. The grated pulp is compressed with heavy stones or wood in Hessian sacks. The pulp is left to ferment for up to four days. The fermented pulp is sifted using handmade fabrics and the finer grains are toasted on an open fire and sifted again. Palm oil could be added and finally, the product is packaged [25].
2.1.5 Fufu

Fufu is widely consumed in eastern Nigeria [26]. Similar to other cassava fermented food, the tubers are washed, peeled, cut into thick chunks, and steeped in water in earthenware pots to ferment for four to five days. The tubers are disintegrated in clean water, sieved, and allowed to settle for decantation of water. The sediment can be consumed after hydrothermal gelatinization forming a stiff dough [13].

2.1.6 Mokopa

Mokopa is commonly utilized in Uganda, Tanzania, Rwanda, and the Democratic Republic of Congo [16]. It is prepared by peeling and slicing of cassava roots. Then surface dried for one to two hours and covered with straw or leaves. The roots are given into three or four days fermentation until become moldy. The fermented and moldy roots are again sun-dried until the molds have been scraped off. Then finally, milled into flour, mokopa.

2.1.7 Meduame-M-bong

Meduame-M-bong originated from Cameroon. As Bull [27], mentioned steps of Meduame-M-bong preparation, cassava roots are washed and cut into large pieces. The cut roots are then boiled (30 min to 1 hr). After discarding the water, cassava roots are again cut into small pieces and soaked in running water (for 12 to 36 hours). Finally, it can be eaten with meat, fish, groundnuts, green leaves.

2.1.8 Chikwangue

Chickwangue is the main cassava processed food in the Democratic Republic of Congo. Nowadays, it is also prepared and appreciated in many central African countries like Cameroon, Gabon, Congo Brazaville, Central African Republic [26].

This cassava-based food product is prepared as follows. The cassava roots are peeled and the rind is removed, and then soaked in water (for three days up to two weeks). The fibers are removed from the pulp, which is covered with leaves and pressed using heavy objects to drain off excess liquid. The pulp is then grounded and sieved. The fine pulp is steamed in pots and utilized [28].

2.1.9 Injera

Injera is a common staple food in Ethiopia and Eritrea [29]. It is prepared from different types of cereals such as teff (Eragrostis tef), wheat, barley, sorghum, maize, or a combination of this cereal with cassava [10].

The process of production is that cassava root is first washed, peeled, cut in to pieces, oven dried at 65°C for 24 hours, pounded into flour and mixed with teff. This is then, fermented (24 to 72 hours) [14] and subsequently thinned to a batter. The only required ingredients are mixed flour of cassava, teff, and water. The batter is then poured on to a hot griddle in a thin layer to cook, developing its color, flavor, and texture (Fig. 2).

3. MICROORGANISMS ASSOCIATED WITH FERMENTATION IN CASSAVA BASED FOOD IN AFRICA

Microorganisms of various groups appear to be involved in the fermentation of cassava-based foods indigenous to different parts of the world. The sources of these microorganisms are usually raw ingredients and the traditional utensils used for the processes. Initiation of fermentation processes in most traditional fermented foods may be undertaken by different groups of microorganisms as far as sufficient fermentable sugars are available in the substrate [20]. Some genera/species of microorganisms have been reported concerning various cassava fermented foods in Africa (Table 1).

3.1 Cassava Fermentation Process

The cassava fermentation process varies from one region to another. Many fermentation techniques in cassava processing are broadly categorized into solid-state and submerged fermentation [11].

In solid-state fermentation, cassava root is not soaked in water. Gari production explained by [24], Attieke production by [21], and Injera production by [14] are produced by solid-state fermentation processes. Whereas in submerged fermentation processes, cassava roots are soaked in water for the duration of fermentation [11]. Fufu production as reported by [13], Pupuru production by [31], and Chikwangue production by [28] are submerged fermentation process.
Table 1. The main microorganisms associated with fermentation in some cassava-based food

