Hindawi
Journal of Food Quality
Volume 2023, Article ID 7238309, 17 pages
https://doi.org/10.1155/2023/7238309

Review Article

Gari, a Cassava (*Manihot esculenta* Crantz) Derived Product: Review on Its Quality and Their Determinants

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Received 30 October 2022; Revised 3 January 2023; Accepted 4 January 2023; Published 2 February 2023

Academic Editor: Sapna Langyan

Gari or Tapioca or Rale, a roasted yellow or white granulated product found on market stalls of sub-Saharan African countries (SSA), is made from cassava through the successive steps of peeling, grating, fermentation and/or dewatering, and roasting, and is the most consumed cassava derived product. The strengthening of its value chain can contribute to food sovereignty as well as improve the lifestyle of many urban and rural dwellers of SSA. This strengthening of the Gari value chain requires the identification of its weaknesses and proposes research and development initiatives that will increase its contribution to food sovereignty. The present review aimed thus at achieving this goal through a review of up to now knowledge on (i) end-users preferences for cassava and Gari in SSA; (ii) the quality (nutritional and microbiological) of Gari found on market stalls; (iii) processing and raw material determinant of this quality; (iv) research and development trials which have been done to improve the nutritional quality of Gari. It also proposes some scientific challenges to overcome in SSA in order to have all the ingredients for success.

1. Introduction

Africa is both one of the poorest regions of the world and the most urbanized one, and by 2040, half of its population will live in urban areas [1, 2]. Africa is organized into 5 subregions East Africa, Central Africa, West Africa, Southern Africa, and Northern Africa. Out of northern Africa, all the remaining subregions constitute what is known as sub-Saharan Africa (SSA). SSA is the poorest region of the world, with 34 out of 49 countries found in this region belonging to the least developed countries (LDC), where half of the population lives below the poverty line of 1.25 US dollars [3, 4]. In SSA, starchy commodities are the main staple food and the rural population represents 78% of the poor [5, 6]. 44% of starchy commodities consumed in SSA countries are imported, a situation which worsens the poverty level of the rural population and thus of these countries [5]. Imported starchy products, mainly made of rice and wheat, are more eaten in urban areas where they constitute 40 to 90% of the diet of urban dwellers [5]. Since the production and/or processing of many commodities is done in rural areas and urban areas are important consumption areas [5], improving the performance of the value chain of starchy commodities might decrease the number of poor in both rural and urban areas as well as increases the revenues of these countries. Food sovereignty is thus a way to alleviate poverty in this region. To achieve this goal, the overall value chain of locally produced starchy commodities must be scrutinized and the limitations of their success revealed. Owing to the importance of cassava in the diet of African dwellers, it is a good candidate for this purpose.

Cassava (*Manihot esculenta* Crantz), which is an important staple in Africa, is farmed in 40 countries of the continent and is a major source of calories for 40% of Africa, 60 to 80% of its production is used for food consumption [7]. Its production has tripled in three decades (1975–2005), with Africa being among all the continents, the highest producer (Initiative Régional pour la Production et la Commercialisation du Manioc [8, 9]. In SSA, cassava is processed into many products, amongst which some are specific to some countries (e.g., *Attieke* in Côte d'Ivoire, miondo and Mitumba in Cameroon, and Chikwangue/Bobolo in the Democratic Republic of Congo and Cameroon), while few are common to all the countries where cassava is produced and processed (e.g. Gari/Tapioca and dried cassava chips).

Gari (Figure 1), which is also known and spelled as Garri, Tapioca, or Garry, is the most consumed cassava-derived product in west Africa and many other SSA countries [10–12]. It is a roasted granulated product obtained from cassava through peeling, grating, fermentation, and roasting. It is a convenient food owing to its cheapness, ease of storage, and ease of preparation [10]. Although Gari is found in supermarkets in some countries (e.g. Nigeria, Gabon, and the Democratic Republic of Congo), in many other countries, it is only found in traditional markets [8, 12, 13], and thus contributes to lessening the extent to overall revenues of SSA countries. Due to the importance of traditional products like Gari in the diet of urban dwellers as well as the upcoming importance of supermarkets in urban areas of SSA [5, 6], there is a need to strengthen the value chain of Gari in order to improve its contribution to revenues of SSA countries. Achieving this objective from a food science perspective needs (i) an understanding of end-users needs (cassava farmers, Gari processors, and Gari consumers); (ii) a mastering of the determinants (process and cassava) of Gari quality; and (iii) an understanding of the stability of Gari on storage as well as the nutritional and microbiological quality of Gari found on market stalls. This understanding will allow identifying the actual strengths and weaknesses of the Gari value chain as well as to suggest some research areas which have to be addressed. The present paper aimed at reviewing these aspects.

2. Cassava in SSAImportance, Cultivation, Typology, and Farmers' Preferences

2.1. Importance of Cassava in SSA. Cassava is a plant belonging to the Euphorbiaceae family and originates from South America [9]. In Africa, cassava was initially introduced in the coastal and humid areas of West Africa, and its expansion was done from these areas to dryer ones [14]. Cassava is mainly farmed for its roots, but also its leaves which are consumed in a few SSA countries including Cameroon and Tanzania [15]. The success of cassava cultivation in Africa is due to some of its advantages when compared to many other crops such as the ability to grow in poor soils, resistance to drought, ability to be harvested progressively when on a farm, ability to withstand pests and diseases, the highest quantity of starch produced per hectare, and very low cost required for its cultivation [8, 16–19]. In many SSA countries, it is ranked among the three first commodities (e.g. first in Nigeria, Ghana, and Benin; second in Cameroon) [20–22].

Yellow Gari White Gari

Figure 1: Yellow and white Gari found on market stalls in Cameroon.

2.2. Cassava Cultivation in SSA. In Africa, cassava is farmed on a family scale, mainly by women [8, 23, 24]. Cassava is generally farmed on surface areas varying between 0.25 and 1 hectare [8, 11, 22, 25]. Data concerning cassava root yield and cassava proportions used for home consumption by farmers are scarce. In Cameroon (a country in Central Africa), it has been shown that 65–70% of cassava production is consumed by farmers, and cassava root yield varies between 6 and 14 tons/hectare [22, 23, 26, 27]. This also seems to be the case elsewhere since the average yield is 11 tons/hectare worldwide [9, 14]. The proportion of cassava consumed at the household scale seems to have changed since a recent study has shown that only 20% and 40% of cassava roots produced are consumed in Cameroon and Nigeria, respectively [7], the difference being processed into different cassava-derived products. The root yield is far from those of improved varieties (20–40 t/hectare) [11, 28]. The observed difference might be explained by the fact that cassava is farmed in SSA without fertilizer and its cultivation seems to reduce the productivity of soils where they are farmed [17], especially when not farmed in combination with legumes. Since many cassava roots have high water content [7, 29], in order to express the profitability of processed cassava varieties, cassava root yields should also be expressed using their dry matter content per hectare.

