



## Nutritional and antioxidant potential of «ATTIÉKÉ» (Cassava semolina) enriched with soybean

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### Abstract

«Attiéké» is a fermented steamed cassava semolina produced mainly in Côte d'Ivoire. This food is an excellent source of energy, but it contains small amounts of protein and micronutrients. The objective of this study was to evaluate the nutritional and antioxidant potential of soy-enriched «attiéké».

Eight formulations of soy-enriched «attiéké» were produced. Soybean flour was incorporated in proportions ranging from 0 to 12%. Micronutrients (minerals and vitamins A, B and C), phytonutrients, antinutrients and antioxidant activity were evaluated according to standard methods.

The results showed that the contents of phosphorus, calcium, zinc, β-carotene and vitamin B12 increased significantly with the amount of soy incorporated. The values changed from 60 to 260 mg/100g; 17.5 to 27.23 mg/100g; 1.52 to 3.08 mg/100g; 172.29 to 858.90 μg/100g and 1.18 to 1.28 μg/100g, respectively. Total polyphenols (136.51 to 337.61 mg/100g) and tannins (49.84 to 177.65 mg/100g) were positively influenced by soy level and fermentation. On the other hand, fermentation caused phytate (20.57 to 35.11 mg/100g) and oxalate (14 to 64.28 mg/100g) contents to decrease to acceptable levels. The molar ratios were favorable to the assimilation of minerals by the body. Total antioxidant activities ranged from 34.78% (plain «attiéké») to 66.64% (soybean flour).

The consumption of soy enriched «attiéké» by providing micronutrients and phytochemicals essential for good health, could be beneficial to prevent and correct micronutrient deficiencies in malnourished people.

**Keywords:** enriched soybean «attiéké», micronutrients, antinutrients, phytonutrients, antioxidants

### Introduction

Protein-energy malnutrition and micronutrient deficiencies are the most feared nutritional problems encountered in developing countries [1]. High-income people can achieve food security because they have easy economic access to supplement their staple foods with micronutrient-rich foods, such as: meat, fish, poultry, eggs, milk, dairy products, and a wide variety of fruits and vegetables. However, these foods still cannot be affordable for low-income people who rely primarily on more monotonous diets of grains, roots, and tubers that are mostly lacking in valuable nutrients [2].

Fortifying low-nutrient foods with high nutritional quality staples at lower costs could be an effective approach to ensure nutritional balance [3]. This is the case for «attiéké», the main product derived from cassava consumed in Côte d'Ivoire. This food is obtained after fermentation of ground cassava, pressing of the fermented cassava paste, followed by sieving, granulation, partial drying and steaming of the semolina [4]. «attiéké» is consumed two to three times a day with fish, meat or sauces [5, 6]. However, the problem with the consumption of this dish is its low nutritional value. Indeed, «attiéké» is known for its high caloric value (88% total carbohydrates) and low protein (2%) and micronutrient (0.6% ash) content.

Among the legumes, soybeans are widely used in both human and animal nutrition. Soybeans contain about 40-45% protein, 18-22% lipids [7], about 3-4% minerals [8], and vitamins (A, B1, B2, B9, C and E) [9]. Fabiyi and Hamidu [10] reported that the quality of soy protein can be comparable to animal protein sources, such as: meat and

milk. It is limiting in sulfur-containing amino acids, such as: methionine and cysteine, but contains enough lysine to make up for the lysine deficit in roots and tubers [11]. It also contains 14% saturated fatty acids, 23% monounsaturated fatty acids and 63% polyunsaturated fatty acids [12]. Soybeans owe their therapeutic value to the functional proteins, polyunsaturated fatty acids, dietary fiber, phytoestrogens, isoflavones, and anthocyanins they contain [13, 14, 8, 15].

Soybeans also contain many anti-nutritional factors, such as trypsin inhibitors, phytic acid, and saponins that reduce their nutritional value and cause health problems [16, 15]. Increasing the nutritional quality of soybean can be achieved by several processing methods such as: heat treatments, salt treatment, fermentation, sprouting, soaking, and urea treatment [17].

Given the public's interest in nutrients in food products, it is important to develop a product that can meet their needs. Fortification of cassava products with legumes has been widely studied and reported by scientists [18, 8, 19]. However, few studies have been conducted on the fortification of «attiéké». In addition, the in vivo study conducted by Kouakou *et al.* [20] revealed that consumption of «attiéké» enriched with 9 and 12% soybeans promotes good growth in rats. Thus, the present study aims to evaluate the nutritional and antioxidant potential of soy-enriched «attiéké».

### Materials and methods

#### 1. Study material

Tuberous roots of cassava (*Manihot esculenta* Crantz,

variety Bonoua) were purchased from producers in the city of Bonoua (Côte d'Ivoire). Yellow soybeans (*Glycine max* L. Meril, variety Canarana) were purchased from the National Center of Agronomic Research (Côte d'Ivoire).