<table>
<thead>
<tr>
<th>Food product</th>
<th>LAB and other bacteria</th>
<th>Yeasts</th>
<th>Molds</th>
<th>Countries of production</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ikivunde</td>
<td>Lactobacillus plantarum; Lactobacillus brevis; Lactobacillus fermentum; Leuconostoc mesenteroides</td>
<td>Geotrichum candidum</td>
<td>Burundi, Rwanda</td>
<td>[11]</td>
<td></td>
</tr>
<tr>
<td>Chikwangue</td>
<td>Lactococcus lactis; Leuconostoc sp; Lactococcus Plantarum; Lactobacillus Plantarum; Clostridium spp.</td>
<td></td>
<td></td>
<td>Main central Africa countries</td>
<td>[26]</td>
</tr>
<tr>
<td>Gari</td>
<td>Bacillus subtilis; Bacillus coagulans; Bacillus species; Lactobacillus plantarum; Lactobacillus fermentum; Lactobacillus brevis; Lactobacillus pentosus; Lactobacillus acidophilus; Lactobacillus sp; Leuconostoc Alcaligenes; Leuconostoc fallax; Corynebacterium manihot; Corone bacterium species, Pseudomonas mesenteroides, Weissella para mesenteroides; Corynebacterium; Bacteroides sp; Actinomyces sp</td>
<td>Saccharomyces fragilis; Saccharomyces cerevisiae; Saccharomyces rouxi; Geotrichum candidum</td>
<td>West, Central, and East Africa countries</td>
<td>[25], [32]</td>
<td></td>
</tr>
<tr>
<td>Attieke</td>
<td>Lactobacillus plantarum; Lactobacillus; fermentum; Lactobacillus cellobiosae; Lactobacillus brevis; Leuconostoc mesenteroides; Lactobacillus sp; Bacillus sp, Bacillus sphaericus; Bacillus brevis, Bacillus; coagulants, Enterococcus faecium</td>
<td>Candida krusei; Kloeckera japonica; Saccharomyces cerevisiae</td>
<td></td>
<td>Bénin, Mali, Sénégal, Togo</td>
<td>[21], [20]</td>
</tr>
<tr>
<td>Inyanga</td>
<td></td>
<td></td>
<td></td>
<td>Burundi</td>
<td>[11]</td>
</tr>
<tr>
<td>Pupuru</td>
<td>Lactobacillus plantarum</td>
<td>Geotrichum capitatum</td>
<td>South western and west Africa</td>
<td>[15], [16]</td>
<td></td>
</tr>
<tr>
<td>Fufu</td>
<td>Lactobacillus cellobiosus; L. burgaricus, L. brevis, L. plantarum</td>
<td>Candida famata</td>
<td>Nigeria</td>
<td>[13]</td>
<td></td>
</tr>
</tbody>
</table>
4. ROLE AND FUNCTION OF FERMENTATION ON CASSAVA BASED FOOD

4.1 Aroma and Flavor Change

Fermentation modifies the unfermented food in diverse ways, resulting in new sensory properties in the fermented product. The change in aroma and flavor of food depends on the balance of volatile compounds (aldehyde, organic acids, alcohol, alkanes, terpenes, ketones, nitrogen compounds), produced during fermentation [4]. Hasan et al. [33] also reported that volatile compounds increased in fermented rice due to fermentation by *Saccharomyces cerevisiae* and some lactic acid bacteria. The number of volatile compounds such as organic acid, aldehyde, alcohols alkanes and ketone produced during fermentation produced depends on the involved microorganisms in the fermentation as described by [29], [30].

4.2 Food Preservation

During the cassava fermentation process, some biochemical compounds such as hydrogen peroxide can be inhibitory to some microorganisms [11], whereas carbon dioxide, formed during fermentation, may directly create an anaerobic environment and is toxic to some aerobic food microorganisms through its action on cell membranes [8]. Gunawan et al. [34] showed that the optimum pH condition of *Lactobacillus plantarum* and *Saccharomyces cerevisiae* was 3.5-4.5 and 3.5-6.0 respectively. The lowering of pH below 4 by organic acid production inhibits the growth of pathogenic microorganisms [29], hence prolong the shelf-life of food.

4.3 Antinutrient Reduction

Antinutrient compounds, such as phytates are abundant in cassava (624 mg/100 g in roots) [35].
and can bind cations such as magnesium, calcium, iron, zinc, and molybdenum. Therefore, interfering with mineral absorption and utilization [36]. Phytic acid may also bind proteins preventing their complete enzymatic digestion.

In a study by Taiwo [29] fermenting cassava, reduced phytic acid from 6.12 to 0.66g/kg in ikivunde and from 6.12 to 1.44g/kg in inyanga. The loss of phytate during fermentation is due to the enzymes phytase and phosphatase that hydrolyze phytate into inositol and orthophosphate. As indicated by Marfo et al. [35] reduction of phytate is more significant after 24 to 48h of fermentation and decreases after 48h, after 48 hours there will be a lowering of pH that slows down the breakdown of phytate.