With respect to the chemical composition of cassava, out of the water which represents 60–65% of fresh cassava roots, carbohydrate is the most important nutrient, representing up to 33.6% of the fresh roots [19, 30, 31]. Cassava also contains 2 cyanogenic glucosides, mainly linamarin and lotaustralin, linamarin being the most important [18, 32–34]. The enzymatic hydrolysis of these cyanogenic glucosides leads to the formation of hydrogen cyanide (HCN) through a breakdown of acetone cyanohydrin [32, 35]. HCN is known to be toxic for humans at a dose of 20 mg/kg of flour [35].

2.3. Typology of Farmed Cassava Varieties and Farmers' Preferences in SSA. Cassava varieties which are farmed in SSA are different in terms of the color of their pulp (white and yellow), the color of their second peel (red, white, and yellow), their vegetation cycle (short and long), and their bitterness (bitter and nonbitter/sweet) [24, 28, 29, 32, 36]. Many authors have related cassava bitterness to the quantity of cyanoglucosides components, with those with higher quantities being bitter while those with lessened quantities are sweet [18, 33, 34, 37]. In this respect, according to [8], sweet cassava roots have less than 50 mg of equivalent HCN/Kg of fresh roots, moderately bitter cassava roots have 50–100 mg of equivalent HCN/Kg of fresh roots, and bitter cassava roots have more than 100 mg of equivalent HCN/Kg of fresh roots. In roots, cyanogenic glucosides can be up to 952 mg of equivalent HCN/Kg of fresh roots [32]. This relationship between cassava bitterness and the cyanoglucoside content of cassava roots can be understood because many cassava roots which are bitter also have a higher quantity of these compounds. However, this is not a rule of thumb since some sweet and bitter varieties have the same quantity of these cyanoglucosides [38–40]. To add more complexity to the quantity of cyanoglucoside associated with cassava bitterness, some cassava varieties which allow obtaining bitter roots have an equivalent HCN content varying between 12 and 27 mg of HCN/kg of roots [40]. In order to justify cassava bitterness, some authors have tried to establish the relationship between cassava bitterness/sweetness and the quantity of soluble sugars found in their pulp [38]. They have found that bitter cassava varieties have higher soluble sugars than sweet ones, despite their bitterness. All these results seem to justify the fact that other identified (apiosyl glucoside) and nonidentified compounds are also involved in the expression of cassava bitterness as shown by some authors [39]. The full understanding of all the compounds involved in cassava bitterness is therefore still incomplete.

These cyanogenic glucosides are also found in cassava leaves in various quantities (380–590 mg of equivalent HCN/Kg of fresh leaves) [8] and this can justify the fact that they are rarely consumed as vegetables.

The lower yield of cassava varieties has led to the breeding of improved cassava varieties throughout the continent. In this respect, initially, cassava varieties were bred for a few characteristics such as improved yield, low cyanogenic content; high dry matter, and improved resistance/tolerance to diseases [29, 41, 42]. The low adoption rate (55%) of such improved varieties has been the main reason for the understanding of end-users preferences concerning cassava varieties [41]. In this respect, characteristics that are common to farmers of many areas are high yielding of cassava roots, ease of peeling, big and/or large size of roots, short vegetation cycle (early maturity like 6 months), the sweetness of cassava roots, high dry matter content of cassava roots, resistance to infestation by insects, and long underground storability [7, 11, 24, 28, 29, 42, 43]. The importance of each characteristic depends on the fact that the person is a farmer only, a processor only, or a farmer who also processes [42]. From a gender perspective, since women are most involved in cassava processing [7, 29], some characteristics such as the ease of peeling or the big size of roots (which also facilitates the ease of peeling) is generally reported by women since peeling of cassava roots at household level is the duty of women [7]. Other characteristics are specific to some areas and are either associated with agroecological conditions prevailing there or the use of some parts of cassava plant or the type of plant which is associated with cassava culture or the product into which cassava is processed. In this regard, with respect to agroecological conditions, cassava farmers living in dry areas prefer cassava varieties that are drought-tolerant and give fibrous roots [28]. With respect to cultures done in association with cassava, when cassava is farmed with other long vegetation cycle plants (coffee or cocoa), farmers want tail cassava varieties [28]. With respect to the use of other parts of the plant, in areas where cassava leaves are used, farmers want early branching varieties [28]. When cassava is processed into Gari, the farmers, who are also processors, associate some characteristics like high Gari yielding, good swelling of Gari while roasting, heaviness of Gari, and brighter Gari as important characteristics for a variety to be adopted [42, 43]. The fact that cassava is generally processed into many products by farmers who process it certainly justifies their preference for cassava varieties that have multiple usages [7, 43]. While one characteristic is related to the availability of planting material [43], the other one is related to the ability of cassava plants to suppress weeds (high branching or good canopy) [7, 43]. It seems that many of these wanted characteristics can't be found in the same variety. In this respect, cassava varieties which allow obtaining sweet roots are generally more prone to diseases and give low root yields [40]. When a given cassava roots are easy to peel, they generally have high water content and a low processing yield, the reverse being true when they are difficult to peel (low water content and high processing yield) [7]. Early maturing cassava varieties generally have high water content and low storability in soil, while late maturing cassava varieties have low water content and high storability in soil [7]. Cassava varieties with high and stable dry matter content seem to be difficult to obtain since this characteristic is the result of the interaction between genotype and environment [41]. These limitations of each cassava variety are therefore the justification of the fact that farmers and processors plant cassava varieties with many opposed characteristics (late maturing and early maturing, bitter and sweet, and mealy and nonmealy) in order to overcome these limitations all year round [7, 38].

Due to the high water content of cassava which does not allow its conservation beyond 2 days, and sometimes its bitterness and/or cyanogenic glucosides content, cassava roots are always processed before their consumption, Gari being one of the commonly processed products.

3. Quality of Gari on Market Stalls

Gari, which is also known in French-speaking localities of Cameroon as Tapioca [44–46] or Rale in Mozambique [47] exists on market stalls in yellow and white colors, the yellow one is made with red palm oil or from cassava varieties with yellow pulp (in some localities of Nigeria) while the white one is made without oil (Figure 1). Because of its importance in the diet of many SSA countries, the quality of Gari found on market stalls has been assessed by many authors, mainly in Nigeria, Benin, and Ghana (Table 1). This quality has been assessed in terms of chemical/nutritional composition (proteins, fat, ash, crude fibers, moisture, HCN, and

Table 1: Nutritional composition, physical characteristics, functional, physicochemical, and pasting properties of Gari found on market stalls or produced with processors of some SSA countries.

