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Enhancement of Nutritional Value and Sensory Properties of Fermented Cassava Semolina (*Attiéké*) Enriched with Soy Flour

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Abstract *Attiéké* is a fermented and steamed cassava semolina made in Côte d'Ivoire. It is an excellent source of energy, but it contains a low quantity of proteins and micronutrients. This study was carried out to evaluate the nutritional value and sensory properties of soy-enriched *attiéké*. Pearson's square method was used to determine the cassava and soy proportions. Three soy flours were combined with cassava in proportions ranging from 8 to 30%. The ferment contents and fermentation duration were ranged from 6 to 12% and from 12 to 24 hours respectively. Chemical and sensory characteristics of soy-enriched *attiéké* formulations were determined according to standard methods. Results showed that protein contents (1.24 to 12.33%), fat (0.26 to 3.42%), ash (0.60 to 1.83%) and energy (352.50 to 378.73 Kcal/100 g) of soy-enriched *attiéké* were increased significantly in relation to their soybean contents. Moreover, addition of soy flour induced a significant increase of the pH from 4.46 to 5.18; while increase of ferment content and fermentation duration decreased it from 4.46 to 4.10. The incorporation of soy flours increased the stickiness of *attiéké* which is less valued by consumers whereas increasing ferment and fermentation duration improved this parameter. In addition, beyond 10% of ferment added and 18 hours of fermentation duration, the sourness of soy-enriched *attiéké* was more accentuated. The pre-cooked soy flour added to cassava before fermentation process gave the most acceptable foods compared to soy flour that had undergone fermentation process and that was obtained with soy residue. This work suggests that addition of pre-cooked soy flour to *attiéké* and adequate fermentation improve both nutritional value and sensory properties of soy-enriched *attiéké*.

Keywords: *attiéké, soy flour, enrichment, fermentation, nutritional value, sensory properties*

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1. Introduction

Cassava (*Manihot esculenta* Crantz) roots play important role in human feeding in Côte d'Ivoire. It is the second food mostly consumed by Ivorian with a production of 4.5 million tons in 2016 [1]. In Côte d'Ivoire, it's transformed in about ten dishes of which the most known are *attiéké, placali, gari*, *attoukpou* and *tapioca* [2,3]. However, cassava has three major disadvantages: (i) toxicity associated with presence of cyanogenic compounds and potentially responsible for neurological and metabolic disorders [4]; (ii) enormous post-harvest losses due to its short life; (iii) low protein content contributing to protein-energy malnutrition, especially in areas where cassava accounts for more than 60% of daily energy intake [5]. Though the first two constraints mentioned above have been resolved through innovative processing technologies and scientific research, the one related to protein value remains a major concern because of the persistence and the increase of protein-energy malnutrition in Africa [6].

The processing of cassava into *attiéké* is as follow: crushed cassava fermentation, mash dewatering followed by sieving, granulating, sun drying and steaming of granular product [7]. It is consumed two or three times a day with either meat, fish or vegetables [8,9]. *Attiéké* is known for its high caloric value and low levels in proteins and micronutrients contents [5].

Protein-energy malnutrition and micronutrient deficiencies are the most nutritional problems in developing countries [10,11]. Food fortification is therefore a recommended strategy for food nutritional quality improving [12].

Enrichment of *attiéké* with vegetable protein sources, especially soybean, could improve its nutritional quality. Indeed, soybean is an excellent source of proteins (40%), lipids (20%) and fibers (18%) [13,14,15]. Protein composition of these seeds largely covers needs of essential and semi-essential amino acids of human. It is one of the oleaginous seeds rich in polyunsaturated fatty acids accounting for 54 to 72% of total lipids [16]. Among these polyunsaturated fatty acids, linoleic acids (omega 6) and alpha-linolenic (omega 3) are essential for human body [17]. It could be a good substitute for animal protein [18]. To improve nutritional properties of cassava products, several studies have been carried out on its products [19,20,21,22,23,24,25], but little on *attiéké* (fermented cassava semolina).

