

Chemical Composition and Nutritional Value of Three Varieties of Cassava Produced in Guinea, Processed into Gari and Enriched with Protein and Lipids from Sesame

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Abstract

In Guinea, gari is a consumer product for children. However, gari taken in isolation is a nutrient-poor food and does not cover the nutritional needs of the latter. The objective of this study is to biochemically characterize gari enriched with sprouted sesame flour. Thus, the roots of three varieties of cassava (TME419, Samou-ya and Banankougbe) produced in Guinea and supplied by the Agronomic Research Center of Foulaya were studied at the UFR of Biotechnology at the University Félix HOUPHOUËT-BOIGNY (Côte d'Ivoire) for the production of sesame-enriched gari at rates of 0; 5% and 7.5%. Physicochemical analyses of the various products obtained from the three varieties showed pH varying between 4.71 and 5.44 for the non-supplemented gari and between 5.7 and 7.5 for the enriched gari. In addition, in all products, the levels of protein (1.53%; 1.54% and 1.54%), fat (6.60%; 7.73% and 8.13%), fibre (10.60%; 10.76% and 13.87%) and ash (1.43%; 1.46% 1.83%) were higher in the 7.5% fortified gari than in the non-supplemented gari. On the other hand, the non-supplemented gari were higher in carbohydrates. In short, the supplementation of gari with sesame flour at 7.5% has helped to improve the nutritional quality of this widely consumed food. Popularizing the practice can be a viable way to address nutritional deficiencies in children.

Keywords

Nutritional Quality, Cassava Varieties, Gari, Sesame

1. Introduction

Cassava (*Manihot esculenta Crantz*) has been recognized as ensuring food security in Africa [1] because it is very high in energy (350 kilocalories per 100 grams of dry matter) [2]. More than 90% of cassava produced in Africa is used for human consumption, compared to 50% in Asia and 43% in South America, while the remaining 10% is used for the production of animal feed [3] [4].

It is the fourth largest food product in the world, with an estimated production of 250 million tonnes in 2008. Its production continues to increase. It stood at 302.7 million tonnes in 2020, compared to 175.8 million tonnes in 2000, 124.1 million tonnes in 1980, and 71.3 Mt in 1961 [5].

In the Republic of Guinea, according to data provided by the National Agency for Agricultural and Food Statistics (ANASA) based on data from the 2022/2023 campaigns, national cassava production has practically doubled in eight years. National production increased from 1,334,701 tonnes in 2015 to 2,815,628 tonnes in 2023 and the cultivated area increased from 171,168 hectares to 180,365. Cassava therefore ranks second in the country's agricultural production after rice (with 3,158,141 tonnes) [6] [7].

Although production is high worldwide, cassava faces two major problems, namely rapid post-harvest deterioration [8] [9] with shelf life of less than 3 days after harvest [10] and toxicity due to cyanogenic glycosides [9] [11]. To avoid these problems, processing is a way to obtain long-life products (thus reducing losses); it also creates added value at the local level [12] [13]. Fermentation is the most widespread method used for cassava processing. Moreover, this fermentation process has proven to be a suitable method to improve the safety, organoleptic and nutritional quality of many cassava-derived foods [9] [14]. It also significantly decreases the amount of cyanide in the roots [15].

Bechoff *et al.* in 2018 reported that gari is a fermented granulated food that may have beneficial prebiotic or probiotic activity [16]-[18].

In Guinea, gari is the most consumed food in schools and universities (in the form of Attiékè) and second only to rice in the country's cities.

Despite this large production of cassava tubers and the high consumption of gari in the country, very few processing systems are in place to limit post-harvest losses of this highly perishable commodity [6], and the vast majority of this semolina is imported from neighboring countries such as Sierra Leone and Côte d'Ivoire.

However, cassava and its products are low in protein and deficient in essential amino acids and therefore have low qualitative protein content [19]. Moreover, Yetunde and collaborators in 2017, reported that gari is known for its high caloric

value, low protein, fat and micronutrient content. Furthermore, a low protein gari-based diet may predispose consumers to protein-energy malnutrition with compromised kidney functions. They also report that, protein-energy malnutrition and micronutrient deficiencies are the most feared nutritional problems encountered in developing countries [20].

