JOURNAL OF FOOD TECHNOLOGY

MEDWELL PUBLICATIONS SINCE 2000

Garification Process, Nutrient Composition and Quality Evaluation of Combined Formulas of Gari made with Cassava (*Manihot esculenta*) and Sweet Potato (*Ipomoea batatas*) from Cameroon

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Key words: Garification, gari, cassava, sweet potato, nutritional quality

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Page No.: 1-6
Volume: 19, Issue 1, 2021
ISSN: 1684-8462
Journal of Food Technology

Abstract: Garification is a process that consists of processing cassava into a by-product called gari. The process involves peeling of tubers, their washing, grating, bagging, fermentation, pressing, defibering, sieving and simultaneous cooking and drying. Gari is widely consumed but one of the major limiting factors of its consumption is the low nutrient content and huge post-harvest losses to which it is subject every year. It will be interesting to supplement cassava with sweet potato. This has led to investigate the potential production of gari from sweet potato tubers and to evaluate the nutritional quality of different prototypes made both from cassava and sweet potato. Gari was produced from mixes of cassava and sweet potato tubers at different ratios (100:0, 25:75, 50:50, 75:25 and 0:100 cassava and potato tubers, respectively). Nutritional, microbiological and functional analyses carried out on the various mixtures showed that the sweet potato tubers suited well to the garification process. With a higher dry matter (89.06%), total sugar (8.72%), dietary fiber (7.52%) and calcium (1.55%) content, sweet potato-based gari showed a better nutritional quality than the one obtained from cassava. Gari made from an equal mixture of cassava and sweet potato led to a product rich in protein and fat. Panellists showed a preference for 75% cassava and 25% sweet potato for its smell, taste and color. Replacing partially cassava with sweet potato for the production of gari is an alternative for the valorization of local products and fight against malnutrition through the development of new energy-rich food products.

INTRODUCTION

Cassava and sweet potato are two tubers known for their high energy content and those are widely grown and consumed in several countries in sub-Saharan Africa in general and in Cameroon in particular[1]. Both cassava and sweet potato hold a prominent place in the diet of populations living in the tropics[2]. Sweet potato belongs to the Convolvulaceae family. This tuber has high sucrose content (10-25%) which gives its sweet taste and increases its acceptance by consumers, especially young children[3]. On the other side, cassava tubers are rich in carbohydrates, vitamin B and C, calcium and other minerals recommended for daily nutrition[4]. An important challenge for cassava producers is post-harvest losses. In fact, cassava tuber usually deteriorates due to a physiological process that occurs 2-3 days after harvest[5] and also microbial weathering about 5-7 days after harvest[6]. This requires either immediate consumption or rapid treatment of cassava tubers soon after harvest. To overcome this problem, cassava is generally transformed into several products[7, 5] mostly obtained from tubers fermentation such as Gari which is one of the most produced cassava by-product. Generally, gari is consumed either as a snack (after soaking in water and adding sugar and/or roasted peanuts) or in the form of a lump (after cooking with water) to eat with a sauce. Gari is a by-product obtained as a result of a process called "garification" (combined cooking and drying operation applied to cassava tubers after fermentation). This process constitutes with fermentation an important step in obtaining the qualities required for the final product: color, granulometry, degree of cooking, swelling power, digestibility[8]. In several countries in sub-Saharan Africa, the alternation of seasons necessarily implies an adaptation of the population's eating habits[9]. In order to provide consumers with a technologically similar by-product, although, garifrom cassava roots is known; little or nothing is known of sweet potato gari; its production will reduce its high post-harvest loses and therefore cassava and sweet potato would be subject to transformation processes. The aim of this work is to show the importance of using sweet potato instead of cassava during the garification process. These new formulations will allow consumers to manufacture gari made either from cassava and sweet potato alone or from a mixture of both. This will help people to consume gari at any time when sweet potato abounds while cassava is scarce.

MATERIALS AND METHODS

Collection of raw materials: Non-bitter cassava and sweet potato tubers (variety IRA1112) were harvested at maturity from Bafia Division (Centre Region of Cameroon) and transferred to the Food technology laboratory of Food and Nutrition Research Center (CRAN), IMPM.