	Norm (African organization for standardization)	Nigeria	Ghana	Benin
Carbohydrates/starch* (%)	NS	82.6–84.4 (83.2)	ND	66.4–82.7 (77.8)
Cellulose (%)	NS	ND	ND	1.6–3 (2.57)
Hemicellulose (%)	NS	ND	ND	8.6–25 (12.56)
Lignin (%)	NS	ND	ND	0.2–1.3 (0.44)
Fats (%)	NS	0.33–1.58 (0.72)	ND	ND
Proteins (%)	NS	1.96–2.88 (2.46)	ND	ND
Moisture (%)	7 max	4–14.87 (11.33)	4.70–7.71(6)	1.8–10 (7.21)
Ash content (%)	1.50 max	0.5–2.67 (1.34)	0.72–1.96 (1.26)	ND
Crude fibers (%)	2 max	0.48–2 (1.24)	1.47–2.5 (2.04)	3.1–3.9 (3.46)
HCN** (mg/kg)	20	15.5–100 (39.88) [**13/27**]	ND	6.1–29 (14.18) [**2/9**]
Vit A activity (yellow Gari) UI/100 g	NS	13.2–732	ND	ND
pH	NS	3.76–4.94 (4.66)	3.75–5.5 (3.97)	4.1–4.4 (4.19)
Total acidity (%)	0.6–1	0.004–0.04 (0.022)	ND	0.7–3.2 (1.39)
Granulometry	NS	Coarse	Particle size (630–1050 μm)	D50 (439–1.145 μm)
Bulk density (g/mL)	NS	0.54–0.84 (0.66)	0.52–0.63 (0.59)	ND
Swelling index	NS	2.5–3.5 (2.98)	2.9–3.6 (3.17)	ND
Water absorption capacity (mL/g)	NS	5–7.2 (6.22)	ND	ND
Gelatinization degree (%)	NS	ND	ND	82.9–97 (91.26)
Pasting temperature (°C)	NS	63.55–83.60 (70.95)	ND	ND
Peak time (min)	NS	4.4–6 (5.06)	ND	ND
Final viscosity (RVU)	NS	195.92–315.33 (248.29)	ND	ND
Peak viscosity (RVU)	NS	133.55–324 (275.02)	ND	ND
Trough (RVU)	NS	85.08–259.75 (174.11)	ND	ND
Setback viscosity (RVU)	NS	47.25–101.42 (74.19)	ND	ND
Breakdown viscosity (RVU)	NS	48.42–162.92 (101.06)	ND	ND
References	[35]	[48–52]	[53, 54]	[55]

ND: not done for the corresponding country; NS: not supplied for the corresponding norm; *in the case of Benin, it is starch content that has been done; **for HCN content, the number in the bracket represents the number of samples (out of the total number of analyzed samples for the country) which has HCN content above the safe limit; the number in the parenthesis represents the average for a given country, all the samples of all the studies being considered.

carbohydrates), physical characteristics (granulometry and bulk density), physicochemical properties (pH and titratable acidity), functional properties (swelling capacity, water absorption capacity, and gelatinization degree), pasting properties (pasting temperature, peak viscosity, peak time, trough viscosity, breakdown viscosity, setback viscosity, and final viscosity), and microbiological quality [18, 48, 50, 51, 53–59]. Generally, there is a variation of Gari quality in and between countries in terms of physicochemical properties, physical characteristics, and functional and pasting properties (Table 1). This wide variation of Gari quality is a visible expression of the existence of consumers' preferences.

3.1. Nutritional Composition and Granulometry of Gari. As observed from the nutritional composition of cassava, Gari, a product made from cassava, is poor in proteins, fats, and crude fibers, but has important carbohydrate content (Table 1). Important nutrient losses are observed when processing cassava into Gari. These losses are around 22% for carbohydrates and largely above 50% for other macronutrients (proteins and fibers) and micronutrients (vitamins and minerals) [60]. Gari found on market stalls of different countries (Nigeria & Benin) have HCN content which is sometimes above the safe level (20 mg of HCN/Kg of dried product), and some samples have been shown to contain up to 5 times the HCN safe level limit [48]. Since Gari is rarely consumed in a dry state, it will be therefore important to assess the HCN content of its consumption forms because the consumption of cassava-derived products with HCN content above the safe level has been associated with some diseases like Konzo [61]. However, due to the fact that these diseases are scarce in areas where Gari is highly consumed (e.g. Nigeria and Ghana), it can be hypothesized that during the preparation of Gari to their final consumption form, there is still a continuous decrease of HCN content, resulting to safe consumption form, even from unsafe Gari. Gari standards are known to exist in Nigeria and in Africa. Gari has a pH between 3 and 5, can swell up to 3 times its initial volume, and can absorb up to 7 mL of water/g (Table 1).

With respect to Gari granulometry, according to [56], the Standards Organization of Nigeria (SON) distinguishes four types of Gari as follows: extrafine, fine, coarse, and extracoarse. Extrafine Gari is the one in which more than 80% of its granules passes through a sieve of less than 350 μm. Fine Gari is the one in which more than 80% of its granules passes through a sieve of less than 1000 μm sieve. Coarse Gari is the one that less than 20% of its granules pass through a sieve of 1000 μm. Extracoarse Gari is the one in that at least 20% of its granules are retained on a sieve of 1400 μμm. On this basis, Gari found on market stalls in Nigeria can be classified as coarse Gari [48, 51]. In fact, with respect to granulometry, different authors have either used sieves of different sizes [48, 51, 53] or D50 [55]. Since these results can't be compared across countries, it is recommended to standardize the sieves used in the determination of Gari granulometry across countries based, for instance, on African standards.

3.2. Microbiological Quality of Gari. The microbiological analysis of Gari found on market stalls has only been done in Nigeria. Both bacteria (mainly *Lactobacillus* spp., *Pseudomonas* spp., *Bacillus* spp., and *Staphylococcus* spp.) and molds (mainly *Aspergillus* spp., *Fusarium* spp., *Rhizopus* spp., and *Penicillium* spp.) are found in Gari samples found on market stalls (Table 2). Some of these microorganisms result from fecal contamination (*Mucor* spp., *Kblesiella* spp., *Actinomyces* spp., *Bacteroïdes* spp., and *Bacillus subtilis*), urinary contamination (*Pseudomonas aeruginosa*), nasal contamination (*Staphylococcus aureus*), and sweat contamination (*Staphylococcus epidermis*). This shows that Gari processors should be trained in good hygienic and good manufacturing practices in order to avoid such kind of contamination and have products that are safe for consumers. Other microorganisms which are found in gari are involved in the fermentation of cassava mash (*Lactobacillus* spp., *Leuconostoc* spp., *Lactococcus* spp., and *Streptococcus* spp.) (Table 3). Since many bacteria found in Gari are well-known to be generally recognized as safe (GRAS), are probiotic, and have health-promoting effects (Lactobacillus for instance), it is therefore sure that the consumption of Gari may improve the health and well-being of its consumers. The load and diversity of these microorganisms, as well as the effect of the addition of red palm oil in their load and diversity, should therefore be assessed when doing the microbiological analysis of Gari. Some molds which are found in Gari are known to produce mycotoxins (*Aspergillus* spp. and *Fusarium* spp.). Since the moisture content of Gari found on market stalls is generally important (10%) in a humid region like Nigeria (Table 1), the growth of molds producing mycotoxins can be important and thus leading to unsafe consumption forms. Assessment of mycotoxins in Gari found on market stalls of different countries will be important for the overall evaluation of Gari quality across countries. Therefore, processors should be trained to produce Gari with moisture content which avoids the development of molds, and since Gari is a dried product, it should directly package after production in order to avoid any effect on its quality. Some authors have assessed the microbiological load (bacteria and molds) of Gari and have found important quantities of microorganisms [58]. Since Gari is obtained from fermentation, there is a need to define normal microbiological load for Gari. The classification scheme of Lactobacillaceae and Leuconostocaceae has recently been modified [63] and therefore, in the next studies, authors must refer to the new classification scheme for more accuracy.