**2. Methods**

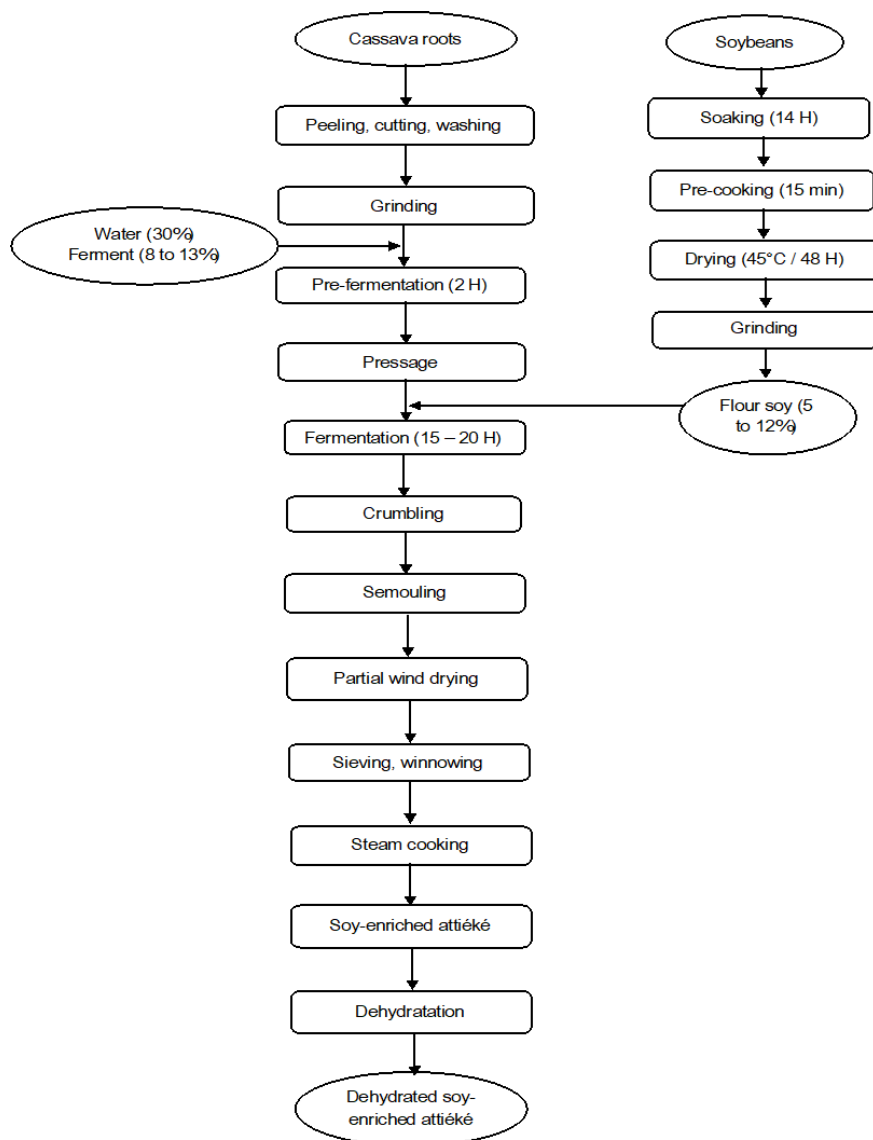
**2.1. Production of soy-enriched «attiéké»**

Soy-enriched «attiéké» formulations were produced using the method described by Kouakou *et al.* [21] (Figure 2). Tuberos cassava roots were peeled, defibered, cut with a stainless knife, ground, and mixed with the ferment (8-13 % of cassava pulp). The dough, partially fermented for 2 h, was packed in a jute bag and then squeezed out with a screw press until it became a set dough. To this paste was added soy flour, whose values were between 5 and 12 % of the cassava pulp. The resulting mixture was fermented for 15 to 20 hours at room temperature. After the fermentation period, the pressed paste was crushed (sieved with a raffia

sieve), granulated manually, and then partially wind dried. Two (2) more sieves were performed. The semolina was winnowed, then steamed for 10 min in a couscous maker. The formulations were dehydrated in an oven at 45°C for 48 h.

**Table 1:** Formulations developed

«attiéké» formulations enriched with soybean	Variables		
	Fermentation rate	Soybean rate	Fermentation time
FO <sub>1</sub>	11,731	5,538	14,115
FO <sub>2</sub>	8,269	5,538	19,885
FO <sub>3</sub>	11,731	5,538	19,885
FO <sub>4</sub>	11,731	12,462	19,885
FO <sub>5</sub>	13	9	17
FO <sub>6</sub>	10	9	22
FO <sub>7</sub>	10	9	



**Fig 1:** Flow chart for the production of soy-enriched «attiéké»

**2.2 Methods of analysis of soy-enriched «attiéké»**

**2.2.1. Determination of micronutrients**

Minerals were measured according to the methods of Clément and Françoise [22]. Ash from the incineration of the samples was used to quantify: potassium, magnesium,

calcium, phosphorus, sodium, manganese and zinc.

The determination of β-carotene was carried out according to the method described by Aké *et al.* [23]. The vitamin A content of the samples was determined by dividing the β-carotene content by 6 [24].

The contents of vitamins B1, B2 and B12 were determined by high performance liquid chromatography. The assay method is based on the separation of these three (3) water-soluble vitamins by reverse phase HPLC using a C18 column and UV detection at 272 nm.

The method used for the determination of vitamin C in the samples was the one described by Pongracz *et al.* [25], whose principle is based on the reduction of 2,6 DCPIP (2,6 dichlorophenol-indophenol) by it.

### 2.2.2. Determination of phytonutrients

The determination of total polyphenols was done according to the method of Singleton *et al.* (1999) [26] and that of tannins according to the method of Bainbridge *et al.* [27]. The method used for the determination of flavonoids is that of Meda *et al.* [28].