Therefore, enriching gari with oilseeds such as sesame can help improve the nutritional quality of this highly valued commodity in Guinea. Indeed, sesame (*Sesamum indicum*), from the Pedaliaceae family, is an indigenous oilseed plant cultivated mainly for its seeds [21] and having great therapeutic and nutritional importance due to its richness in proteins, lipids and minerals [22] [23].

The objective of this study was to produce high nutritional quality garis from three cassava varieties (Banankougbé, TME419 and Samou-ya) cultivated in Guinea [6].

2. Materials and Methods

2.1. Collection of Cassava Samples

The fresh cassava roots of the three cassava varieties (TME419, Samou-ya and Banankougbé,) aged 8 months, 12 months and 11 months respectively, were harvested in a collar field of the cassava cultiva of the Foulay Agronomic Research Center (CRAF) under the supervision of the Institut de Recherches Agronomiques de Guinée (IRAG). Then transported the next day to the Laboratory of the UFR Biosciences of the Felix Houphouët Boigny University of Côte d'Ivoire for the production of the garis and the rest of the analyses (Figure 1).

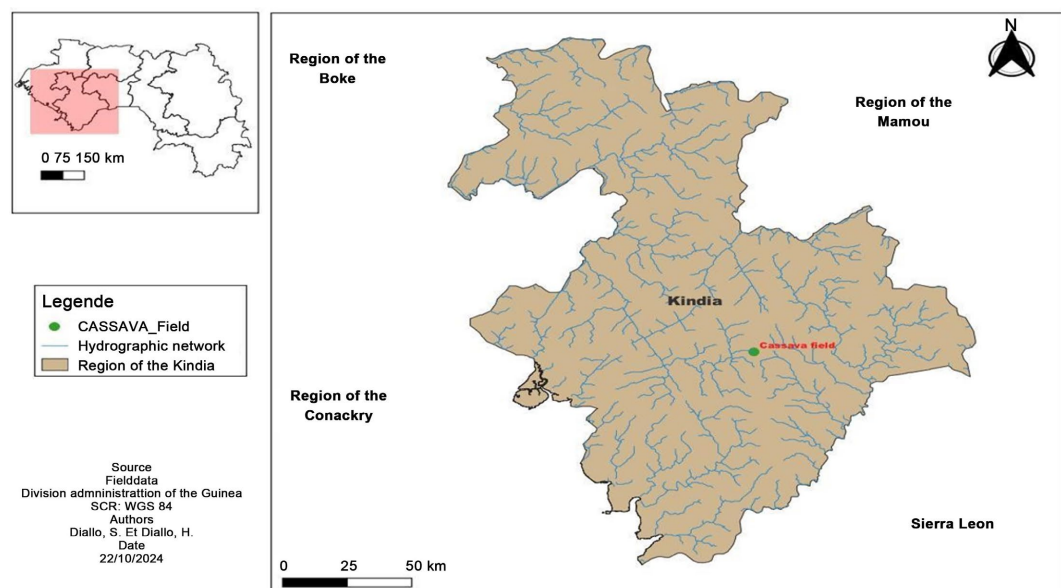


Figure 1. Area of origin of cassava samples.

2.2. Preparation of Sesame Flour

The sesame seeds were bought in a market in the city of Conakry, then sorted,

cleaned and soaked in tap water for 24 hours. Then drained and left under humidity for 30 hours (for germination), then soaked in a little water and pounded with a mortar to remove the bran from the seeds and washed to obtain the white sesame seeds. Then they were covered with a tablecloth and dried under the sun for a day, then pounded and sieved with a 0.5 to 1 mm mesh sieve to obtain the sprouted sesame flour. The flour was put in a skirt bag and also transported to the laboratory for further work.