This work aims to enrich cassava semolina (*attiéké*) with soy flour using "Pearson's square" method to improve its nutritional value.

2. Materials and Methods

2.1. Raw Materials

The main raw materials used in this project work are cassava roots and soybeans. Fresh cassava roots (*Manihot esculenta* Crantz) and yellow soybeans (*Glycine max* L. Meril) were purchased from the market of Bonoua (Côte d'Ivoire) and the National Center of Agricultural Research of Bouaké (Côte d'Ivoire) respectively.

2.2. Methods

2.2.1. Preparation of the various soy flours

Soybeans underwent several treatments (pre-cooking, fermentation and obtaining the soy residue by elimination of the "soymilk") as shown in Figure 1. These treatments led to three various flours of soy.

The first soy flour was obtained after pre-cooking of soybeans and the second soy flour after fermentation. The third soy flour was obtained after wet milling of soybeans and removal of "soymilk".

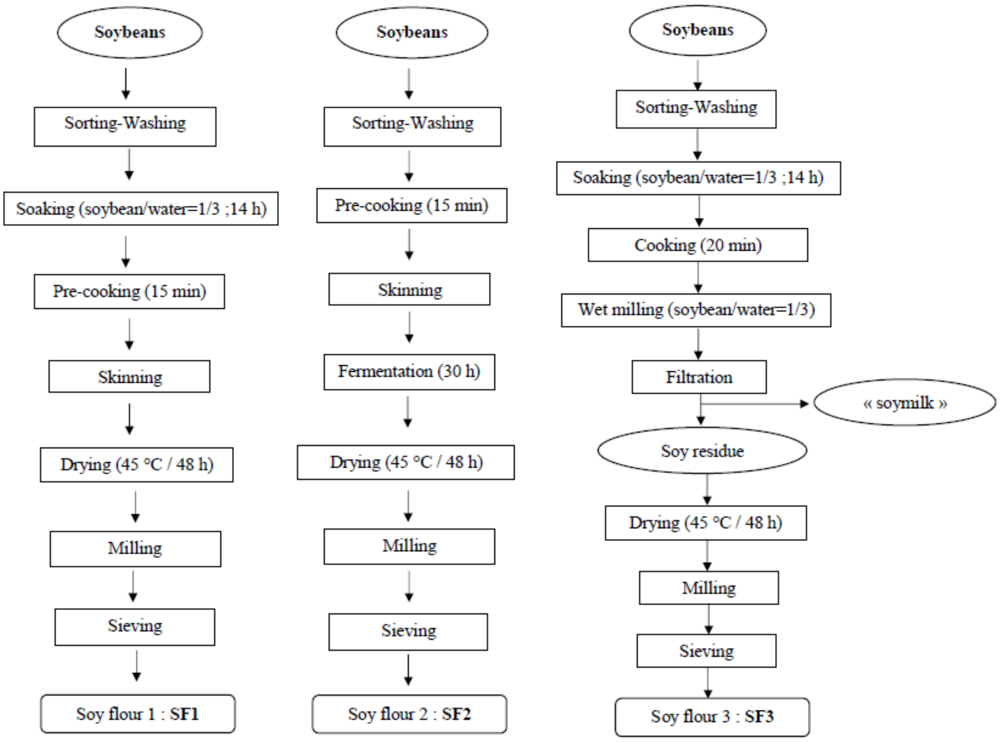


Figure 1. Diagram of preparation of the various soy flours (SF1, SF2 and SF3)

2.2.2. Preparation of soy-enriched *attiéké*

Pearson's square method below (Figure 2, Table 1) was used to determine proportions of the two feed ingredients which are cassava and soy flour.