### 2.2.3. Determination of antinutrients

The method used for the determination of phytates is that of Latta and Eskin [29]. The oxalate content was determined by titration with potassium permanganate (KMnO<sub>4</sub>) according to the method of Day and Underwood [30].

### 2.2.4. Determination of total antioxidant activity

The method of Choi *et al.* [31] was used for the evaluation of DPPH radical scavenging capacity. Antioxidant activity was expressed as % relative inhibition compared to the control.

### 2.2.5. Enzymatic hydrolysis of carbohydrates

Enzymatic hydrolysis of carbohydrates was evaluated using the method of Yeboua *et al.* [32]. The digestive juice of snail *Achatina ventricosa* was used as an enzyme source. Digestibility was monitored for 180 min (0; 5; 10; 20; 40; 60; 90; 120; 150; 180 min). Soluble sugars were determined by the 3,5-dinitrosalicylic (DNS) method [33]. The degree of hydrolysis of the samples was expressed as the amount of

reducing sugars / hydrolysis time.

## 2.3- Statistical analysis of the data

The statistical analysis of the data covers the calculation of the mean affected by the standard deviation. The statistical differences between the samples and the measured parameters were verified with ANOVA by the IBM SPSS Statistics version 22.0 software. The comparison of the means was done with Duncan's test with a significance level of 5%.

## Results

### 1. Micronutrient contents

The mineral contents of the plain «attiéké» and the FO2, FO4 and FO6 soy enriched «attiéké» formulations are presented in Table 2.

The results obtained indicate that phosphorus contents vary between 60 (control) and 260 mg / 100 g (FO4). Potassium levels ranged from 393.33 (plain «attiéké») to 613.67 mg/100 g (FO4); calcium levels ranged from 17.5 (plain «attiéké») to 27.23 mg/100 g (FO4). Magnesium contents range from 18 (plain «attiéké») to 26 mg / 100 g (FO4). Zinc contents vary between 1.52 (plain «attiéké») and 3.08 mg / 100 g (FO4). The mineral content of plain «attiéké» is lower than that of the soy-enriched «attiéké» formulations, except for iron.

The amount of  $\beta$ -carotene represents 6 times the amount of vitamin A. The  $\beta$ -carotene and vitamin A contents of cooked semolina and dehydrated semolina were compared with each other for each formulation. The  $\beta$ -carotene contents varied from 303.68 to 809.82  $\mu$ g / 100 g of cooked semolina and between 172.29 and 858.90  $\mu$ g / 100 g of dehydrated semolina. As for vitamin A contents, the values varied from 50.61 to 134.97  $\mu$ g / 100 g of cooked non dehydrated semolina and from 28.72 to 143.15  $\mu$ g / 100 g of cooked dehydrated semolina.

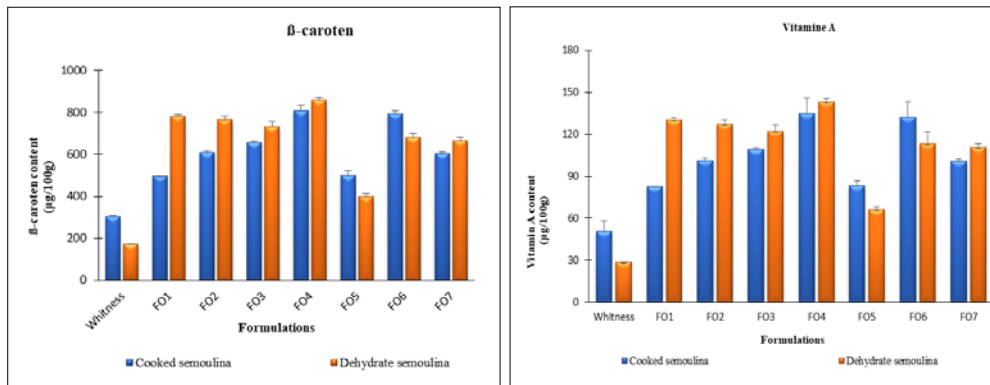
**Table 2:** Mineral content of formulations

Minerals	Formulations			
	«attiéké» nature	FO <sub>2</sub>	FO <sub>4</sub>	FO <sub>6</sub>
	(g / 100 of dehydrated semolina)			
Phosphorus	60,00 <sup>a</sup> ±0,00	79,33 <sup>b</sup> ±1,15	260,00 <sup>d</sup> ±0,00	180,00 <sup>c</sup> ±0,00
Potassium	393,33 <sup>a</sup> ±0,57	595,00 <sup>b</sup> ±1,00	613,67 <sup>d</sup> ±1,15	608,67 <sup>c</sup> ±1,15
Calcium	17,50 <sup>a</sup> ±0,10	18,07 <sup>b</sup> ±0,11	27,23 <sup>d</sup> ±0,05	26,00 <sup>c</sup> ±2,00
Magnesium	18,00 <sup>a</sup> ±0,00	20,00 <sup>ab</sup> ±0,00	23,50 <sup>c</sup> ±0,10	21,33 <sup>b</sup> ±1,15
Sodium	0,01 <sup>a</sup> ±0,00	0,10 <sup>a</sup> ±0,00	3,00 <sup>c</sup> ±0,01	1,46 <sup>b</sup> ±0,00
Manganese	2,58 <sup>a</sup> ±0,02	2,73 <sup>b</sup> ±0,00	2,91 <sup>d</sup> ±0,00	2,75 <sup>c</sup> ±0,00
Zinc	1,52 <sup>a</sup> ±0,02	2,72 <sup>b</sup> ±0,02	3,08 <sup>d</sup> ±0,00	2,90 <sup>c</sup> ±0,00
iron	0,02 <sup>a</sup> ±0,00	0,02 <sup>a</sup> ±0,00	0,02 <sup>a</sup> ±0,00	0,02 <sup>a</sup> ±0,00