2.3. Preparation of Gari Samples

The roots of the three sweet varieties of cassava (Banankougbé, TME419 and Samou-ya) were peeled, washed and grated manually using a metal grater then put in an electric mixer to obtain a paste, then put in three plastic trays for each variety and left to ferment at room temperature. This fermentation was carried out for 72 hours. At the end of fermentation, the pastes were manually pressed with a white cloth. The pressed musts were sieved, added sprouted sesame flour according to the method described by [20] at different percentages (0%, 5%, and 7.5%) then roasted in a steel pan on a hot plate. The granules obtained were cooled to room temperature for a few minutes and then sieved using sieves of size (0.50 mm to 1 mm). The different garis obtained from the three varieties were placed in sealed skirt bags and kept for the rest of the analyses. The different analyses were carried out on these three pastes and their gari for each variety (Figure 2).

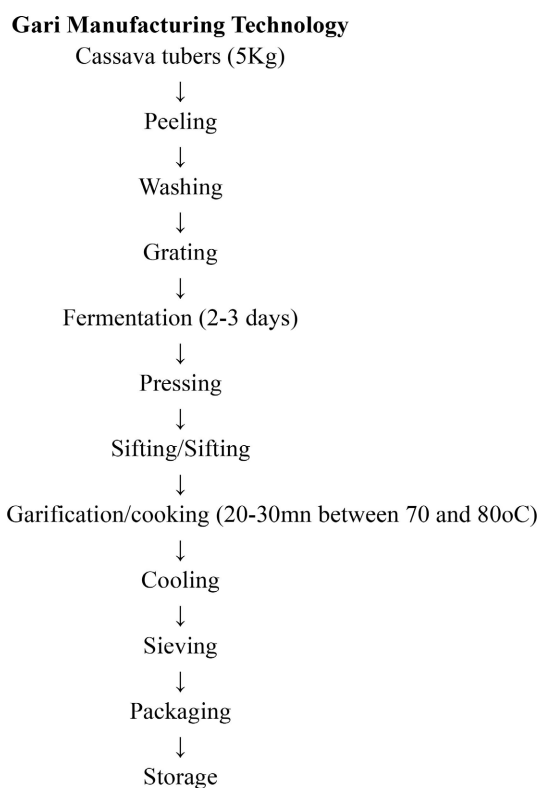


Figure 2. Diagram of the transformation of cassava tubers into Gari (Dr. Oti *et al.*, 2010).

2.4. Study Variables

Our variables were the analysis of the physico-chemical parameters of the unfermented, fermented cassava paste and the different gari: on the determination of water content, crude proteins, fat, total ash, total carbohydrates, fibers, cyanuric acid, energy value and pH measurement according to the methods described by AOAC (1990; 2000), FAO (1998; 2002); Van Soest (1963) and Liebig-Denige (1971) [24]-[27].

- Determination of moisture: The method described by AOAC (2000) was adopted, where the fresh samples weighed were dried in an air oven (Memmet, UFE-600), at 105°C to a constant weight. The percentage of moisture was calculated as the difference between fresh weight and dry weight.
- Determination of total ash content: The ash content was determined by the drying method described by AOAC (2000) where the weighed sample was heated to 550°C for 5 hours to ensure proper incineration. The percentage of ash content was calculated.
- Determination of crude protein content: The method for determining nitrogen and crude protein was performed using the Micro Kjeldahl method (AOAC, 2000). The sample was digested using sulfuric acid and a mixed catalyst (96% CuSO₄ + 3.5% Na₂SO₄, 0.5% selenium oxide) in the digestion apparatus (Kjeltec System HT 2, Foss tecator, Hoganäs, Sweden). The distillate, trapped in a boric acid solution, was titrated to 0.1 M HCl using a mixture of methyl blue and methyl red as indicators to obtain total nitrogen. Crude protein content was calculated using a correction factor of 6.25.
- Determination of lipids: Cassava flour was extracted using petroleum ether in a Soxhlet extraction unit (Soxtec system, Hoganäs, Sweden), according to the method described by AOAC (2000).
- Determination of total carbohydrates: The total carbohydrate content was calculated by difference. For this reason, the other constituents of the food, namely fat, protein, ash and fibre, are determined separately, added and subtracted from the total weight of the food. The determination of the total carbohydrate content was obtained by the FAO formula (1998).
- Determination of fibre content: The crude fibre content was determined according to the method of Van Soest (1963). 2 g of gari or dried paste is brought to a boil in 50 ml of sulphuric acid (1.25 N) and then in 50ml of soda (1.25 N) respectively for 30 minutes. The residue obtained is dried at 105°C for 3 hours and then incinerated at 550°C for 3 hours. The crude fibre content is calculated according to the formula of Van Soest (1963).
- Determination of hydrocyanic acid: the determination was carried out according to the method of Liebig-Denige (1971). 20 g of sample was macerated in 200 cm³ of distilled water for 3 to 4 h, followed by distillation to collect the distillate on 20 cm³ of soda solution containing 0.5 g of soda. Then, 100 cm³ of the distillate is taken and 8 cm³ of 5% potassium iodide (KI) is added. The assay is done with a silver nitrate solution (AgNO₃ at 0.02 N).

