Original Research Article

Improvement of Nutritional Properties of *Attiéké* by Co-Fermenting Cassava Paste with three Local Legume (Cowpea, *Voandzou* and Bean) Flours

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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 contains low amounts of protein and micronutrients. This study was conducted to assess the nutritional value and sensory properties of *attiéké* enriched with three legumes (cowpea, *voandzou* and common bean). The *attiéké* enriched with legume flours was prepared in different proportions of 10%, 15% and 20%. The samples were produced by incorporating the flour of the three legumes into the cassava paste in a single step (fermentation). The ferment content and fermentation time were 12% and 24 hours respectively. The chemical and sensory characteristics of the cowpea, *voandzou* and common bean enriched *attiéké* formulations were determined using standard methods. The results showed that the protein (1.13-9.93%), fat (0.06-2.06%), ash (0.1-1.13%), fibre (2-6.33%) and energy (353.747-372.06 Kcal/100 g) contents of the legume-enriched *attiéké* increased significantly with the cowpea, *voandzou* and common bean content. In addition, the addition of legume meal induced a significant increase in pH from 4.6 to 4.9. The incorporation of 10, 15 and 20% legume flours changed the appearance, aroma, taste, colour, and overall acceptability of the enriched *attiéké* compared to the control *attiéké* which were less appreciated by consumers. Flours with 10% legumes added to the cassava paste before the fermentation process yielded the most acceptable food compared to flours with 15 and 20% legumes added. This work suggests that the addition of 10% legume flour to the *attiéké* and proper fermentation improves both the nutritional value and sensory properties of the *attiéké* enriched with legumes.

Keywords: Cassava paste, legume flour, cowpea, voandzou, bean, improvement, attiéké, nutritional properties

1. INTRODUCTION

Cassava is one of Africa's most important root and tuber crops and is highly valued for its ease of agronomic handling, high productivity and tolerance of poor soils and drought [1]. Cassava derives its importance from its starchy tuberous roots, which are an excellent and inexpensive source of calories, particularly in developing countries [2]**.** In sub-Saharan Africa, the main cassava-growing region, cassava plays a vital role in food security. It is also a major source of income for millions of people [3, 4]. In Côte d'Ivoire, cassava is the second most widely consumed foodstuff after yam and ahead of rice, with production of 5 million tonnes per year [5].

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In Côte d'Ivoire, it is transformed into around ten dishes, the best known of which are *attiéké*, *placali*, *gari*, *attoukpou* and *tapioca*[6]**.** However, cassava has three major drawbacks: toxicity due to the presence of cyanogenic compounds, potentially responsible for neurological and metabolic disorders [7]; post-harvest losses due to its short lifespan; and a very low protein content. It should also be noted that the low protein content of cassava and derived products contributes to protein-energy malnutrition, particularly in areas where cassava accounts for more than 60% of people's daily energy intake [8].

Attiéké, which is made by processing cassava [9], is one of the most popular traditional dishes eaten (two or three times a day) in Côte d'Ivoire households. Unfortunately, it’s very low protein and