Values are the mean  $\pm$  standard deviation of three independent measurements (n = 3). Values followed by different letters on the same line are statistically different ( $P < .05$ ). FO2: formulation obtained with 8.27% ferment, 5.54% soy and 19h 52min fermentation; FO4: formulation obtained with 11.73% ferment, 12.46% soy and 19h 52min fermentation; FO6: formulation obtained with 10% ferment, 9% soy and 22h fermentation.

Figure 2 indicates that the  $\beta$ -carotene and vitamin A contents of soy-enriched «attiéké» formulations are higher than those of plain «attiéké». In addition, dehydration

caused a variation in the  $\beta$ -carotene and vitamin A contents of cooked and dehydrated semolina. Indeed, a decrease of the values was observed with the plain «attiéké» and the FO5 and FO6 formulations. On the other hand, an increase in values was observed with formulations FO1, FO2, FO3, FO4 and FO7. The formulation FO4 has the highest content (809.82  $\mu$ g / 100 g of cooked semolina and 858.90  $\mu$ g / 100 g of dehydrated semolina). In addition, there were no significant differences at the 5% threshold between the  $\beta$ -carotene contents of cooked and dehydrated semolina of the FO4 formulation.



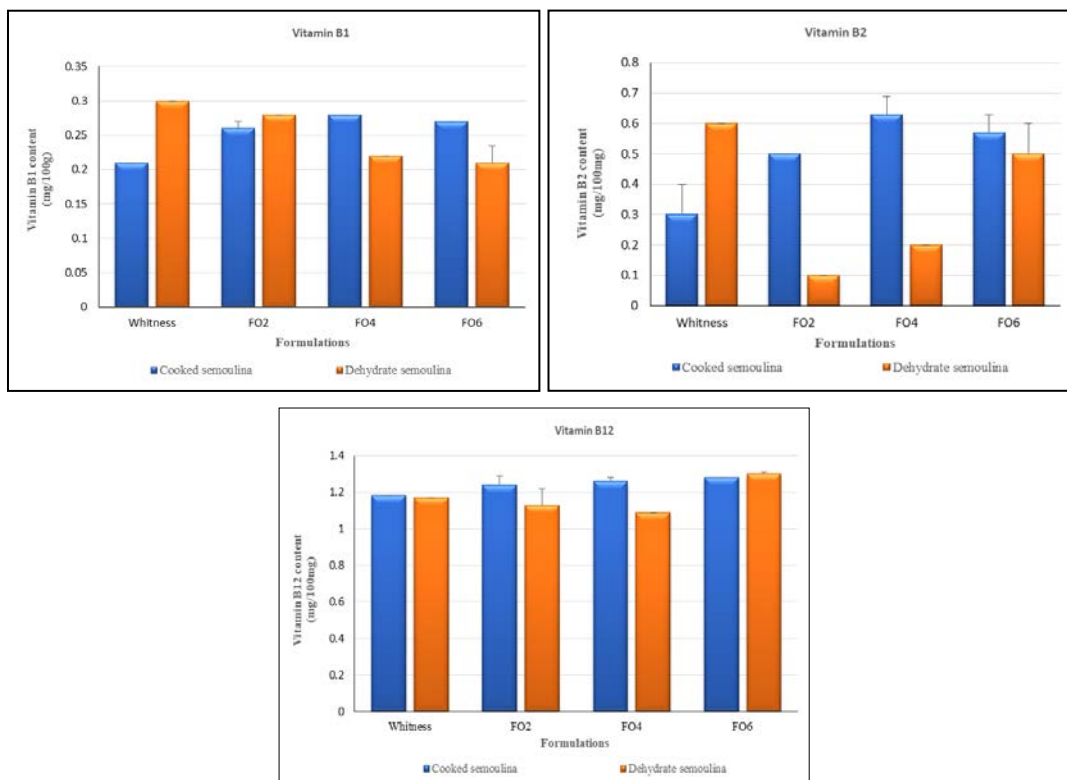
**Fig 2:**  $\beta$ -caroten and vitamin A content of formulations

Error bars indicate the standard deviation of the mean of three determinations (n = 3). Values followed by different letters are statistically different ( $P < .05$ ). FO1: formulation obtained with 11.73% ferment, 5.54% soy and 14h 6min fermentation; FO2: formulation obtained with 8.27% ferment, 5.54% soy and 19h 52min fermentation; FO3: formulation obtained with 11.73% ferment, 5.54% soy and 19h 52min fermentation; FO4: formulation obtained with 11.73% ferment, 12.46% soy and 19h 52min fermentation; FO5: formulation obtained with 13% ferment, 9% soy and 17h fermentation; FO6: formulation obtained with 10% ferment, 9% soy and 22h fermentation; FO7: formulation obtained with 10% ferment, 9% soy and 17h fermentation.