- Energy value: The energy value was calculated according to the application of the FAO formula (2002).
- pH determination: pH was determined using the potentiometric method of AOAC (1990) using the electrode of a pH meter. 5 g of cassava paste was weighed and added to 10 ml of distilled water in a beaker, 2 to 3 drops of phenolphthaleins were weighed, then the electrode tip of the PSD1 pH meter set to 25°C was immersed in the solution and the pH value is instantly displayed on the screen.

2.5. Data Processing

Our data were entered into Excel 2013 software and statistical analyses were performed using IBM Statistical Package for Social Sciences (SPSS) version 26 on the comparison of means in the form of means \pm standard deviations, the ANOVA table to show the difference in parameters between varieties, the nonparametric kendall test to test the difference between varieties, and the representation of the results by diagrams.

3. Results and Discussions

In this study, three varieties of cassava produced in the Republic of Guinea were processed into simple gari and sesame-enriched gari in the Biosciences laboratory of Felix Houphouët Boigny University in Abidjan. Kendall's non-parametric tests of the results of the three samples for each variety at all levels studied gave a P-Value equal to 0.000. And are presented in the form of tables and figures below.

3.1. Representation of the Variation in pH before and after Fermentation and in the Different Garis of the Three Varieties in the Form of a Diagram

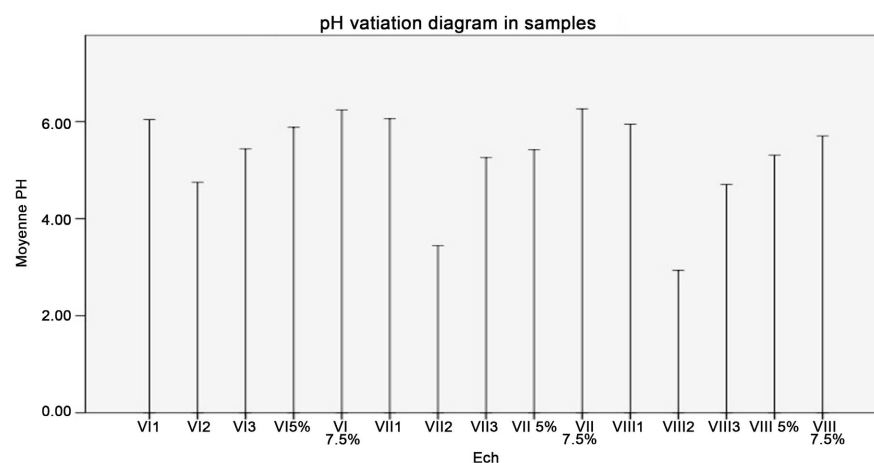


Figure 3. Diagram representing the variation of pH in the samples. **Legend:** VI = Variety 1 (TME419); VII = Variety 2 (Samou-ya); VIII = variety 3 (Banankougbe); 1 = Unfermented paste of the variety; 2 = fermented paste of the variety; 3 = simple gari of the variety; 5% = gari enriched with 5% of sprouted sesame flour; 7.5% = enriched with 7.5% of sprouted sesame flour.