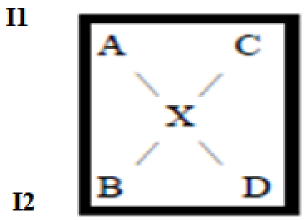


Figure 2. Pearson's square [26]

- **X** is the required proteins.
- **A** et **B** represent the protein contents of the cassava (**I1**) and soy (**I2**) to get the required proteins.
- **C** is difference between **B** and **X** ignoring the sign; It's the share of cassava in the mixture.
- **D** is difference between **A** and **X** ignoring the sign; it's the share of soybean in the mixture.
- Cassava proportion (**I1**) = $\frac{C}{C+D} \times 100$.
- Soybean proportion (**I2**) = $\frac{D}{C+D} \times 100$.

Soy-enriched *attiéké* was prepared following the method described in Figure 3. Samples were produced by incorporation of soy flour into cassava dough in two steps: (A: fermentation or B: granulating). A traditional biological ferment (whole cassava roots cooked for 10 minutes and fermented for 48 hours) commonly named "mangnan" was added to cassava dough at rates from 6 to 12% (w/w). Cassava dough obtained was fermented in the synthetic fibre bags from 12 to 24 hours to allow the development of aroma and taste as well as texture of soy-enriched *attiéké*.

Table 1. Soy-enriched *attiéké* according to Pearson's square

Samples	A (%)	B (%)	X (%)	C	D	Proportion of cassava (g/100g of mixture)	Proportion of soybean (g/100g of mixture)	Step of adding soybean	Various flours of soy
F1	2	38	6	32	4	88.89	11.11	Granulating	SF1
F2	2	38	8	30	6	83.33	16.67	Fermentation	SF1
F3	2	38	13	25	11	69.44	30.56	Fermentation	SF1
F4	2	38	13	25	11	69.44	30.56	Granulating	SF1
F5	2	36	5	31	3	91.18	8.82	Fermentation	SF2
F6	2	36	8	28	6	82.35	17.65	Fermentation	SF2
F7	2	36	8	28	6	82.35	17.65	Granulating	SF2
F8	2	38	8	30	6	83.33	16.67	Fermentation	SF3
F9	2	38	10	28	8	77.78	22.22	Fermentation	SF3

A: Cassava protein content, B: Soy flour protein content, X: Required protein content, C: Difference between B and X, D: Difference between A and X, SF1: Soy flour obtained after pre-cooking, SF2 Soy flour obtained after pre-cooking and fermentation, SF3: Soy flour obtained after wet milling of soybeans and removal of "soymilk".