4. Consumers' Preferences for Gari

Quality attributes of Gari are related to their color (white or yellow), their taste (mild sour, sweet, or very sour), the uniformity and size of their granules (uniform and not powdery; small or big), their appearance (cleanness/low fibers content and brightness), texture in hands and mouth (dryness, resistance to chewing, high density), their good aroma and flavor, and their properties when used (e.g. swelling capacity when soaked, firmness or elasticity when

Table 2: Microbiological quality of Gari found on market stalls in Nigeria [5, 57–59].

Microorganism	Characteristics	Genus	Species
Bacteria	Cause food-borne disease (*B. cereus*), found in the human gastrointestinal tract (*B. megaterium*), Ubiquitous (*B. megaterium*), and technological	*Bacillus* spp. (+,sb, nol(2/4))	*B. megaterium* (nol(1/4)), *B. cereus* (dcs, nol(1/4)), and *B. subtilis* (nol (1/4))
		Lactobacillus spp. (+, nsb, nol(2/4))	
	Found in the human respiratory tract and skin	*Staphylococcus* spp. (+, dcs, nol (2/4))	*S. aureus* [nol (1/4)]
	Ubiquitous, some species causing disease (*P. aeruginosa*)	*Pseudomonas* spp. (−, dcs, nol (3/4))	*P. aeruginosa* [nol(1/4)]
	Ubiquitous, found in the human gastrointestinal tract, and some species cause diseases	*Klebsiella* spp. (−, nol (1/4))	
	Found in the gastrointestinal tract	*Bacteroïdes* spp. (−, nol(1/4))	
	Ubiquitous, found in the gastrointestinal tract	*Actinomycetes* spp. (+, nol(1/4))	
	Ubiquitous, found in the mucosa and skin flora	*Corynebacterium* spp. (+, nol(1/4))	
	Mainly found in the respiratory and urinary tract, some species cause diseases	*Enterobacter* spp. (−, nsb, nol(1/4))	
	Found in the mouth, skin, intestine, and upper respiratory tract, and some may cause diseases	*Streptococcus* spp. (+, nol (1/4))	
Fungi	Found in soil and digestive system	*Mucor* spp (nol(1/4))	
	Ubiquitous, may cause food spoilage, and maybe technological	*Penicillium* spp. (nol(2/4))	
	Found in soil, can ferment organic material	*Rhizopus* spp. (nol(3/4))	*R. stolonifer* (nol(1/4))
	Ubiquitous in the environment, some produce toxins (*A. glaucus, A. niger,* and *A. fumigatus*) that cause food-borne diseases, and some are technological	*Aspergillus* spp. (mp, nol(2/4))	*A. niger* (nol(1/4)), *A. fumigatus* (nol(2/4)), *A. utrinum* (nol(1/4)), *A. flavus* (nol(2/4)), and *A. glaucus* (nol(1/4))
	No information found	*Scolecotrichum* spp. (nol(1/4))	*S. graminis* (nol(1/4))
	No information found	*Tallospora* spp. (nol(1/4))	*T. aspera* (nol(1/4))
	No information found	*Passolara* spp. (nol (1/4))	*P. bacilligera* (nol(1/4))
	No information found	*Varicosporium* spp. (nol(1/4))	
	No information found	*Culicispora* spp. (nol(1/4))	*C. gravida* (nol(1/4))
	Found in the environment and produce toxins that cause food-borne diseases	*Fusarium* spp (mp, nol(1/4))	*F. monoliforme* (nol(1/4))
	Ubiquitous and mainly found on winegrapes	*Botritys* spp. (nol(1/4))	*B. cinerea* (nol(1/4))

"+" and "−"represent gram+ and gram - bacteria, respectively; nol: number of occurrences in literature out of the total number of consulted papers (4); sb: sporulating bacteria; nsb: nonsporulating bacteria; mp: mycotoxin-producing molds; dcs: bacteria containing some disease-causing strains.

Table 3: Microorganism founds during the fermentation of cassava, mainly into Gari [57, 62, 63, 34, 64, 65]

Type of microorganism	Genus	Species
Bacteria	*Bacillus* spp. (+,sb, nol(2/6))	*B. subtilis* (nol (1/6))
	Lactobacillus spp. (+, nsb, nol(6/6))	*L. cellobiosus* (nol(2/6)), *L. bulgaricus* (nol(1/6)), *L. brevis* (nol(2/6)), *L. coprophilus* (nol(1/6)), *L. plantarum* (nol(6/6)), *L. fermentum* (nol(3/6)), *L. acidophilus* (nol(2/6)), *L. buchneri* (nol(1/6)), *L. pentosus* (nol(1/6)), *L. coprophilus* (nol(1/6)), and *L. delbruckii* (nol(1/6))
	Klebsiella spp. (−, nol (1/6))	
	Leuconostoc spp. (+, nol(6/6))	*L. mesenteroïdes* (nol(3/6)), *L. cremoris* (nol(1/6)), *L. plantarum* (nol(1/6)), and *L. lactis* (nol(1/6))
	Alcaligene spp. (−, nol(2/6))	*A. faecalis* (nol(1/6))
	Corynebacterium spp. (+, nol(3/6))	*C. manihot* (nol(1/6))
	Lactococcus spp. (+, nsb, nol(1/6))	
	Streptococcus spp. (+, nol (1/6))	
Fungi	*Candida* spp (nol(2/6))	*C. tropicalis* (nol(1/6)) and *C. krusei* (nol(1/6))
	Penicillium spp. (nol(1/6))	*P. expansum* (nol(1/6))
	Aspergillus spp. (mp, nol(1/6))	*A. niger* (nol(1/6)) and *A. tamari* (nol(1/6))
	Geotrichum spp. (nol(1/6))	*G. candidum* (nol(1/6))

"+" and "−"represent gram+and gram− bacteria, respectively; nol: number of occurrences in literature out of a total number of consulted papers (6); sbs: porulating bacteria; nsb: nonsporulating bacteria; mp: mycotoxins producing mold.

cooked) [7, 16, 29, 32, 42, 47, 49, 67, 68]. In fact, out of the color and the taste which have different and sometimes opposed characteristics, consumers of different areas generally agree well on other characteristics as being those for high-quality Gari, the variation range (inside and across countries) needed to be studied through adequate instruments. The variation of Gari taste and color is the major determinant of its quality in and between countries. In Nigeria, consumers' preference for Gari is associated with tribal and regional belonging. In this respect, Idoma (tribal belonging of the majority of persons living in Benue and North Central states) prefer yellow and a little bit of sweet Gari, while Yoruba (South West) and Igbo (South East) prefer the sour one, the one produced by Yoruba (they prefer the white color) being sourer while Igbo produce both colors (white and yellow) despite their preference for the yellow one [7, 16, 29, 42, 47, 68]. In Cameroon, the language is the main factor of differentiation, Francophone (majority of people living in 8 out of 10 regions of Cameroon) generally have a preference for yellow and a little bit sweet Gari while Anglophone (living in the 2 Anglophone regions of Cameroon) generally prefer the white and little bit sour/sour Gari [7, 32, 67]. In Benin, although people living in a given region (Center North, South East) like Gari with different characteristics (sieved or not after roasting, slightly wetter), it seems that there is a regional preference for other characteristics (Gari which is slightly wet in South East or Gari obtained through 5 to 8 days fermentation of cassava mash) [55]. The reason behind these preferences has not been supplied and the preferred color of Gari at the level of the country seems to be white [55]. However, it can be observed that Gari like in the South part of Benin seems to be similar to the one liked by Yoruba in Nigeria. Since Yoruba are also found in Benin, their tribal belonging can justify their preference. In the western part of Cameroon (North West and South West Anglophone regions), it has been suggested that the sharing of the same colonial inheritance and proximity to South East states of Nigeria can justify their preference for sour Gari [7].