This **Figure 3** shows that the pH of the unfermented pasta of the three cassava varieties was all around 6 and that after 72 hours of fermentation the pH was below 4 except for the first variety (TME419) whose pH was at 5.75. The pH of the different non-enriched gari was 5.43 respectively; 5.26 and 4.70 (Codex Standard 151 1989) in the three varieties of cassava. This shows that the gari of the third variety (Banankougbe) had the best pH. It also shows that the higher the sesame level, the more the pH increases in the different gari with pH values (5.88; 5.43 and 5.31) at an enrichment rate of 5% sesame and pH values (6.24; 6.26 and 5.70) at an enrichment rate of 7.5% sesame.

The results of the pH of the unfermented pastes are similar to those found by [5] in Guinea who had found pH between 6.29 and 7.29 in 12 varieties of cassava grown in Guinea. In single (unenriched) gari, our results are also similar to those of [22] in Nigeria who found a pH equal to 5.9 in their samples of unfortified gari and those of [24] in Cameroon who found pHs between (3.31 and 4.84) in samples of gari produced from five different varieties of cassava. In enriched gari, our results differed from those of [20] in Nigeria which had found pH between (3.87 and 4.22) in samples of gari enriched to 5% and 10% with defatted and non-defatted sesame seed flour. But comparable to those of [22] in their 5% fortified gari samples with flour from moringa, soybean and Lemon seeds.

3.2. Presentation of the Level of Hydrocyanic Acid in the Fresh Roots of the Three Varieties and in the Different Gari

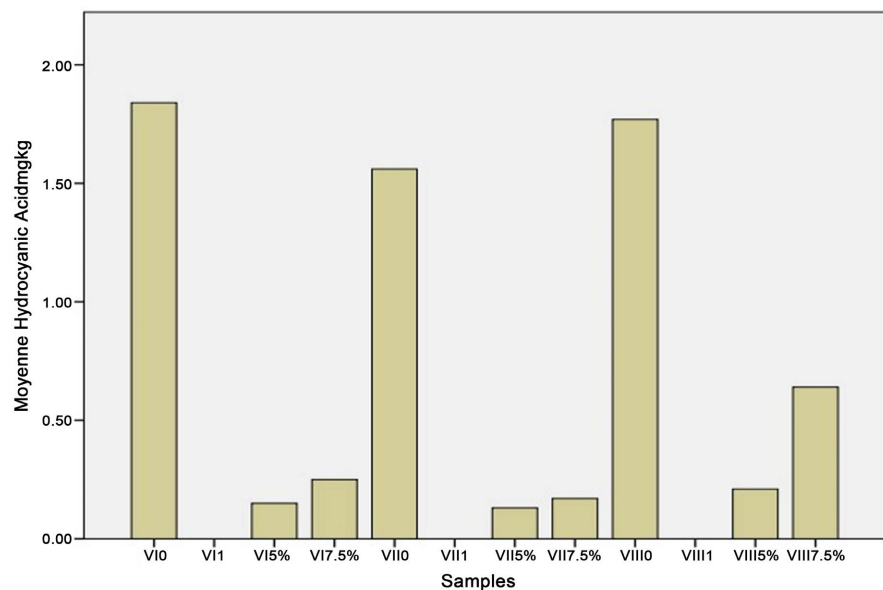


Figure 4. Diagram representing the reduction of hydrocyanic acid during the gari production process. **Legend:** VI = Variety 1 (TME419); VII = Variety 2 (Samou-ya); VIII = variety 3 (Banankougbe); 0 = Unfermented paste of the variety; 1 = simple gari of the variety; 5% = gari enriched with 5% of sprouted sesame flour; 7.5% = enriched with 7.5% of sprouted sesame flour.

Figure 4 shows that the pastes of fresh cassava roots had hydrocyanic acid val-

ues greater than 1.50 mg/kg, and that after fermentation and pricing, the content of hydrocyanic acid was zero in the simple gari. On the other hand, the insertion of sesame increased the content of this acid as the insertion rate increased, especially for the third variety whose content was 0.64 mg/kg.