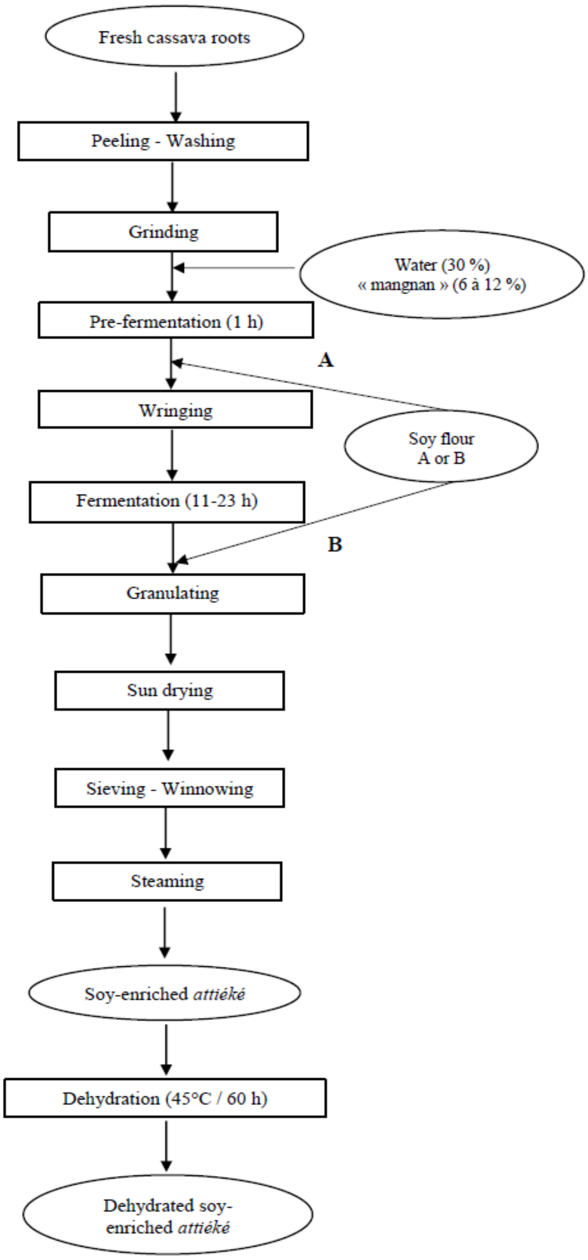


Figure 3. Diagram of preparation soy-enriched *attiéké*

2.2.3. Chemical Analysis

Dry matter, ash, protein, fat, pH, and titratable acidity were determined using the Association of Official Analytical Chemists (AOAC) methods [27]. Dry matter was determined by oven drying at 105°C for 24h and ash using a muffle furnace at 550 ° C for 24 h. Crude Protein was determined by the Kjeldahl method and its content was obtained by multiplying the corresponding total nitrogen content by a factor of 6.25 [28]. Fat content was determined according to the Soxlhet method using hexane as solvent. Total carbohydrates were determined by difference of the total material to other biochemical compounds. The energy value was calculated using the Atwater's calorie conversion factors: 4 kcal/g for crude protein, 9 kcal/g for crude fat and 4 kcal/g for available carbohydrate [28]. pH and total titratable acidity were determined with a pH-meter and acid-base assay respectively.

2.2.4. Sensory Evaluation

A descriptive test was conducted to evaluate the stickiness, firmness and sourness of the semolina [29]. Therefore, a focus group (6 people) was recruited based on their experience in the production of *attiéké*. The test consisted in describing each formulation on a descriptive scale at seven (7) points according to the intensity of stickiness, firmness and sourness.

A hedonic test was also performed [29]. The panel consisted of 30 people was recruited based on their availability. Each panelist, isolated from others, received samples of about 50 g of samples. The test consisted of recording each formulation on a hedonic five (5) point scale ranging from very bad (1) to very good (5). The studied parameters were colour, aroma, taste and overall acceptability.

2.2.5. Statistical Analysis

All the analyses were carried out in triplicate. The statistical package in IBM SPSS STATISTICS 22.0 computer program was used. Data obtained were subjected to Analysis of Variance (ANOVA). Differences between means were evaluated using Duncan's test and significance accepted at α=0.05 level.

3. Results and Discussion

3.1. Chemical Characteristics of the Soy-enriched *attiéké*

The formulation of the foods consists of mixing two or more ingredients to optimally satisfy the nutritional needs of body.

The chemical composition of the three soy flours is shown in Table 2. Protein levels were ranged from 36.33 to 37.86%. Results didn’t show any significant difference ($p<0.05$) between these three soy flours protein contents. Moreover, fat and ash values are affected by treatments. It can noticed that fat contents of soy flour SF2 and SF3 (20% and 18.60%) are significantly lower than those of SF1 (24.20%). For SF1, pre-cooking for 15 minutes would lead to less fat loss, whereas for SF3 flour, the separation of the soy residue from "soymilk" induces a significant loss of lipids in the soy residue. Kolapo and Sanni [30] have shown that the separation of the soy residue from "soymilk" leads to a distribution of lipids between these two by-products. In addition, SF3 has the highest ash content of 4.10% compared to 3.25% and 3.20% for SF1 and SF2 respectively.

The particularity of soy flour SF2 is that it has a higher acidity (pH = 5.56) compared to other two soy flours (pH = 6.56 for SF1 and pH = 6.12 for SF3). The fermentation process adopted to produce this flour may be the reason of the pH lowering [31,32].