Due to the fact that characteristics given by consumers are very subjective, there is also a need to associate measurable values (e.g. pH or titratable acidity for sweet, little bit sour, and sour Gari) to characteristics of Gari as supplied by consumers of different areas, in order to give rise to national and cross-country comparisons.

5. Determinants of Gari Quality

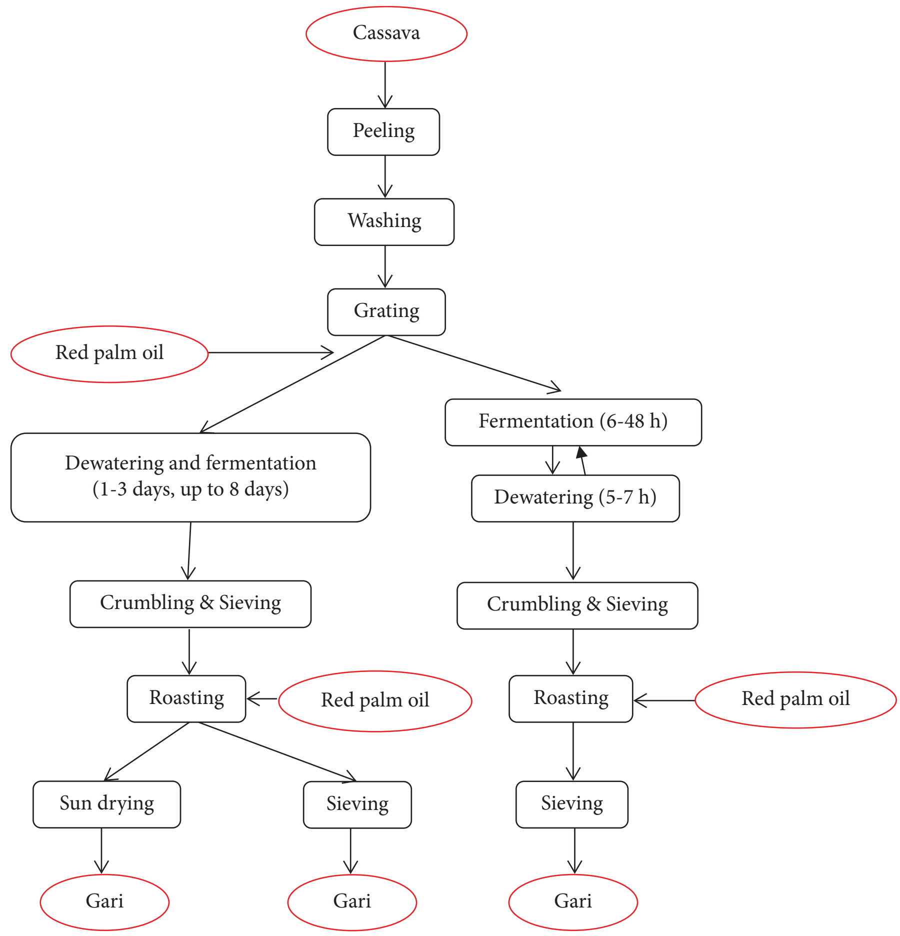
The quality of Gari is affected by the process (mainly fermentation and roasting), cassava age at harvest, and storage methods.

5.1. Processing Determinant of Gari Quality. The successive steps which allow the processing of cassava into Gari are peeling, washing, grating, bagging, dewatering, fermentation, crumbling, sieving, roasting, cooling, sieving, grinding, and sieving (Figure 2). Differences in these processes are observed in terms of the combination and succession of dewatering and fermentation (dewatering then fermentation; fermentation then dewatering; dewatering and fermentation being done at the same time), the allocated time for each step (fermentation during 6 to 48 hours, dewatering during less than 5 hours to 3 days), the step at which red palm oil is added when used (during grating or during roasting), the presence or absence of sieving after Gari roasting, and the presence of an additional step (sun drying) after the roasting stage.

Sun-drying step has been reported in Benin and Nigeria [7, 55], and processes 2 and 3 are likely to occur in all the countries since they have been reported in the production of Gari at laboratory scale in many countries including Cameroon, Nigeria, and Ghana [18, 34, 36, 59, 69–72]. Reported Gari yield (from cassava) varies between 11.6% and 34.6%, with an average of 31% [20, 36, 37, 42, 73, 74]. This important variation of Gari yield (up to 3 times) emphasizes the necessity to express cassava yield in terms of dry matter content per hectare because of the important variability of the water content of cassava roots [7, 29, 42]. However, it is worth noting that some authors have associated Gari yield with cassava age at harvest [72, 75].

Amongst the steps of Gari production, studies have mainly been done on the effect of fermentation and roasting on Gari quality.

5.1.1. Effect of Fermentation on Gari Quality. For cassava fermented products, fermentation is known to affect the chemical composition (ashes, protein, fibers, HCN, and fat contents), physicochemical properties (e.g. pH), and functional properties (e.g. swelling index) of the resulting cassava mash [10, 47, 62, 76]. With respect to chemical composition, during the fermentation of cassava mash, there is a concentration of proteins and minerals, resulting from the decrease of other components (fibers, fat, and HCN content) [10, 76]. It seems that fermentation time has an effect on the swelling index of Gari, with increasing fermentation times being associated with an increasing swelling index [42, 76]. During fermentation, there is a continuous decrease of HCN content with increasing fermentation time, the decrease (when going from HCN content of peeled roots) can be up to 90% after 2 days of fermentation, grating alone accounting for up to 30% of the decrease [10, 32, 76]. This decrease in HCN content during fermentation is due to the linamarase activity of both lactic bacteria (mainly *Corynebacterium* spp., *Leuconostoc* spp., and *Lactobacillus* spp.) and some fungi species (mainly *Candida* spp. and *Aspergillus spp.*) (Table 3) [62, 64], the activity of linamarase being more important for bacteria than for fungi [62]. It seems that fungi grow (in number) up to the 3rd day of fermentation while lactic acid bacteria grow up to the 2nd day of fermentation, except for *Leuconostoc cremoris* of which the growth begins to decrease on the 4th day [62]. The progressive production of lactic acid by lactic bacteria during fermentation contributes to the decrease of the pH of the resulting mash (pH 4.24–6 after 24 hrs, pH 4.05–4.8 after



Process	Process 1	Process 2	Process 3
Countries	Benin, Nigeria	Nigeria and Cameroon	Nigeria, Ghana, and Cameroon
References	Adinsi *et al.*, 2019; Ndjouenkeu *et al.*, 2021; Teeken *et al.*, 2021	Fon & Djoudji, 2017; Ndjouenkeu *et al.*, 2021; Olanrewaju & Idowu, 2017; Onasoga *et al.*, 2014; Teeken *et al.*, 2021	Adebayo *et al.*, 2012; Afoakwa *et al.*, 2010; De Moura *et al.*, 2015; FAO, 2018; Graham, 1986; Ikpe & Essienubong, 2016; Ndjouenkeu *et al.*, 2021; Olanrewaju & Idowu, 2017; Ukpabi *et al.*, 2012

FIGURE 2: Processes used for the production of Gari from cassava in some SSA countries.