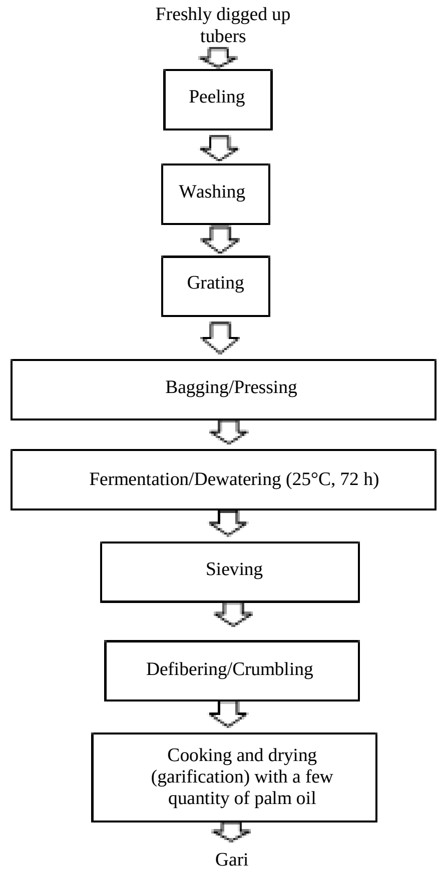

Fig. 1: Flow chart for the production of gari

Garification process: Gari made from cassava or sweet potato was obtained following the production process presented in Fig. 1.

The freshly harvested cassava or sweet potato tubers were peeled with a stainless knife and then washed and pulped using an artisanal grater made from a perforated metal plate with sharp edges. The pulp was poured into jute bags upon which, heavy stones were placed to facilitate the draining of water (dewatering). The pulp was then left for 72 h. The pressed cake was crumbled by hand to give the pulp a granular structure and passed through a traditional sieve; the filtrate was deposited with a little palm oil on a frying pan placed on a stove heated with fire wood. During cooking, the pulp was continuously stirred with a wooden ladle until a sufficient degree of gelatinization of the starch was achieved and the water content of the product was sufficiently low to ensure good storage[5].

Production of different types of gari: Five types of gari were produced and analyzed in triplicate for their quality. They were made from different initial proportions of cassava and potato tubers (100:0, 25:75, 50:50, 75:25 and 0:100) as shown in Table 1.

Table 1: Different types of gari produced

Gari	Cassava (%)	Sweet potato (%)
100 C	100	0
25 C/75 SP	25	75
50 C/50 SP	50	50
75 C/75 SP	75	25
100 SP	0	100

C = Cassava; SP = Sweet Potato

Chemical analysis: Dry matter and crude protein content were determined as described by AOAC[10]. Lipids were extracted with hexane by soxhlet and the amount assessed following AFNOR[11] procedure. Soluble sugars were previously extracted before their assay according to the method of Cerning and Guilbot[12] and then assayed according to the method described by Montreuil *et al*.[13]. The dietary fiber content was determined following the method of Wolff[14]. Total ash content was evaluated according to AFNOR[11]. Calcium and iron were determined by atomic absorption spectrophotometry[10].

Functional analysis: The real water holding capacities and the lowest gelling concentration of the different samples were assessed as described by Phillips and Mc Watters[15] and Dengate[16], respectively.

Microbiological analyses: Total coliforms and molds concentrations of the 5 samples were assessed. A stock solution was prepared for each of the samples. The 2.5 g was weighed and mixed with distilled water for a final volume of 25 mL. Serial dilutions were then made from the stock solution. The germs of interest were total coliforms and molds. About 0.5 mL of each sample was seeded on EMB and Mac Conkey media for coliform count. After incubation of the inoculated media at 37°C for 24-48 h, colony counting was performed by macroscopic observation of microbial colonies on petri dishes. On the other hand, 0.5 mL of each sample was inoculated on Sabouraud agar for fungal count.