Table 3 presents the chemical characteristics of soy-enriched *attiéké* samples. Dry matter contents of cooked semolina are between 44 and 49%, while those of dehydrated *attiéké* are between 86 and 92%. These values are close to those of Yao *et al.* [33], whose contents are 53.40% for fresh *attiéké* and 89.40% for dehydrated *attiéké*. The low moisture of dehydrated semolina inhibits the growth of microorganisms [34], which would promote a better stability and extend the shelf life of products.

The addition of the soy flour (SF1) from 0 to 30 % led an increase of the protein, fat and ash contents respectively 1.24 to 12.33%; 0.26 to 3.42% and 0.60 to 1.80%. As for SF2, the addition soy flour from 0 to 17% induced an increase of protein, fat and ash contents respectively from 1.24 to 8.00%; 0.26 to 2.82% and 0.60 to 1.80%. For soy flour SF3, its addition from 0 to 22% led an increase of 1.24 to 7.00% of proteins, 0.26 to 3.35% of fats and 0.60 to 1.83% of ashes. Those increase could be attributed of soy flour because of it high protein and fat contents. The results obtained are in accordance with those of Folake *et al.* [35] who reported an increase in protein content with addition of the soy flour. Despite increases in initial protein value, better results are observed with soy flour SF1. The applied treatments during production of these different soy flours would have an impact to nutrient content of samples [24].

The protein contents of the samples obtained are comparatively lower than the protein requirements fixed with the "Pearson's square". The wringing, steaming and dehydration steps during the manufacturing process would be responsible for this loss of protein. Indeed, the incorporation of soy flour before wringing crushed cassava causes significant losses of nutrients, including proteins and ashes. In their work, Sotomey *et al.* [36] showed that the wringing stage caused significant mineral losses (79% ash loss). The results obtained on the one hand with the formulations F3 and F4 and on the other hand with the formulations F6 and F7 corroborate this argument, since the protein contents are 9.12% and 12.33% for F3 and F4 and 6.19% and 8% for F6 and F7. The formulation F4 has the highest protein content. According to Labat [37], soy contains in equilibrium proportions proteins of good biological value containing all the essential amino acids. As a result, the incorporation of soybeans could improve the quality of the proteins of the enriched *attiéké* at the same time as their contents. The increase in protein content in *attiéké* would allow the prevention of protein-energy malnutrition.

Increasing the lipid content is beneficial for the human body. In addition to providing energy, consumption soy-enriched *attiéké* could have other advantages, because according to Demaison and Moreau [17], omega-type fatty acids present in soybean (54 to 72% of total lipids) are responsible for the cardiovascular and immune balance. Also, the presence of lipids in a food is essential to prevent the deficiency of fat-soluble vitamins, particularly vitamin A.

The pH of the food products was ranged from 4,1 to 5.2. These values are consistent with the accepted pH range for *attiéké* quality as defined by CODINORM [38] which is between 4 and 5, except for the formulation F7. As for titratable acidity, it changes inversely with pH. The increase in pH observed with the F5, F6 and F7 formulations relative to the control would be related to the gradual addition of soybeans. This result agrees with Ogunlakin *et al.* [24]. On the contrary, fermentation decreases the pH value. Akely *et al.* [39], Adsokan *et al.* [40], Emire and Buta [41] reported in theirs studies that the fermentation increased the acidity. During this process, microorganisms, including lactic acid bacteria produce organic acids [42], responsible for the acidity of the food. Afoakwa *et al.* [43] stated in their study that enrichment of gari with soybeans by up to 20% causes only minimal changes in pH and acidity. A pH above 5 exposes the food to rapid degradation, while a pH below 5 promotes its preservation.