These results are similar to those of [24] in Cameroon, who found hydrogen cyanide levels between 0.88 and 1.56 in their samples of fresh cassava roots and values (0.08 to 0.74) in the gari of its roots.

But lower than those found by [25] in Benin on nine gari samples, including six simple gari with hydrocyanic acid values between (6.1 to 28.1) mg/kg and three enriched gari (1.5 to 9.3) mg/kg. And also to those of [20] who had found hydrogen cyanide acid contents in their samples of the gari simple and enriched with 5% and 10% with defatted and non-defatted sesame seed flour, values between (6.29 to 6.73) and (3.81 and 4.22) respectively.

3.3. Physicochemical and Nutritional Composition of the Roots and Gari of the Three Cassava Varieties

Nutrient composition and dry matter content are important factors in the selection and utilization of cassava roots, and the results of these parameters are shown in **Table 1**.

Table 1. Presentation of the means and standard deviation of the physicochemical parameters and the energy value of unfermented, fermented and unenriched gari of the three varieties.

| Paramètres | Variété 1 | | | Variété 2 | | | Variété 3 | | |
|-----------------------|-----------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | Pâte fraîche | Pâte fermentée | Gari | Pâte fraîche | Pâte fermentée | Gari | Pâte fraîche | Pâte fermentée | Gari |
| Dry Matter (%) | 38.06 ± 0.41* | 47.33 ± 0.41*** | - | 41.13 ± 0.30* | 47.53 ± 0.94*** | - | 44.23 ± 0.45** | 49.53 ± 0.11*** | - |
| Moisture (%) | 61.93 ± 0.41*** | 52.66 ± 0.41** | 6.33 ± 0.11* | 58.86 ± 0.30*** | 52.46 ± 0.94** | 5.66 ± 0.11* | 55.76 ± 0.45*** | 50.46 ± 0.11** | 5.53 ± 0.12* |
| Ash (%) | 2.30 ± 0.10*** | 1.30 ± 0.10** | 1.46 ± 0.11** | 1.46 ± 0.11** | 1.31 ± 0.17** | 0.86 ± 0.11* | 1.96 ± 0.63** | 1.27 ± 0.11** | 1.06 ± 0.11** |
| Lipids (%) | 0.70 ± 0.10** | 0.23 ± 0.50* | 0.47 ± 0.12* | 0.53 ± 0.11** | 0.53 ± 0.11** | 0.66 ± 0.11** | 0.66 ± 0.11** | 0.55 ± 0.11** | 0.60 ± 0.20** |
| Proteins (%) | 0.16 ± 0.01** | 0.01 ± 0.00* | 0.01 ± 0.01* | 1.34 ± 0.02*** | 0.09 ± 0.11** | 0.07 ± 0.11** | 0.01 ± 0.00* | 0.01 ± 0.00* | 0.01 ± 0.01* |
| Fibers (%) | 2.76 ± 0.25** | 2.70 ± 0.26** | 2.93 ± 0.12** | 2.40 ± 0.17** | 2.50 ± 0.30** | 2.66 ± 0.28** | 1.93 ± 0.11* | 2.31 ± 0.25** | 2.30 ± 0.32** |
| TCarbohydrates (%) | 94.07 ± 0.24* | 95.75 ± 0.35* | 95.12 ± 0.11* | 94.26 ± 0.17* | 95.57 ± 0.06* | 95.74 ± 0.27* | 95.48 ± 0.66* | 95.86 ± 0.29* | 95.99 ± 0.16* |
| Energy (kcal/100 gMs) | 342.09 ± 1.72* | 343.82 ± 1.37* | 343.52 ± 0.56* | 344.24 ± 1.36* | 345.88 ± 1.17* | 347.51 ± 1.12** | 346.26 ± 2.75* | 346.69 ± 1.72** | 347.72 ± 1.58** |

Légende: VI = Variété 1 (TME419); VII = Variété 2 (Samou-ya); VIII = variété 3 (Banankoubé); P Values with the same number of exponents in the row are not significantly different from each other.