Acceptability test: A hedonic test was performed as described by Potter[17] and Ellong *et al*.[18]. It consisted in analyzing the organoleptic properties of the prototypes of gari. The different samples were suspended in 10% (soaking the gari in water). A panel of 25 people aged from 25-40 years old of both sex was recruited and installed in a suitable room. A hedonic evaluation sheet was given to each panelist. The panelists imperatively provided a response (situation of forced choice) and their judgment was focused on 5 parameters (consistency, color, smell, taste and texture) and on a scale of five levels ranging from 'not at all' to 'love extremely. At the end of this analysis, the general assessment made up of the average of the marks awarded in each section was developed.

Statistical analyzes: All the results obtained were the mean of three repetitions. Statistical analyses were performed using the Statgraphics 5.1 package which allowed the comparison of the effect of the different treatments on the responses using the Analysis of Variance (ANOVA). When the difference was significant, the Duncan test was used to rank the averages.

RESULTS

Nutritional composition: From the garification process, five gari prototypes were produced (Fig. 2).

The components determined namely dry matter, total ash, crude protein, total lipids, total sugars, crude fiber, calcium and iron contents were recorded in Table 2.

The dry matter content ranged between 84.82±1.23-89.06±2.67% for gari made from cassava and sweet potato, respectively. Ash contents ranged from 0.47-1.70%. Concerning the organic part, all the gari prototypes registered lower protein content. But also the 50C/50 SP gari (gari based on 50% cassava and 50% sweet potato) had the highest levels of protein (0.21%) and lipids (19. 24%) in contrast to gari 100 SP (gari made from 100% sweet potato) which had the lowest levels (0.15% protein and 16.74% lipid). Moreover, the gari made from 100% sweet potato was almost 6 times higher in raw fiber than that in cassava. Gari made from the mixture of 75% cassava and 25% sweet potato had the highest values of calcium and iron values of 1.31±0.01 g/100 g MS and 405±3.74 mg/100 g MS, respectively.

Functional analysis: The Results of functional analyses obtained from the five types of gari were showed in Table 3.

The Lowest Gelling Concentration (LGC) observed was for gari made from 100% cassava. There was statistically significant difference between the five grades of the LGC ($p<0.05$). The result of real water holding capacity (RHWC) showed that sweet potato-based gari had a lower capacity to retain water (62%) than cassava-based gari (111%). In addition, cassava-based gari had a higher swelling capacity than that of sweet potato.

Microbiological analyzes: The total coliform count of the gari did not register the presence of coliform bacteria (0 CFU/mL) above the detection limit. The presence of molds, in all the gari samples varied from 2.43×10^3 for 50C/50SP gari to 8.11×10^3 for 100% sweet potato gari (Table 4).

The 100% SP (Sweet Potato) gari had a higher rate of mold compared to cassava. Colony count ranged from 4.95×10^3 for 100% gari made from cassava to 8.11×10^3 for 100% sweet potato-based gari.

Sensory analysis: The results of sensory analysis were presented in Fig. 3.

Table 2: Nutritional composition of the different gari types*

Variables	100%C	75%C/25%SP	50%C/50%SP	25%C/75%SP	100%SP
Dry matter (% FM)	84.82±1.23^{a}	85.63±3.09^{a}	87.14±4.44^{b}	88.22±2.56^{b}	89.06±2.67^{b}
Total ash (g/100gDM)	0.67±0.02^{b}	1.70±0.11^{e}	1.27±0.01^{d}	0.47±0.03^{a}	0.90±0.05^{c}
Crudeprotein (g/100gDM)	0.16±0.03^{a}	0.19±0.01^{b}	0.21±0.02^{c}	0.19±0.01b	0.15±0.06^{a}
Total lipids (g/100gDM)	19.15±4.08^{c}	17.90±2.87^{a}	19.24±0.99^{c}	18.45±1.04^{b}	16.74±1.2^{a}
Total sugar (g/100gDM)	1.78±0.04^{a}	2.58±0.12^{b}	4.58±1.03^{c}	6.60±1.32^{d}	8.72±1.04^{e}
Dietaryfibers (g/100gDM)	3.58±0.15^{a}	9.30±1.13^{b}	13.39±1.09^{c}	15.30±2.76^{d}	7.52±2.65^{e}
Calcium (g/100gDM)	1.04±0.02^{a}	1.31±0.01^{a}	1.19±0.01^{a}	1.03±0.03^{a}	1.55±0.07^{b}
Iron (mg/100gDM)	361.98±2.98^{c}	405.74±3.74^{d}	250.26±3.55^{b}	225.94±2.76^{ab}	65.58±2.4^{a}