48 hrs, pH 4.14–4.57 after 72 hrs, and pH 4.05–4.42 after 96 hours) [32, 47, 62]. Given the facts that (i) many processes are used for the processing of cassava into Gari, (ii) fermentation is either done with an important quantity of water (fermentation before dewatering) or with a low quantity of water (simultaneous fermentation and dewatering or dewatering before fermentation), (iii) fermentation duration can vary up to 8 days [55], (iv) red palm oil is often added to cassava mash before fermentation [7, 55], the effect of all these factors on microorganism diversity and a load of cassava mash or Gari as well as on the chemical composition and physicochemical properties of cassava mash and Gari should be studied in order to have a deeper understanding of biochemical events occurring during the processing of cassava into Gari using each process.

5.1.2. Effect of Roasting on the Quality of Gari. Gari roasting is a succession of cooking and dehydration processes. Dewatered cassava mash is first cooked (partial gelatinization) with its residual moisture and then dehydrated [47, 56]. Laboratory experiments show that roasting does not have any effect on the quantity of proteins and fat, but on HCN content, pasting properties (peak viscosity, breakdown viscosity, and final viscosity), functional properties (swelling index and water absorption capacity), and physicochemical properties (pH) [18, 32]. During roasting, there is an increase in pH and a decrease in HCN content. It seems that if the roasting step is properly done, the overall decrease of HCN content after roasting of cassava mash fermented during 24 hours will be similar to that of cassava mash fermented during 48 hours [32]. Modifications of pasting and functional properties are the result of the modification of starch during roasting. Red palm oil is generally added during the roasting stage for the production of yellow Gari (Figure 2). Since red palm oil contains a precursor of vitamin A, it has been shown for yellow Gari that during roasting, there is a decrease in the activity of vitamin A, the magnitude of losses increases with increasing roasting temperature and time and can be up to 98% [52, 77, 78]. The temperature at which roasting is done at the village level has not been reported. The quantity of red palm oil added at the household level by processors seems to vary depending on the area. In this respect, the quantity of oil used has been reported to be 320 mL of red palm oil (*Eleais guineensis*) for 100 kg of fresh roots in Nigeria [42], and 1 L pour 100 kg of fresh roots in Benin [55]. Since the water content of roots is highly variable and that water is evaporated during roasting, the quantity of oil used should be associated with the dry matter content of cassava roots used for accurate comparison. Due to the fact that some processors add red palm oil to cassava mash while grating and before fermentation, it has been reported that this practice allows for facilitating Gari roasting, and to obtain Gari with homogeneous yellow color and no lumps [7]. From studies involving Gari production at a laboratory scale, roasting temperature varies between 80°C–140°C and roasting time between 10–50 minutes [34, 59, 68, 71, 79]. The quantity of red palm oil used for the production of yellow Gari at the laboratory level is either 1000 g/100 kg of cassava mash [52, 77] or varies between 1 and 5 L/100 kg of cassava roots [71, 75]. Since the density of red palm oil used is variable, depending on the fraction used (liquid or solid), peel losses can represent up to 33% of cassava weight [36], and different cassava roots have different water content, the quantity of red palm oil to use in future studies should be expressed in g/kg of dried cassava mash for more reproducibility.

Due to the fact that Gari involves many steps, in Nigeria, some authors have optimized the quality of Gari at the laboratory scale through the optimization of two major steps which are fermentation and roasting [68]. In this respect, two conditions allow for obtaining the most appreciated Garisuch as fermentation duration12 hours, roasting temperature95°C, and roasting time50 minutes; and fermentation duration120 hours, roasting temperature120°C, and roasting time40 minutes. When taking into consideration the taste of Gari which is preferred by persons from different parts of Nigeria (very sour and sweet/mild sour), the duration of fermentation time for both optimum parameters as well as the decrease of pH observed during the fermentation of cassava mash, it is obvious that preference was associated to Gari taste if all the other parameters (granule size, shininess, and color) are considered as equal.

5.1.3. Mechanization of Gari Production Chain and Quality of Gari. Owing to the importance of Gari in the diet of Nigerians and Ghanaians, machines for the whole processing of cassava into Gari have been designed in these countries. Some models of these machines are UNIBADAN model, UNN model, FABRICO model, and PRODA model [31, 80]. Some of these models can produce up to 2 tons of Gari per day [81]. Generally, these models are too expensive, equipped with nonadapted equipment, with design mistakes and women who use to produce Gari were not interested [14]. Also, Gari processed by these machines was not competitive when compared to Gari produced at the household scale by women and was of low quality since peeling was not properly done [14]. Although smaller models have been developed to produce 20 kg of Gari/hour [31], there is still a need to deeply understand some key operational units like roasting (temperature variation during roasting) in order to obtain Gari which is similar to the one produced at the household scale. In fact, one possible solution for the success of the mechanization of the overall processing chain of Gari could be the mechanization of each processing step, beginning with the most difficult which seems to be peeling and roasting [14, 17]. At the moment, the grating step is mechanized almost everywhere, and there exists, in some areas, hydraulic dewatering machines, improved stainless steel fryers and chimneys, and mechanical peelers with a capacity of 2 tons/hours [37, 47]. This mechanization of unit operations, if repeated everywhere in SSA, can reduce the drudgery associated with Gari production, as well as increase productivity and thus, reduce the overall cost of Gari on market stalls. However, this mechanization of Gari production should be mainly done by improving materials used at the household scale due to the financial importance of Gari commercialization in poverty alleviation of women.

5.2. Raw Material Determinant of Gari Quality. Owing to the fact that cassava can be progressively harvested, some authors have studied the effect of age at harvest on the nutritional composition (proteins, carbohydrates, lipids, and minerals) of cassava and Gari as well as on Gari yield and sensorial characteristics [72, 73, 75]. Some authors were assessing only the effect of age at harvest on this quality [72, 73] while others were also taking into account the harvesting season (dry or rainy) [75].