The vitamin B1, B2 and B12 contents of FO2, FO4 and FO6 formulations and of plain «attiéké» (cooked semolina and dehydrated semolina) are shown in Figure 3. These vitamins

were compared to each other for each of the four formulations. The fortification of cassava paste with soybean flour in the production of soy-enriched «attiéké» significantly increases the vitamin composition of the «attiéké». The results also revealed that dehydration significantly affected ( $P < .05$ ) the vitamin B content of the formulations studied.

The results obtained indicate that vitamin B1, B2 and B12 contents varied respectively between 0.21 (FO6) and 0.3 mg /100 g (plain «attiéké»); 0.1 (FO2) and 0.6 mg /100 g (plain «attiéké») and finally between 1.09 (FO4) and 1.3  $\mu\text{g}$  /100 g (FO6) for dehydrated semolina. For cooked semolina, the values varied between 0.21 (FO6) and 0.28 mg /100 g (plain «attiéké») for vitamin B1; 0.1 (FO6) and 0.63 mg /100 g (FO4) for vitamin B2; 1.18 (plain «attiéké») and 1.28  $\mu\text{g}$  /100 g (FO6) for vitamin B12.



**Fig 3:** Vitamin B1, B2, and B12 content of the formulations

Error bars indicate the standard deviation of the mean of three determinations (n = 3). Values followed by different letters are statistically different ( $P < .05$ ). FO2: formulation

obtained with 8.27% ferment, 5.54% soy and 19h 52min fermentation; FO4: formulation obtained with 11.73% ferment, 12.46% soy and 19h 52min fermentation; FO6:

formulation obtained with 10% ferment, 9% soy and 22h fermentation.

Figure 4 shows the vitamin C content of the formulations. The vitamin C content of cooked and dehydrated semolina was compared for each formulation. The results showed that dehydration did not significantly ( $P > 0.05$ ) affect the vitamin C content of plain «attiéké» and formulations FO1, FO5 and FO7 ; while it reduces the vitamin C content of FO2 from (8 mg / 100 g SC to 6.33 mg / 100 g SD), FO3 from (14 mg / 100 g SC to 6 mg / 100 g SD), FO4 from (12 mg / 100 g SC to 7.67 mg / 100 g SD) and FO6 from (13 mg / 100 g SC to 6.67 mg / 100 g SD).

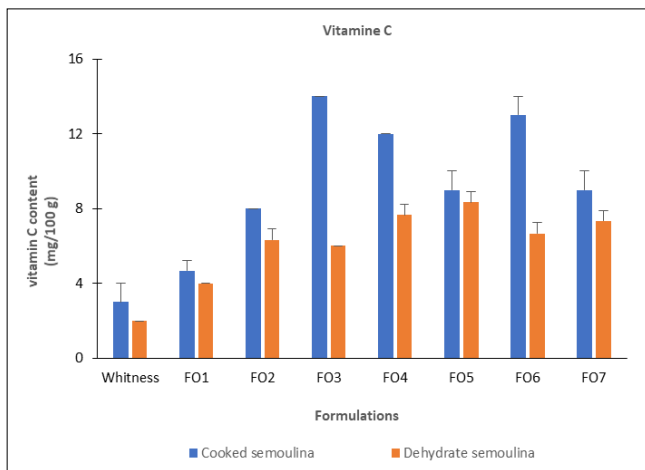


Fig 4: Vitamin C content of optimal formulations

Error bars indicate the standard deviation of the mean of three determinations (n = 3). Values followed by different letters are statistically different ( $P < .05$ ). FO1: formulation obtained with 11.73% ferment, 5.54% soy and 14h 6min fermentation; FO2: formulation obtained with 8.27% ferment, 5.54% soy and 19h 52min fermentation; FO3: formulation obtained with 11.73% ferment, 5.54% soy and 19h 52min fermentation; FO4: formulation obtained with 11.73% ferment, 12.46% soy and 19h 52min fermentation; FO5: formulation obtained with 13% ferment, 9% soy and 17h fermentation; FO6: formulation obtained with 10% ferment, 9% soy and 22h fermentation; FO7: formulation obtained with 10% ferment, 9% soy and 17h fermentation.

**2. Phytonutrient contents**

The formulations contained between 211.66 (control) and 337.67 mg of total polyphenols / 100 g SD (FO4); between 41.8 (FO3) and 177.65 mg of tannins / 100 g SD (FO6) and between 0 (control) and 15.17 mg of flavonoids / 100 g SD (FO4) (Figure 4).

The total polyphenol contents of the plain «attiéké» and the FO2, FO3, FO5, FO6, FO7 formulations are statistically identical. However, they are different from the FO1 and FO4 formulations. The incorporation of soybean flour led to an increase in the amount of total polyphenols. On the other hand, the addition of soybean from 0 to 5.54% of the control and formulations (FO1, FO2 and FO3); as well as the fermentation influenced the tannin contents of these formulations. Indeed, the higher the ferment content and the longer the fermentation time, the lower the tannin content. The plain «attiéké» did not contain flavonoids and the addition of soybean flour from 0 to 5.54% did not lead to any variation in flavonoid content. But from 5.54 to 12.46% of soy flour; a slight variation was observed.