*means C = Cassava; SP = Sweet Potato; Within the same line, values not followed by the same letter are significantly different ($p<0.05$)

Table 3: Lowest Gelling Concentration (LGC) and the real water holding capacity (RWHC) of the five types of gari

Gari	LGC (%)	RWHC (%)
100%C	6^{a}	111±1.21^{e}
75%C/25%SP	8^{b}	106±2.32^{d}
50%C/50%SP	10^{c}	97±1.87^{c}
25%C/75%SP	14^{d}	88±2.43^{b}
100%SP	16^{e}	62±0.98^{a}

*C means = Cassava; SP = Sweet Potato; Within the same column, values not followed by the same letter are significantly different ($p<0.05$)

Table 4: Mould concentration in the five types of gari

Gari*	Concentration (CFU/mL)
100%C	4.95×103
75%C/25%SP	3.08×103
50%C/50%SP	2.43×103
25%C/75%SP	2.16×103
100%SP	8.11×103

*C = Cassava; SP = Sweet Potato

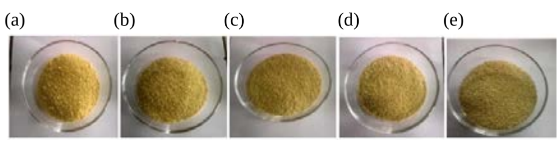

Fig. 2(a-e): Illustration of different prototypes of gari, (a) 100%C, (b) 75%C/25%SP, (c) 50%C/50%SP, (d) 25%C/75%SP and (e) 100%SP. While these codes mean gari made from 100C = 100% cassava; 75C/25SP = 75% cassava+25% sweet potato; 50C/50SP = 50% cassava+50% sweet potato; 25C/75SP = 25% cassava+75% sweet potato; 100SP = 100% sweet potato

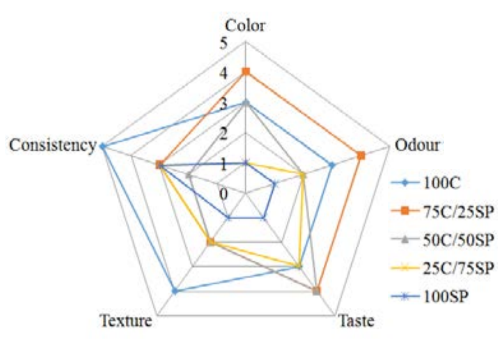

Fig. 3: Appreciation of gari samples by panelists

Panelists had a preference for 75% cassava and 25% sweet potato gari for its smell, taste and color. On the other hand, they preferred the 100% cassava gari for its consistency, texture and color. However, gari made from 100% sweet potato was rejected for all the organoleptic parameters requested.