Table 2. Chemical composition of soy flours

Soy flours	Dry matter (%)	pH	Titratable acidity (meq-g/100g)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Energy value (kcal/100g)
SF1	92.00^{c} ±0.00	6.56^{b} ±0.00	11.33^{b} ±1.15	37.93^{b} ±0.50	24.20^{b} ±0.60	3.25^{a} ±0.25	26.62^{a} ±1.14	476.00^{c} ±2.00
SF2	90.61^{b} ±0.21	5.56^{a} ±0.01	20.33^{c} ±0.57	36.33^{a} ±2.88	20.00^{a} ±0.00	3.20^{a} ±0.00	31.08^{c} ±2.89	449.64^{b} ±0.84
SF3	90.30^{a} ±0.1	6.12^{b} ±0.00	5.99^{a} ±0.00	37.86^{b} ±0.29	18.60^{a} ±1.21	4.10^{b} ±0.10	29.74^{b} ±1.47	437.80^{a} ±6.06

Values are expressed as means ± standard deviation; means with different letters are significantly different ($\alpha = 0.05$) along the column. SF1: Soy flour obtained after pre-cooking, SF2 Soy flour obtained after cooking and fermentation, SF3: Soy flour obtained after wet milling of soybeans and removal of "soymilk"; DM: Dry matter.

Table 3. Chemical composition of soy-enriched *attiéké* samples

Samples	Dry matter of cooked semolina (%)	Dry matter of dehydrated semolina (%)	pH	Titratable acidity*	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Energy value (kcal/100g)
Control	47.51^{f} ±0.09	88.40^{d} ±0.00	4.46^{c} ±002	13.33^{e} ±0.57	1.24^{a} ±0.13	0.26^{a} ±0.03	0.60^{a} ±0.10	86.30^{e} ±0.06	352.50^{b} ±0.22
F1	46.11^{d} ±0.30	87.70^{c} ±0.10	4.85^{g} ±0.00	8.33^{a} ±0.57	5.22^{c} ±0.00	1.31^{b} ±0.00	1.00^{bc} ±0.00	80.17^{c} ±0.10	353.35^{b} ±0.40
F2	46.31^{d} ±0.20	86.50^{a} ±0.17	4.55^{d} ±0.00	14.96^{f} ±0.00	6.67^{cde} ±0.59	2.57^{d} ±0.74	1.20^{cd} ±0.20	76.06^{b} ±1.14	354.07^{b} ±3.83
F3	46.75^{e} ±0.15	91.17^{f} ±0.16	4.95^{h} ±0.00	9.00^{ab} ±0.00	9.12^{f} ±2.03	2.68^{d} ±0.41	1.70^{e} ±0.10	77.67^{b} ±2.41	371.27^{d} ±150
F4	49.40^{i} ±0.30	91.27^{f} ±0.06	4.92^{h} ±0.00	10.33^{c} ±0.57	12.33^{g} ±1.22	3.42^{f} ±0.27	1.80^{e} ±0.00	72.72^{a} ±1.40	374.95^{e} ±1.10
F5	48.80^{h} ±0.00	86.80^{b} ±0.20	4.40^{b} ±0.00	14.67^{f} ±1.15	2.76^{b} ±0.00	0.69^{a} ±0.00	0.80^{ab} ±0.20	82.55^{d} ±0,.00	347.45^{a} ±0.00
F6	43.51^{a} ±0.11	91.40^{fg}±0.00	4.71^{f} ±0.01	12.00^{d} ±0.00	6.19^{cd} ±0.61	2.00^{c} ±0.53	1.30^{d} ±0.10	81.91^{cd} ±0.70	370.40^{d} ±0.40
F7	48.16^{g} ±0.25	88.84^{e} ±0.16	5.18^{i} ±0.00	9.32^{b} ±0.57	8.00^{ef} ±0.00	2.82^{de} ±0.00	1.80^{e} ±0.00	76.22^{b} ±0.59	362.23^{c} ±2.62
F8	45.46^{c} ±0.40	91.67^{g} ±0.33	4.61^{e} ±0.07	12.33^{d} ±0.57	5.45^{cd} ±1.26	3.00^{def} ±0.00	1.70^{e} ±0.30	81.51^{cd} ±1.55	374.87^{e} ±2.54
F9	44.22^{b} ±0.31	92.33^{h} ±0.11	4.10^{a} ±0.01	20.00^{g} ±0.00	7.00^{de} ±0.00	3.35^{ef} ±0.21	1.83^{e} ±0.16	80.15^{c} ±0.14	378.73^{f} ±1.42