**3. Anti-nutrient contents and molar ratios**

The addition of soy resulted in a decrease in phytate content and an increase in oxalate content of the formulations. Moreover, the oxalate content of the formulations is higher than the phytate content. The phytate and oxalate contents of the formulations expressed as mg / 100 g SD ranged from 20.57 to 35.11 and 14 to 64.28 respectively (Figure 5). The fermentation time affected the anti-nutrient content, because for the same amount of soybean, increasing the fermentation time caused a decrease in phytate and oxalate levels. This is the case for the FO5, FO6 and FO7 formulations, both for phytate and oxalate contents.

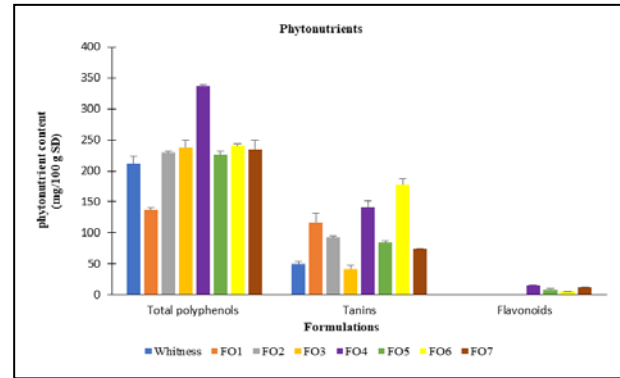


Fig 5: Phytonutrient content of formulations

Error bars indicate the standard deviation of the mean of three determinations (n = 3). Values followed by different letters are statistically different ( $P < .05$ ). FO1: formulation obtained with 11.73% ferment, 5.54% soy and 14h 6min fermentation; FO2: formulation obtained with 8.27% ferment, 5.54% soy and 19h 52min fermentation; FO3: formulation obtained with 11.73% ferment, 5.54% soy and 19h 52min fermentation; FO4: formulation obtained with 11.73% ferment, 12.46% soy and 19h 52min fermentation; FO5: formulation obtained with 13% ferment, 9% soy and 17h fermentation; FO6: formulation obtained with 10% ferment, 9% soy and 22h fermentation; FO7: formulation obtained with 10% ferment, 9% soy and 17h fermentation. The antinutrient/mineral molar ratios of the plain «attiéké» and the FO2, FO4 and FO6 formulations were determined in order to evaluate the effect of the presence of these antinutrients on the bioavailability of calcium and zinc. The oxalate/Ca, phytate/Ca and phytate/Zn molar ratios are shown in Figure 6. The oxalate/Ca ratios ranged from 0.8 (plain «attiéké») to 3.06 (FO2) while the phytate/Ca ratios of the formulations ranged from 0.87 (FO4) to 2.01 (plain «attiéké»). The phytate/Zn ratios of the formulations ranged from 7.09 (FO6) to 23.1 (plain «attiéké»).

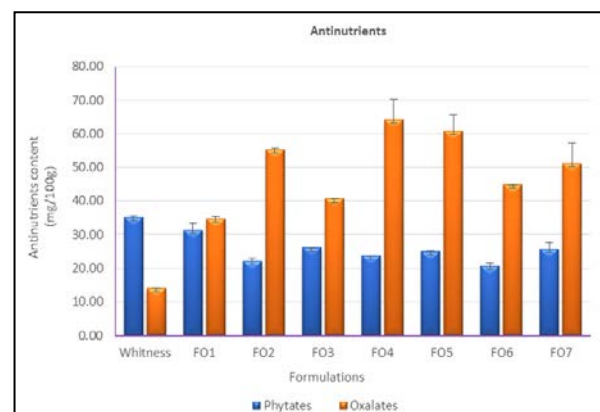


Fig 6: Antinutrients content of formulations

Error bars indicate the standard deviation of the mean of three determinations ( $n = 3$ ). FO2: formulation obtained with 8.27% ferment, 5.54% soy and 19h 52min fermentation; FO4: formulation obtained with 11.73% ferment, 12.46% soy and 19h 52min fermentation; FO6: formulation obtained with 10% ferment, 9% soy and 22h fermentation.

#### 4. Total antioxidant activity of the formulations

The antioxidant activity of the formulations was evaluated by studying their ability to scavenge DPPH free radicals by methanolic extracts (Figure 7). Compared to plain «attiéké», the results indicate that the methanolic extracts of the formulations have DPPH free radical scavenging capacities from 34.78 (plain «attiéké») to 48.73% (FO4). The methanolic extract of soybean flour has a scavenging power of 66.64%. These results show that all methanolic extracts have variable capacities to scavenge DPPH free radicals which evolves positively with the increase of soybean content.

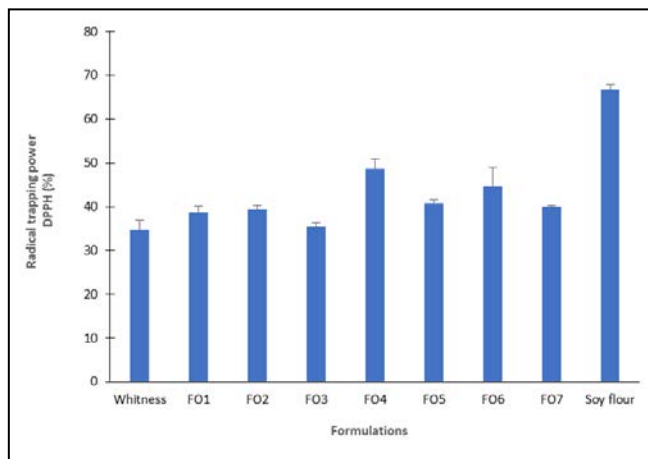


Fig 7: DPPH free radical scavenging powers of the methanolic extracts of the formulations.