DISCUSSION

Nutritional composition: The range of dry matter content corroborate those obtained by Sanni[19] and Agbetoye and Oyedele[20] who have shown that both commercial and industrial gari have a moisture content that varies between 7 and 17%. For this reason, gari are generally subject to microbial degradation which significantly reduces their shelf life and consumption. Most of the microbial development is attributed to the moisture content of the environment[21]. Humidity (about 17%) provides a suitable medium for catalytic reactions that may affect flavor, texture and physical and chemical properties[20]. Results of ash contents are in agreement with those obtained by Aiyelegun *et al*.[22] who showed that several varieties of cassava produced in Southwestern Nigeria have ash levels ranging from 0.48-2.59%. This may mean that tuber mixtures have no impact on the mineral value of the final product. It should be noted that gari composed of 75% cassava and 25% sweet potato has the highest mineral content which correlates its high total ash content (1.70%) compared to the other four gari types. The values of protein content reported here are lower than those reported by Kolapo and Sanni[23] who carried out a study on a gari made in Nigeria having protein content between 1 and 1.5%. The difference could also be as a result of factors ranging from tuber varieties, time of harvesting, age of plant and other environmental factors. The relatively low total carbohydrate values indicate a degradation action of hydrocarbon macromolecules conducted by microorganisms such as lactobacilli. These sugars in turn are converted into organic acids, leading to acidification of the system and lowering of carbohydrate content during fermentation[24]. In fact, the decrease in the carbohydrate content of the tubers consequently resulted to higher level of carbohydrate break down[25]. Results of raw fiber content for gari made from 100% sweet potato may be a major advantage in order to facilitate peristaltic movement and to limit malfunction of the digestive tract. Indeed, dietary fibers decrease intestinal transit times which may affect satiety and satiation[26]. Values of calcium and iron obtained from gari made from the mixture of 75% cassava and 25% sweet potato is essential for solidification of the bones (calcium) and for the cellular constituents of the blood (iron).

Functional analysis: The Lowest Gelling Concentration (LGC) observed here revealed that by making a fair mixture, it would take 10 g of gari in 100 mL of water to obtain a gari ready to be consumed. From the result of real water holding capacity (RHWC), it is evidenced that that cassava starch has a low amylose content which makes it resistant enough to retrogradation. The amylose/ amylopectin ratio in cassava being 17/83 gives it a fairly long, supple and creamy texture after cooking[27].

Microbiological analyzes: No registration of coliform of the gari indicates that there is no health risk for the consumer associated with its consumption given the fact that gari is a ‘ready-to-eat’ food. Moreover, the absence of this group of foodborne bacteria in our final by-product testifies the good manufacturing and hygienic practices during processing. This complies with the microbiogical standards for ready-to-use foods defined by the CFS[28]. The high presence of mold in 100% sweet potato compared to cassava may be due to its low pH and nutritional compositions which make it susceptible to infection by fungi. Indeed, during fermentation, carbohydrates are converted into organic acids by the microorganisms in the presence of molds in the reaction medium. At this time, the pH becomes low (acidic) and therefore favorable for the development of yeasts and molds which are generally acidophilic; their optimum growth pH is between 4 and 6 with extreme values. The range of Colony count is similar of suggestion of Sanni[19]. According to this author sweet potato gari is more favorable to mold growth than that made with cassava-based. Though general mold count in this study is lower than that reported by Gacheru *et al*.[29] in cassava flour, the fungal load in cassava-made gari is slightly above the set limit defined by the East African Community Standard[30]. A high level of molds may reduce the storage time of the product apart from the risk associated with mycotoxin production.

Sensory analysis: Panelist’s appreciation of the 100% cassava gari for its consistency, texture and color could explain by the fact that fermentation improves the color of cassava due to mold’s catalyze effect of tannins, responsible of the bad color[21]. On the other hand, the dark color of sweet potato-based gari could be explained by the consumption of carotenoids by microorganisms during fermentation[31], making the product dull and less attractive[32].

CONCLUSION

The production of gari made from the mixture of sweet potato and cassava is an appropriate alternative to combat child malnutrition in areas where both tubers are grown. Moreover, gari made from 100% sweet potato has good nutritional characteristics that can be exploited as a sustainable food during food shortage season and fight against post-harvest losses. The technique of garification can well be applicable to the sweet potato. However, the addition of cassava is necessary to obtain a food with a high energy potential because the nutritional value of one or the other taken separately is very low. Gari obtained after a blend of 75% cassava and 25% sweet potato tuber has nutritional characteristics of interest for both the consumer and food technologists. Gari made from sweet potatoes could be used for other agri-food uses such as pastry.

ACKNOWLEDGMENTS

The authors express their gratitude to the National Committee for Technological Development (CNDT) for their financial support during this study.

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