Values are expressed as means±standard deviation; means with different letters are significantly different (α= 0.05) along the columns. Sample codes are stated in Table 1; Titratable acidity (meq-g/100g); DM: Dry matter.

3.2. Sensory Characteristics of the Soy-enriched *attiéké*

Table 4 and Figure 4 show that the sensory parameters are influenced by the amounts of added soy and ferment, as well as the fermentation duration.

The increase in the stickiness of semolina is due proportionally to the soy incorporation rate. This is reflected with the formulation F1 versus F4 and F2 versus F3. These results are corroborated with those of Ezinwanyi and Ndaeyo [25]. The protein structure influences stickiness of enriched semolina. The presence of hydrophilic chains in the protein structure could be responsible of changes observed in cooking semolina [44]. In addition, it is higher when soy flour is added to cassava dough during semolina. The evaluation of stickiness was used to classify the quality of semolina in a decreasing manner according to the three different soy flours used as follows: *attiéké* enriched with SF1 flour, then *attiéké* enriched with flour SF2 and finally *attiéké* enriched with flour SF3. In addition, the sticky nature changes inversely with the ferment rate and the fermentation duration. This result agrees with those of Adegunwa *et al.* [45]. In fact, fermentation produces organic acids that are responsible for modifying the rheological behaviour of foods during cooking [31]. A ferment content of 10% and a fermentation duration of 16 hours are the optimum values of the semolina manufacturing process. Akely *et al.* [39] suggested that low ferment content and insufficient fermentation duration lead to poor cooking of cassava semolinas. The stickiness can be improved with the addition of oil before granulating or steaming [46]. The oil could facilitate the formation of grains (semolina) and avoid the caking (agglomeration) of these during steaming [47]. Firmness is the ability of semolina to resist crushing [48]. The incorporation of soy reduces the firmness of the semolina. The high starch content found in cassava is behind this firmness. In addition, the levels of fiber, protein, and the amount of water absorbed could affect the texture of semolina [37,49]. The addition of soybean with low starch content to cassava could be responsible of the change in firmness, which would explain the decrease in semolina resistance when adding soy.

Fermentation is the main factor affecting the sourness of semolina. Beyond 10% of ferment and 18 hours of fermentation, the sourness is significantly pronounced. The production of organic acids by the microorganisms would be at the origin of this phenomenon.