Error bars indicate the standard deviation of the mean of three determinations ( $n = 3$ ). Values followed by different letters are statistically different ( $P < .05$ ). FO1: formulation obtained with 11.73% ferment, 5.54% soy and 14h 6min fermentation; FO2: formulation obtained with 8.27% ferment, 5.54% soy and 19h 52min fermentation; FO3: formulation obtained with 11.73% ferment, 5.54% soy and 19h 52min fermentation; FO4: formulation obtained with 11.73% ferment, 12.46% soy and 19h 52min fermentation; FO5: formulation obtained with 13% ferment, 9% soy and 17h fermentation; FO6: formulation obtained with 10% ferment, 9% soy and 22h fermentation; FO7: formulation obtained with 10% ferment, 9% soy and 17h fermentation.

#### Discussion

The amounts of phosphorus in the optimized formulations increased from 32.22 (FO2) to 333.33% (FO4) and that of calcium from 3.26 (FO2) to 55.6% (FO4) compared to plain «attiéké». These two minerals are beneficial for the body. Indeed, phosphorus and calcium are involved in the body by strengthening bones and promoting growth in children [34]. Magnesium is also present in the optimized formulations with levels between 20 and 21.33 mg / 100 g compared to plain «attiéké» which is 18 mg / 100 g. According to Abiodun *et al* (2012), magnesium is essential for the

metabolism of carbohydrates and nucleic acids and the electrical potential of muscle and nerve cells. A lack of magnesium can lead to muscle weakness and cramps. A significant amount of potassium is contained in the optimized formulations (595 to 608.67 mg / 100 g) compared to the natural «attiéké» which is 393.33 mg / 100 g. This mineral plays an essential role in protein synthesis [34]. The consumption of soy-enriched «attiéké» could thus provide populations with a fairly satisfactory quantity of macro-minerals.

The  $\beta$ -carotene and vitamin A contents of the optimized formulations increase with the amount of soy incorporated. The higher amount of  $\beta$ -carotene in soy flour (1411.05  $\mu\text{g}/100\text{ g}$ ) than in cassava flour (15.34  $\mu\text{g}/100\text{ g}$ ) is thought to be responsible for this increase. Also, the temperature applied for dehydration of these formulations would not have had a negative impact on the  $\beta$ -carotene content. Fermentation would also have had a positive impact on the  $\beta$ -carotene content, as the higher the ferment content and the longer the fermentation time, the higher the  $\beta$ -carotene content. This was the case for the 5% soy formulations (FO1, FO2 and FO3) and the 9% soy formulations (FO5, FO6 and FO7).  $\beta$ -carotene, a carotenoid, is the precursor of vitamin A. Vitamin A is a fat-soluble vitamin primarily involved in vision, growth, maintenance of epithelial cell integrity and immune defenses as an antioxidant [34]. The daily requirement of vitamin A in children (6-12 years) averages 500  $\mu\text{g}$  (Martin, 2001). Consumption of 100 g of plain «attiéké» covers only 10.12% of daily requirements, whereas consumption of optimized formulations covers between 16.56 (FO2) and 27% (FO4) of daily requirements. The optimized formulations had higher vitamin C contents than the plain «attiéké». Fermentation also increased the vitamin C content of the optimized formulations. During fermentation, vitamin C is maintained in the form of dehydro-ascorbic acid, which is more stable. Work by Oduah *et al.* [35] corroborates that fermentation promotes increased vitamin C content. Also, dehydration of optimized formulations resulted in vitamin C losses. Indeed, vitamin C is very sensitive to heat [36]. As a reminder, Vitamin C (L-ascorbic acid) is a water-soluble vitamin that cannot be synthesized by the human body. Deficiency induces scurvy whose clinical signs are edema and hemorrhage. By virtue of its reducing power, vitamin C has an antioxidant effect by transforming ferric iron into ferrous iron, which is more easily assimilated. As it is directly involved in the absorption of iron, vitamin C can be a cause of anemia in case of deficiency [34].

The daily requirements of thiamine, riboflavin, and cobalamin in children (6-12 years) are successively on average 0.8; 1.3 and 1.4  $\mu\text{g}$  (Martin, 2001). Consumption of 100 g of plain «attiéké» and of the FO2, FO4 and FO6 formulations successively covers 26.25; 32.5; 35 and 33.75% of daily thiamine requirements; 23.08; 38.46; 48.46 and 43.85% of daily riboflavin requirements and 23.08; 38.46; 48.46 and 43.85% of daily cobalamin requirements. In addition, dehydration led to an increase in thiamine content in the plain «attiéké» and FO2 formulations, compared to a decrease in the FO4 and FO6 formulations. Concerning riboflavin, dehydration caused a decrease in the levels of vitamin B, except for the plain «attiéké». Dehydration did not lead to significant losses in cobalamin levels in plain «attiéké» and in FO2 and FO6 formulations. Vitamin B1 or thiamine deficiency is known as beriberi.