Table 1 shows that variety 3 (Banankoubé) had a higher energy value than the other two varieties with a value of 346.26 ± 2.75 kcal/100 mgMS in the unfermented dough. On the other hand, the highest ash and crude fiber rates were for the first variety (TME419) with $2.30\% \pm 0.10\%$ and $2.76\% \pm 0.25\%$. We also observe a slight decrease in protein, lipid and fiber levels after fermentation of cassava dough in the three varieties, certainly due to the action of bacteria during fermentation. Although these doughs were previously low before this fermenta-

tion. And that garification has no major impact on the modification of the chemical and nutritional compounds of the fermented dough.

These results confirm the statement of [20] which indicates that cassava and its products are low in protein and generally deficient in essential amino acids and therefore have a low qualitative protein content. They show a dry matter rate close to 40% for the TME-419 variety while the tubers were dug up at 7 months and >40% for the other two varieties, and this is comparable to the results of [6] which states that these varieties have potential in the production of gari.

They are similar to those found by [15] in Uganda on roots of five cassava varieties with respect to proteins and lipids with values between 0.74% and 1.52% of crude proteins and between 0.39% and 0.63% of fats but higher with respect to fibers and carbohydrates with values between (1.06% and 1.52%; 83.86 and 91.33) respectively. They are lower than those found by [28] in their samples of cassava roots with values between (5.86% - 9.75%) of proteins and (7.79% - 8.64%) of ash, but approaching in relation to fibers (2.88 and 3.70) and in their samples of gari in relation to proteins (4.12% to 5.58%), lipids (4.17% to 8.66%), fibers (3.05% to 7.4%) and carbohydrates (62.62% to 78.07%). They meet the standards recommended by the Codex Standard 151 1989 which recommends for fibers 2% and for ash 2.75%.

3.4. Chemical Composition and Nutritional Values of Garis Enriched with 5% and 7.5% Sesame Flour from the Three Cassava Varieties

The results of chemical composition and energy values of gari enriched at 5% and 7.5% with sesame flour are shown in **Table 2**.

Table 2. Presentation of means and standard deviations of chemical and nutritional parameters in gari samples enriched with 5% and 7.5% sesame flour.

| Paramètres | Variété 1 | | Variété 2 | | Variété 3 | |
|-----------------------|-----------------|-----------------|-----------------|----------------|------------------|----------------|
| | Gari 5%S | Gari 7.5%S | Gari 5%S | Gari 7.5%S | Gari 5%S | Gari 7.5%S |
| Moisture (%) | 4.13 ± 0.12* | 6.41 ± 0.20** | 6.53 ± 0.31*** | 4.73 ± 0.11* | 5.35 ± 0.26* | 6.10 ± 0.17** |
| Ash (%) | 1.70 ± 0.10** | 1.83 ± 0.06** | 1.33 ± 0.12* | 1.46 ± 0.15* | 1.26 ± 0.57* | 1.43 ± 0.50* |
| Lipids (%) | 6.01 ± 0.20** | 7.73 ± 0.12*** | 5.40 ± 0.20* | 6.60 ± 0.20** | 6.50 ± 0.10** | 8.13 ± 0.30*** |
| Proteins (%) | 1.23 ± 0.05* | 1.54 ± 0.02** | 1.35 ± 0.03* | 1.73 ± 0.04** | 1.23 ± 0.01* | 1.57 ± 0.05** |
| Fibers (%) | 11.33 ± 0.58*** | 13.87 ± 0.23*** | 8.23 ± 0.25** | 10.76 ± 0.25** | 5.31 ± 0.10* | 10.60 ± 0.17** |
| TCarbohydrates (%) | 79.73 ± 0.90* | 74.83 ± 0.17** | 83.69 ± 0.5** | 79.43 ± 0.59* | 85.69 ± 0.11*** | 78.26 ± 0.13* |
| Energy (kcal/100 gMs) | 337.94 ± 1.61* | 336.1 ± 1.03 | 347.25 ± 0.50** | 343.05 ± 0.48 | 363.38 ± 0.93*** | 351.30 ± 2.21 |

Legend: VI = Variety 1 (TME419); VII = Variety 2 (Samou-ya); VIII = variety 3 (Banankougbe).