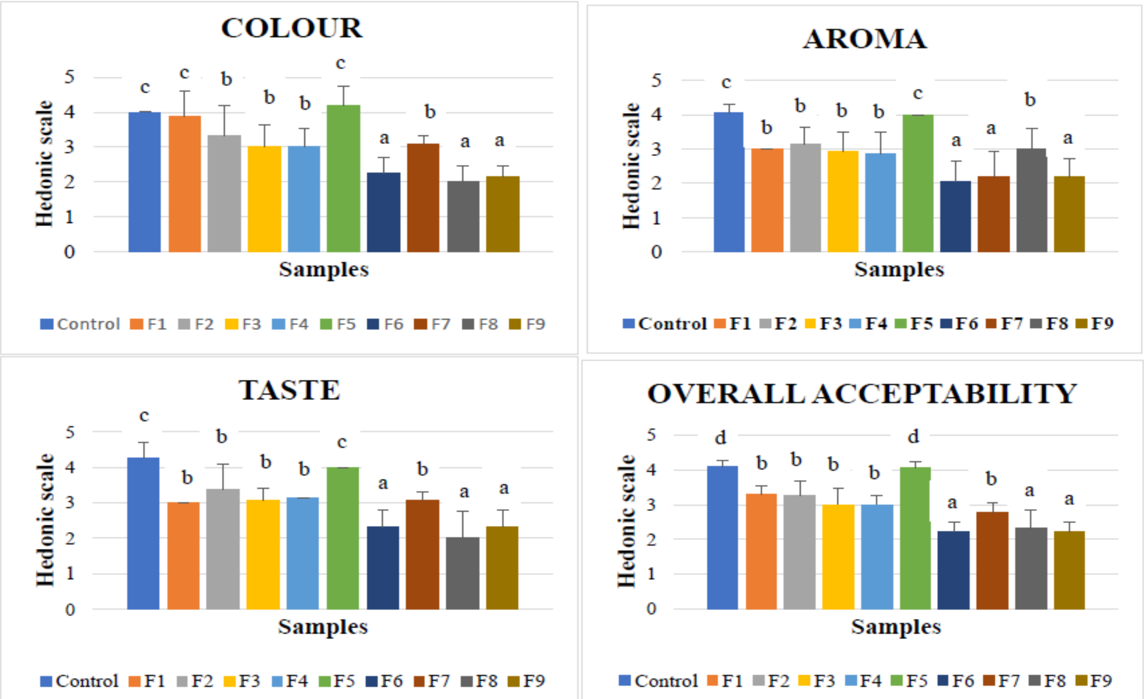
The addition of soy modifies the colour, taste, aroma and overall acceptability of the formulations, except for the 8.82% SF2 (F5) soy flour formulation which is comparable to the control (ordinary *attiéké*).

Figure 3 shows that the formulations are generally appreciated when soy flour SF1 is used for the enrichment of *attiéké*. On the other hand, the addition of SF3 soy flour to *attiéké* is less appreciated. Formulations F1, F2, F3, F4, F5 and F7 are those whose colour and taste are accepted. Taste is the main factor that determines the acceptability of a product [50]. The incorporation of soy also influences the aroma of the formulations. Those having the tolerable aromas are the formulations F1, F2, F3, F4, F5 and F8.

Table 4. Influence of the soybean content, ferment content and fermentation duration on sensory properties of soy-enriched *attiéké*

Samples	Soy flour content (%)	Ferment content (%)	Duration of fermentation (h)	Stickiness	Firmness	Sourness
Control	0	10	16	1	7	2
F1	11,11	10	16	2	5	1
F2	16,67	10	20	2	5	2
F3	30,56	6	16	3	4	1
F4	30,56	10	14	4	4	1
F5	8,82	10	16	1	6	3
F6	17,65	8	12	2	4	2
F7	17,65	8	14	3	4	1
F8	16,67	12	18	2	4	2
F9	22,22	12	24	3	3	2

Descriptive scale: 1 (low intensity) to 7 (high intensity); Sample codes are stated in Table 1.



Hedonic scale: 1 = Very bad 2 = Bad 3 = Acceptable 4 = Good 5 = Very good

Values are expressed as means ± standard deviation; means with different letters are significantly different (α= 0.05); Sample codes are stated in Table 1.

Figure 4. Sensory profile of the soy-enriched *attiéké*

4. Conclusion

The objective of this study was to formulate and characterize soy-enriched cassava semolina (*attiéké*). This study showed that the enrichment with soy flour from 0 to 30% improves the nutritional composition of *attiéké*. The soy flour and traditional ferment contents, as well as the fermentation duration influenced the stickiness, firmness and sourness of semolina. The pre-cooked soy flour incorporated to *attiéké* before fermentation gave the best sensory of soy-enriched *attiéké*. The wringing of the cassava dough previously incorporated soy flour causes a significant loss of nutrients. Thus, to limit nutrient losses and improve the sensory quality of semolina, it would be appropriate to incorporate the soy flour after the wringing step. The enrichment of *attiéké* would help to fight against protein deficiency. Protein digestibility and conservation studies could be performed on this novel food.

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