The other important anti-nutrient in cassava root is tannin. Tannins affect the nutritive value of food products by forming a complex with protein thereby inhibiting digestion and absorption. Taiwo [29] showed that 4.2g/kg of tannin before fermentation reduced to 0.63 and 2.3g/kg in ikuvunde and inyanga respectively at the end of the fermentation period.

4.4 Cyanide Reduction

Cassava contains cyanogenic glucoside in the form of linamarin (93%) and lotaustralin (7%) [29]. This value is higher compare to FAO/WHO [37] recommendation which is $<10$mg cyanide equivalents/kg DM to prevent acute toxicity to humans. The residual cyanogen content in processed cassava such as glucoside, cyanohydrin, or free cyanide is equally toxic as their parent compounds in uncooked food [29].

Fermentation may reduce the cyanide content of cassava, as indicated by [4], [30]. The free cyanide level dropped from 197.19 mg/g of non-fermented cassava to 4.09 mg/g after 24hrs of fermentation with *L. plantarum* at inoculum level of 0.5 ml. Kobawila et al. [38] also reported a drastic reduction of cyanide content from 1158 to 339.6 mg/kg after 48 h of fermentation, which corresponds to $70.67\%$ reduction. According to Niguse et al. [30], *Lactobacillus plantarum* and *Lactobacillus coryneformis* appear to play important roles in cyanide detoxification, as already reported [2], [4]. This indicates that it is possible significantly reduce the residual HCN content of cassava through fermentation using *Lactobacillus coryneformis* and *Lactobacillus plantarum*. The reduction in cyanide content could be attributed to the ability of the inoculated microorganisms (*Lactobacillus plantarum* and *Lactobacillus coryneformis*) to produce linamarase which can hydrolyze linamarin and result in degradation of cyanogenic glycosides in to HCN which is subsequently converted to formamide which is used as both a nitrogen and carbon source [38], [7], [30].

4.5 Protein Enrichment

Even though cassava root is a major source of carbohydrate it is low in protein content. The approach that may increase the protein content of ready-to-eat products is the part of post-harvest processing techniques [39], [30]. As mentioned in finding by Tefera et al. [4], the mean crude protein content of fermented cassava increased from 0.74% to 4.58 % (3 fold increment) after 48 hrs of fermentation. Similarly, crude protein content in cassava-teff flour fermented with 1.5 ml inoculums of *Saccharomyces cerevisiae* (13.31±0.02%) was higher than that of *Lactobacillus plantarum* and *Lactobacillus coryneformis* [30]. Boonnop et al. [40], also demonstrated that fermentation of cassava chips with *Saccharomyces cerevisiae* could increase crude protein content from 2% to 32.4%. The increase in the crude protein content may be due to the secretion of some extracellular enzymes and the effect of microbial cell growth [41].

5. PROSPECTS OF AFRICAN CASSAVA FERMENTED FOOD

The traditional African cassava-based foods are increasingly attracting the attention of scientists and policymakers as a vital part of food security strategies. Cassava-based food products could become even more important in feeding additional segments of the increasing African population in the future. Fermentation may be one of the most simple and economical way of improving cereal nutritional value, sensory properties, and functional qualities available at the local community level. The traditional indigenous technologies need to be improved through research to advance its potential for food safety and nutritional value [42]. New opportunities provided by biotechnology are opening up possibilities to improve or upgrade traditional small-scale processes and make better use of agricultural products. There is the prospect of genetically improving the nutritional quality of cassava through the use of protein enriching microorganisms. Cassava fermenting microorganisms and their enzymes could be
engineered to carry out specific desired functions or improved through modern biotechnological studies [21].

6. CONCLUSION

African communities have developed several processes for cassava-based food production. There are differences in the production of cassava-based food from region to region and also diversity in associate microorganisms in cassava fermentation. These microorganisms are involved in cassava fermented food preservation, flavor and aroma development, protein enrichment, antinutrient, and cyanide content reduction. In the future to keep its quality it is important standardizing the methods of cassava fermentation processes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES


Bala, Emele C. Protein enrichment of cassava with yeast for gari production. BTALJ. 2012;4:120-126.