Values with the same number of exponents in the row are not significantly different from each other.

The results in this table show that the P-value of all the analyzed parameters

were <0.05 and it also shows that there was a significant difference between the samples for all the analyzed parameters.

This table also shows that variety 1 (TME419) had the lowest moisture and carbohydrate levels but on the other hand the highest ash and fiber levels (1.70% - 1.87% and 11.33% - 13.87%). While variety 3 (Banankougbé) had higher lipid, carbohydrate and energy values at 5% and 7.5% than the other two samples, with respective values of (6.50% - 8.13%); (85.69% - 78.26%) and (363.38 - 351.30 kcal/100 gMs). The higher the sesame insertion rate, the higher the ash, lipid, protein and fiber levels. Especially fiber and protein, is in agreement with the statements of [22] [23] that sesame has high contents of mono- and polyunsaturated fatty acids, phytosterols, fiber and others.

Our results are close to those of [20] at 5% compared to ash, lower compared to proteins and lipids. But higher compared to carbohydrates and fibers. With values between (1.76% and 2.47%) of ash, (3.47% and 22%) of proteins, (7.61% and 10.74%) of lipids, (71.02% and 73.79%) of carbohydrates and (2.11% and 3.04%) of fibers. At 10%, they are lower than those of [19] in relation to proteins, lipids, ash and energy value on their samples of gari enriched with 10% of ungerminated sesame flour (undefatted and defatted) with respective values including (10.62% and 18.20%) of proteins, (16.01% and 7.01%) of lipids, (2.58% and 6.04%) of ash and (423.30 and 370.32) kcal/gms.

3.5. Macro- and Micro-Nutrient Composition of Simple and Enriched Garis of the Three Cassava Varieties

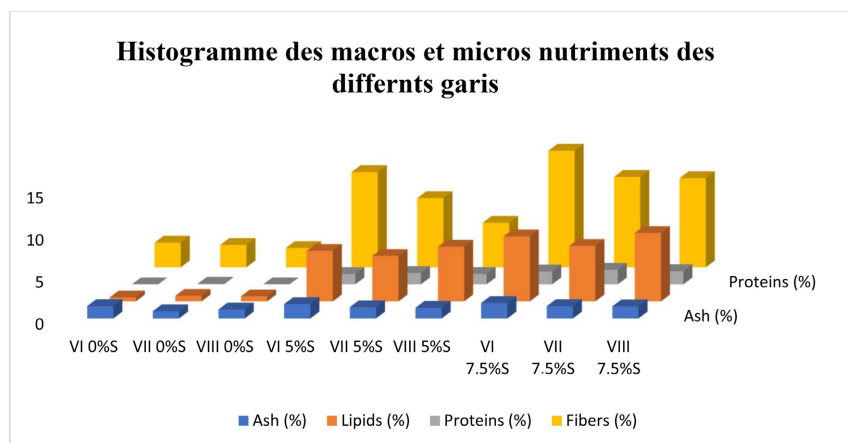


Figure 5. Histogram representing the macro-micronutrient composition of the garis produced.

This **Figure 5** shows that enriching gari with sprouted sesame flour increases the macro and micronutrient values of this food, which is particularly poor in protein and lipids.

4. Conclusions

Enriching cassava with sesame seed flour at 5% and 7.5% significantly improved

the nutritional value of gari products as the insertion rate increased, even though it led to a slight increase in hydrocyanic acid levels. This study also showed that the third variety (Banankoubé) had the highest lipid content and energy value among the three varieties used.

However, protein and lipid levels remain low compared to the nutritional needs of consuming populations. Therefore, the use of ungerminated sesame and an increase in the insertion rate will be considered to effectively assess the impact of this oilseed on the nutritional quality of gari.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the article.

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