Regardless of the variety used, Gari yield is optimal during the dry season and this is due to the higher dry matter of cassava [75]. With respect to chemical composition, in the dry season, Gari and cassava are richer in proteins, carbohydrates, and lipids, and poorer in minerals, cyanogenic glucosides, and fibers [75]. Since in their study, the rainy season was corresponding to the longer harvesting time (15 months after planting), it can be concluded that minerals content, cyanogenic glucosides content, and fibers content of cassava increase with increasing age at harvest [75]. Higher protein, carbohydrate, and lipid contents of cassava during the dry season result from lower contents of fibers, minerals, and cyanogenic glucosides, probably in combination with the concentration of these macronutrients due to higher dry matter. For Gari, only the yield was expected to change as observed by authors but not its chemical composition since Gari is a dry product and these authors have shown that, regardless of the season, there was not a difference in dry matter of produced Gari. Gari(s) from the dry season (12 months after planting) have the highest overall acceptability, regardless of the variety, and this acceptability is mainly determined by the more important shininess, odor, and taste of Gari. It is therefore difficult to say, from these results of overall acceptability, if it is the age at harvest or the season or both factors which determine (s) the overall acceptability.

For authors who were only looking at the effect of age at harvest [73], Gari yield and sensorial characteristics increase with increasing age at harvest up to an optimum (13 or 14 months for yield and 10–14 months for sensorial characteristics, depending on varieties).

From both studies, it seems that the optimum age at harvest of cassava in order to obtain Gari with the highest sensorial characteristics and highest yield is around 12 months. The overall mineral content of cassava and Gari increases with increasing age at harvest [72, 75]. With respect to specific minerals, the maximum quantity of Na and K, and the minimum quantity of phosphorus is at 12 months [72], which corresponds to optimal sensorial characteristics. This might traduce the fact that sensorial characteristics of Gari are dependent on mineral contents, more studies are needed to explain these facts. From all these studies, it is clear that for each variety, there is an optimal season and/or age at harvest for Gari yield, nutritional composition, and sensorial characteristics. However, there is a need to determine the effect of the season and the effect of age at harvest on both cassava and Gari.

5.3. Quality of Gari on Storage. Since Gari is a dried product, once produced, Gari can be sold for many days/weeks/months and thus is kept in different types of containers, the most common being hessian bags and polythene bags. For these reasons, many authors have assessed the effect of these containers on the microbiological quality and acceptability of Gari [57, 79, 82]. It comes out that the decreasing order of efficiency of packaging material is polyethylene, polyester, polypropylene, and hessian bags [79, 82]. When packaged in a polyethylene bag, a microbial load of Gari does not change significantly up to the 12^{th} month while it increases in other containers. It seems to exist a specificity for molds found in Gari on storage, which is both related to Gari color and the type of container [57]. In this respect, *Penicillium* spp. are only found in yellow Gari packaged in polythene bags and kept for 3 months while *Aspergillus glaucus* and *Aspergillus fumigatus* are found in white Gari packaged in the same bag. *Aspergillus glaucus* is found in yellow Gari packaged in the hessian bag while *Penicillium* spp. and *Rhizopus* spp. are found in white Gari packaged in the same container. It thus seems that red palm oil inhibits the growth of *Aspergillus* spp. when yellow Gari is kept in polythene bags. If confirmed, it will be useful and yellow Gari obtained after the addition of red palm oil before roasting will be freed of these molds, especially their mycotoxins. For yellow Gari, regardless of the container, losses of the brightness of its color are observed for Gari kept beyond 3 months [57, 83]. Loss of the brightness of yellow Gari, which results from the oxidation of oil by oxygen and light, can be more important if it is not properly stored since losses of Vitamin A activity have been shown to reach 75% after 4 weeks [52, 77]. This might suggest that for yellow Gari, containers should not permit the entry of light and oxygen. Owing to the fact that cassava varieties that produce yellow flesh roots are farmed in many SSA and sometimes used to produce Gari (in Nigeria for instance), some authors have assessed the retention of vitamin A activity when using these roots for Gari production [77]. They have shown that the retention of vitamin A activity is better for Gari made with yellow flesh roots than for Gari made using 10 g of red palm oil/kg of cassava roots.

6. Improvement of the Nutritional Quality of Gari

Due to the low nutritional quality of Gari and its important consumption in SSA countries, many authors have tried to improve the nutritional quality of Gari through the substitution of cassava with other products. This substitution has been done at proportions varying from 5 to 100% using legumes (African fruit (*Treculina africana*), soybeans (*Glycine max*), melong (plant of *Cucurbitaceae* family) seeds, moringa (*Moringa oleifera*) seeds, and *Pachyrhizus erosus*) [20, 44, 69, 84–87], roots and tubers (cocoyam (*Colocasia esculenta*) and sweet potatoes (*Ipomea batatas*) [74, 88–90], oily matrix (groundnut (*Arachidis hypogea*)), and pseudo-cereal (Sesame (*Sesamum indicum*)) [91]. The majority of studies have been done while substituting cassava with steam-cooked soybeans. Legumes were generally either steam-cooked (soybeans and African fruit) [44, 69, 84–87] or roasted (melong and moringa seeds) [84, 85] or not treated at all (*Pachyrhizus erosus*) [20]. Roots and tubers as well as groundnuts were substituted without any pretreatment(s) while sesame was used after roasting and defatting. The addition of these matrices was done either during the grating stage [88, 89] or after grating [44, 86] or before fermentation [44, 55, 69, 87] or after fermentation [30, 44, 84–86, 89, 92] or after roasting [85, 89]. In general, the substitution of cassava by these matrices has effects on nutritional composition (proteins, fats, carbohydrates, and crude fibers), functional properties (swelling index and water absorption capacity), physicochemical properties (pH), physical characteristics (bulk density), pasting properties (pasting temperature, peak viscosity, and breakdown viscosity), and sensorial characteristics (color, taste, aroma, texture in mouth, and overall acceptability).

6.1. Effects of Substitution on Nutritional Profil, Functional, Physicochemical, and Pasting Properties of Resulting Gari. Substitution of cassava mash with other matrices affects the nutritional quality of the resulting Gari. In this respect, substitution generally increases protein, mineral, fibers, and fat contents, and decreases carbohydrates and HCN contents, the variation being more important with increasing substitution rate [30, 55, 84, 88, 91, 92]. These variations are due to the chemical composition of the matrix used for substitution as well as of cassava. An exception is observed for sesame flour and groundnuts where there is a decrease in fiber content with an increasing substitution rate [30, 91],

Table 4: Gari consumption forms in some SSA countries.