micronutrient content means that it does not meet the recommended daily requirements [8], despite its availability and accessibility.
Although the first two constraints mentioned above have been partly resolved thanks to innovative processing technologies and scientific research, the one linked to protein value remains a major concern due to the persistence and increase in protein-energy malnutrition in developing countries [10]**.**
The lack of adequate supplies of animal proteins due to their high cost [11] and the negative effect of cholesterol on health [12] justify the use of proteins of plant origin such as legumes. (red beans, cowpeas and *voandzou*) which contain proteins of just as good quality as those from animal sources [13]. These legumes are rich in protein, carbohydrates, calorific value, fibre, and vitamins. They are a staple food in many countries [14]. The protein composition of these seeds more than covers human requirements for essential and semi-essential amino acids. They are a major source of nutrients for the population, being the leading plant protein source with a protein intake of 18.6g per day, compared with 13.8g for animal products [15]. Their economic uses make them the crops of choice to reply for food security needs in developing countries [16]. Thus, the use of legumes as a strategy for enriching local foods could help to improve the nutritional quality of these foods as recommended by the FAO[17]. Several studies have already been carried out to improve the nutritional properties of cassava-based products. Oluwamukomi et al [18] fortified gari with soya, melon, and sesame seed flour. Adeniyi et al [19] also worked on fortifying spaghetti and tapioca with soy flour. In the case of *attiéké*, this strategy has been considered. To date, the only known fortification studies are those carried out by Djédji Catherine's team on the fortification of *attiéké* with soy flour alone [20]. It would also be useful to consider enriching *attiéké* with other local legumes to diversify the supply. It is in this context that the objective of this work is to contribute to the food security of populations by improving the nutritional quality of *attiéké*.

2. MATERIAL AND METHODS

2.1. Raw materials

Fresh, healthy tuberous cassava (*Manihotesculenta*Crantz) roots variety IAC (Improved African Cassava) were employed as raw material. They were harvested at Grand-Morié (5° 58′ 60″ N, 4° 7′ 60″W), in Côte d'Ivoire. The legumes *Phaseolusvulgaris* (bean), *Vignasubterranea* (*voandzou*) and *Pignaunguiculata* (cowpea) were purchased from the “Gouro” market of Adjamé (Abidjan, Cote d’Ivoire).

2.2. Cassava paste and ferment preparation

The cassava roots (30 kg) were cut and reduced to cossettes. The resulting cossettes were ground to form cassava paste, to which decolourised palm oil was added after heating at 100°C for 5 min in a proportion of 0.8% (w/v).
For the ferment preparation, 5 kg of cassava roots were peeled and cooked in boiling water for 45 minutes, followed by cooling at room temperature for 30 minutes. The cooked cassava roots were then packed in a polypropylene jute bag. The jute bag containing cooked cassava was then placed in a container with a lid and stored in a confined atmosphere for 72 hours. The resulting traditional ferment called *magnan* was cleaned of mould and rinsed with tap water.

2.3. Preparation of legume flours

The grains were then shelled, dehulled and dried at 50°C for 24 hours before being ground using a blender and then sieved. Finally, the legume flours were stored in sterilised jars for further handling.

2.4. Preparation of *attiéké* enriched with legume flours

Different proportions (10%, 15% and 20%) of flour from the three legumes, namely red bean, cowpea and voandzou were added to 500 g of cassava paste. To this mixture are added 12% ofpre-ground ferment. Everything is then left to ferment for 24 hours at room temperature (about 25°C). After the co-fermentation step, the *attiéké* is prepared according to the method describes by Assanvo[21].

Fermented doughs were pressed manually using a mechanic press. The compact pastes obtained after pressing were crumbled then granulated in a basin. The grains were dried on a tablecloth for 10 min. After drying, the grains were winnowed to remove the fibres. Finally, the semolina was steamed for 7 to 10 minutes in a couscous maker.

2.5. Proximate Composition Analysis

Dry matters were determined by drying in an oven at 105ºC during 24 h to constant weight [22]. Crude protein was determined using the Lowry et al.[23] method. Crude fat was determined by cold extraction method in chloroform-methanol (v/v) according to Folch et al.[24]. Carbohydrate content was determined through the method used by FAO[25]. Total ash was determined by incinerating in a furnace at 550ºC [22]. Method described by Dubois et al. [26] was used to determine total sugars. The pH and the total titratable acidity are determined according to the method AOAC[22]. The energy values of different *attiéké* formulations were evaluated using formula described by Atwater et Rosa[27].*Energy value (kcal/100g) = (4 × % protein) + (9 × % fat) + (4 × % carbohydrate)*. The starch content is deduced from those of total carbohydrates and total sugars. *Starch content = 0.9 (Total carbohydrate content – Total sugar content)*.