This vitamin acts as a cofactor of various enzymes involved in energy production, but also acts as a neuromodulator at the brain level. Vitamin B2 or riboflavin, a growth vitamin, is a yellow crystalline substance (flavin), not very soluble in water, heat resistant, but sensitive to light, involved in energy production. Hypovitaminosis B2, due to insufficient intake, manifests itself by skin and mucous membrane lesions and cracks in the corners of the mouth. The term vitamin B12 includes a group of molecules called cobalamins. Their insufficient dietary intake is responsible for megaloblastic anemia associated with neurological disorders<sup>[34]</sup>.

The daily requirements of thiamine, riboflavin and cobalamin in children (6 to 12 years) are successively on average 0.8; 1.3 and 1.4 µg<sup>[37]</sup>. Consumption of 100 g of plain «attiéké» and of the FO2, FO4 and FO6 formulations successively covers 26.25; 32.5; 35 and 33.75% of daily thiamine requirements; 23.08; 38.46; 48.46 and 43.85% of daily riboflavin requirements and 23.08; 38.46; 48.46 and 43.85% of daily cobalamin requirements. In addition, dehydration led to an increase in thiamine content in the plain «attiéké» and FO2 formulations, compared to a decrease in the FO4 and FO6 formulations.

Concerning riboflavin, dehydration caused a decrease in the levels of vitamin B, except for the plain a «attiéké». Dehydration did not lead to significant losses in cobalamin levels in plain «attiéké» and in FO2 and FO6 formulations. Vitamin B1 or thiamine deficiency is known as beriberi. This vitamin acts as a cofactor of various enzymes involved in energy production, but also acts as a neuromodulator at the brain level. Vitamin B2 or riboflavin, a growth vitamin, is a yellow crystalline substance (flavin), not very soluble in water, heat resistant, but sensitive to light, involved in energy production. Hypovitaminosis B2, due to insufficient intake, manifests itself by skin and mucous membrane lesions and cracks in the corners of the mouth. The term vitamin B12 includes a group of molecules called cobalamins. Their insufficient dietary intake is responsible for megaloblastic anemia associated with neurological disorders<sup>[34]</sup>.

The analysis of the results of the phytochemicals indicates that these compounds are in relatively high quantities in the optimized formulations. The concentration of these compounds in the optimized formulations is influenced by the amount of soy incorporated and the fermentation. Indeed, cassava and soybeans contain high levels of phenolic compounds. Cassava has a higher content of total polyphenols (253.46 mg/100g) than soybean (192.90 mg/100g). On the other hand, soybean has a higher content of tannins (92.18 mg/100g) than cassava (64.31 mg/100g). In addition, Kuligowski *et al.*<sup>[38]</sup> revealed that fermentation of soybeans was a sensible method to increase the level of phenolic compounds. The total polyphenol results obtained are in agreement with Soro *et al.*<sup>[39]</sup> who observed an increase in total polyphenol content after fermentation of yam and soybean. Regarding tannins, the results indicate a decrease in levels during fermentation. This result is in agreement with Olaoye *et al.*<sup>[40]</sup> who obtained decreasing tannin values with the duration of fermentation. Also, epidemiological studies have shown that consumption of foods rich in phenolic compounds could help fight free radicals responsible for cellular senescence and play a role in preventing cardiovascular and degenerative diseases<sup>[15]</sup>. The manufacturing process of the soy-enriched «attiéké»

used led to a reduction in phytate and oxalate content of this food. Indeed, fermentation played a primary role in the reduction of anti-nutritional factors through the action of enzymes that are produced by microorganisms, such as yeasts, molds and lactic acid bacteria. This is the case of phytases that act by hydrolyzing phytate-mineral complexes, which are then removed during drying and steaming<sup>[41, 42]</sup>. Originally, cassava contained 140.69 mg phytates/100g and 192.50 mg oxalates/100g, while soybean flour contained 114.18 mg phytates/100g and 381.19 mg oxalates/100g. During the production of soybean flour; soaking, pre-cooking and drying favored the reduction of the contents of these antinutrients. Our work is justified by that of Pele *et al.*<sup>[43]</sup>. In addition, the work of Lestienne *et al.*<sup>[44]</sup> revealed that soaking induces a 23% loss of phytates from soybeans. Antinutritional factors are defined as compounds that reduce the utilization of nutrients in food and feed<sup>[41, 45]</sup>. In addition, enzymatic hydrolysis is important with natural «attiéké» compared to optimized formulations, because it has more starch than optimized formulations. Also, the presence of soy proteins could slow down the action of amylases. In addition, fermentation improves the nutritional and digestive qualities of the feed<sup>[42]</sup>. The low hydrolysis of soybean meal would be attributed on the one hand to the fact that soybeans contain little starch and less complex sugars and on the other hand, to the presence of non-hydrolyzable or resistant sugars<sup>[46]</sup>.

## Conclusion

This study shows that the technological treatments applied to the plant material (cassava and soybean) significantly influenced the nutritional and antioxidant characteristics of the soybean-enriched «attiéké» formulations. Fermentation reduced phytate and oxalate levels to acceptable levels and increased the *in vitro* digestibility of carbohydrates in the feed. On the other hand, dehydration resulted in vitamin C losses in the formulations. In addition, during the production of the soy-enriched «attiéké», the contents of minerals, B vitamins, total polyphenols and flavonoids were improved with the incorporation of soy compared to the plain «attiéké». The formulations also contain antioxidants that can fight free radicals.

Further studies on antioxidant and biological activities are needed to better understand the impact of consuming soy-enriched «attiéké» on the body.

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