Consumption form	Country	Ingredients/soup	References
Dry	Nigeria	Not supplied	[30]
	Benin		[55]
	Cameroon		[7]
Soaked	Nigeria	Groundnuts (roasted or not), fish (fried, roasted, smoked), sugar, honey, coconut, palm kernel, boiled cowpea, milk, salt, and banana	[79, 95, 30, 48–50, 76, 96, 51, 68]
	Cameroon	Sugar, honey, groundnuts, coconut, beans, and milk	[7, 23, 71]
	Benin	Sugar, groundnuts, and cashew nuts	[55]
Dough prepared with hot water and known as "Eba" or "Fufu Gari" or "Couscous Tapioca" or "Piron"	Nigeria	Not supplied	[95, 7, 16, 18, 30, 31, 48–50, 76, 96, 29, 42, 51]
	Cameroon	Sauce	[23, 32, 71]
	Benin	Not supplied	[55]
Sprinkled on cooked cowpeas bean	Benin	Not supplied	[55]
Fried gari or "*Gari Sauté*"	Cameroon	Oil, spices, and sometimes eggs	[7]
Gari is used as a garniture for eggs or "Omelet Tapioca"	Cameroon	A mixture of crude eggs, Gari, and flavors, fried as an omelet	[7]
"Purée de Tapioca"	Cameroon	A mixture of avocado and Gari	[7]

and this is probably due to the relatively poorer fiber content of these commodities. The increase in mineral content of resulting products does not traduce the increase of each mineral since it has been shown that this overall increase of minerals can be associated with a corresponding decrease of iron [90].

With respect to functional properties, substitution generally leads to a decrease in the swelling index and water absorption capacity of the resulting Gari, the decrease being more important with an increasing substitution rate [84, 85, 88, 92]. This might be explained by the difference in starchy composition (amylose/amylopectin ratio) which is generally lower for cassava [93, 94]. The same cause explains the observed decrease of bulk density and pasting properties (peak viscosity, pasting temperature, breakdown viscosity) of Gari which is associated with substitution, the decrease being more important for increasing the substitution rate [69, 84, 85, 88, 92]. However, an exception seems to exist when the material used for substitution is sweet potato (*Ipomea batatas*). In this case, there is an increase in swelling index and water absorption capacity of resulting Gari, the increase being more important with increasing substitution rate [89, 90]. The reason for justifying this behavior is unexplained.

Substitution has opposite effects on the pH of the resulting Gari, with either a decrease (groundnuts, steam-cooked soybeans, and roasted moringa and melong seeds) [30, 84] or an increase (sweet potatoes, sesame flour, and cocoyam) [74, 91, 92] or an absence of effect on pH [89]. Since the increase of pH is observed for starchy commodities and the decrease of pH is observed with legumes, the nature of matrices used for substitution can explain the difference. In fact, the growth of lactic acid bacteria is more important in a medium richer in proteins and minerals (see the chemical composition of MRS medium used for these microorganisms), and owing to the fact that substitution with legumes is known to create such conditions, it might be suggested that substitution of cassava mash with legumes increase the lactic acid bacteria load in the medium, resulting to faster fermentation and a more important decrease of pH. For starchy matrices, the substitution rate used and the amylose/amylopectin ratio might explain the difference, since cassava is generally richer in amylopectin than the reported matrix [93, 94].

6.2. Effects of Substitution on Sensorial Quality of Gari. Gari is consumed in the following three major forms in countries of SSAdry, soaked with many ingredients including sugar, roasted groundnuts, milk, and coconut; prepared as dough known in Nigeria as *Eba*, in Benin as *Piron* [29], and in Cameroon as *Couscous Tapioca* or *Couscous Gari* or *Fufu Gari*, and which is consumed with many soups; fired with oils and spices; mixed with avocado and eaten as purée; and used as garniture in a fried omelet (Table 4). Sensorial analysis of Gari prepared by substitution of cassava with other matrices was either done on dry Gari [74, 88, 92] or on soaked Gari [84, 89, 90] or on Eba [86, 89, 91]. Due to the fact that Gari has many consumption forms in SSA, it will be important, for such kind of studies, to perform sensorial analysis on dry Gari, since it is the form found on market stalls, and to also perform these analyses on the most consumed form of Gari, which might be variable both in and between countries. Among these consumption forms, "Eba" is the most common (Table 4). It can be prepared using the following two methodsheating of water, addition to Gari contained in a pot or a pan and stirring while maintaining the pot/pan out from fire; and heating of water, the addition of Gari to boiling water while maintained on fire, cooking and stirring of Gari when still on fire up to the end of cooking [7]. These two modes of preparation result from end-users preferences which are associated with localities/ethnicity in Nigeria, and the soup with which the prepared Eba is consumed within Cameroon [7, 42]. In this respect, in Nigeria, *Yoruba* (Osun state for instance) and *Idoma* as well as *Tiv* (Benue state) prefer *Eba* obtained using the second preparation mode as the characteristics are stretchable, mouldable, soft, and smooth while Igbo (Imo state) prefer Eba prepared using the first preparation mode and that the characteristics are nonsticky, firm, less smooth and less stretchable [7, 42]. Since these characteristics are very subjective, their measured values, as obtained with appropriate instruments can allow more information as well as cross countries comparisons.

Substitution of cassava mash with other matrices has different effects depending on the matrix used, proportions used, and pretreatments that have been applied to the matrix of substitution. In this respect, the replacement of cassava by soybeans, sweet potatoes, sesame, cocoyam, and melong seeds generally results to lessen sensorial characteristics of Gari or its consumption forms [74, 84, 86–88, 91, 92]. However, some exceptions have been obtained, mainly when cassava is substituted by sweet potatoes [89, 90]. In this case, substitution with 10–25% allows obtaining Gari with sensorial characteristics which are similar to Gari obtained without substitution. When roasted moringa seeds are used at 5% [84] or when *Pachyrhizus erosus* roots are used for Gari production instead of cassava [20], the resulting Gari is more appreciated.

However, despite these encouraging results related to the improvement of the nutritional quality of Gari, up to now, to the best of our knowledge, fortified Gari is not yet found on market stalls, although some trials seem to be done in some areas of Benin, mainly with the support of research [55]. Another fact is that Gari is never consumed alone and although it cannot be considered alone as nutritious, the remaining ingredients used for its consumption as well as the nutritional status of consumers should be taken into consideration before any consideration of the nutritional improvement.

7. Conclusion

Gari is the most important cassava-derived product in many SSA countries. However, its ability to increase the incomes in these countries and reduce food importation is still limited by the lack of mechanization of some difficult steps at the household level, the poor hygienic and manufacturing practices involved during its production, and the lack of sufficient knowledge to master and reproduce in the standard way its production. Intra and cross-country differences in end-users preferences for Gari allow understanding that only the case-by-case study should be done in order to reach an important contribution of this convenient food to food sovereignty. In order to strengthen the Gari value chain, some work has to be done in SSA both by policymakers and researchers. In this respect, policymakers should organize the training of Gari processors in good hygienic and manufacturing practices. In areas where Gari is processed and/or consumed, research work should be done on (i) the assessment of HCN content of main consumption forms of Gari; (ii) the standardization of methods used for the determination of Gari granulometry with a subsequent classification of Gari using, for instance, Nigeria standards; (iii) assessment of mycotoxins on Gari found on market stalls; (iv) the determination of consumers' preferences in major consuming areas, especially urban ones; (v) the association of consumers' preferences with measurable characteristics in order to give rise to comparison in and between countries; (vi) the determination of the safe microbial load for Gari; (vii) the determination of effects of the variant of process on Gari quality; (viii) the follow-up of Gari production at village level in order to better understand fermentation and roasting stage; and (ix) the determination of the effect of the season and of age at harvest on Gari quality.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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