2.6. Sensory evaluation

A hedonic test was also carried out according to the method described by Watts et al. [28]. The panel of 66 people was recruited based on their availability. Each panelist, isolated from the others, received samples of 20 g of each formulated *attiéké*. The test consisted of rating each formulation on nine (9) hedonic point scale ranging from extremely unpleasant (1) to extremely pleasant (9). The parameters described were appearance, aroma, taste, colour, and overall acceptability.

2.7. Statistical analysis

The results were subjected to variance analysis (ANOVA) carried out with the IBM SPSS Statistics 20.0 software. In the event of a significant difference, Duncan's test made it possible to identify the means responsible for the difference observed at the 5% level.

3. RESULTS AND DISCUSSION

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3.1. Physicochemical composition

3.1.1. pH and titratable acidity

It is well known that the fortification of foods leads to a modification of the biochemical composition. However, the proportions of these different constituents shown great variability depending on the food formulated. Thus, the quality of formulated *attiéké* can only be demonstrated by determining their physicochemical characteristics. The proximate analysis of different *attiéké* formulations showed that they are acidic with pH values sited between 4.6 and 4.9 (Fig 1). These values agree with the pH range indicated for a good quality of *attiéké* as defined by Codinorm[29], which is between 4 and 5. As for the titratable acidity (Fig 2), it evolves in the opposite way at pH. The enriched *attiéké* (pH 4.7 to 4.9) are less acidic than the control *attiéké* (pH 4.6). This pH variation observed with the enriched formulations would be linked to the incorporation of legume flours in the cassava paste. Similar results were obtained by Ogunlakin et al. [30] in their study of enrichment of gari with soybeans up to 20%. The high rate of titratable acidity of control and formulated *attiéké* would be because these foods are fermented. Emireand Buta[31] reported in their studies that fermentation increases acidity. Indeed, during fermentation, microorganisms, including lactic acid bacteria, produce organic acids [32], responsible of food acidity. Note that the pH values and the high level of acidity obtained would make the *attiéké* more resistant to deterioration by microorganisms.

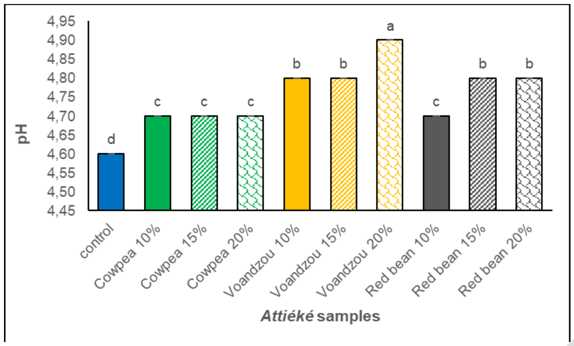

Fig. 1. pH of the different *attiéké* formulations

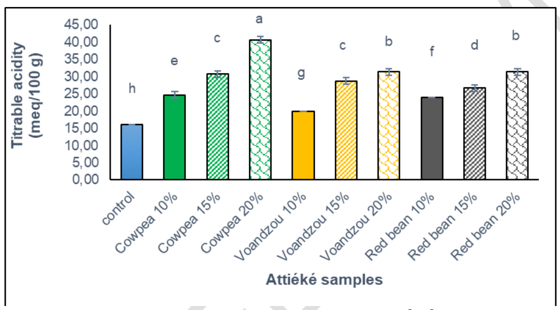

Fig. 2. Titratable acidity of the different *attiéké* formulations

3.1.2. Moisture, dry matter and ash contents

The determination of the moisture content is essential in the analysis of a food to express the values in relation to a fixed base which is the dry matter. Also, it significantly affects the shelf life and growth of microorganisms. The moisture contents of the various *attiéké* formulated (Table 1) are between 44 and 51.90%. The control *attiéké* has the highest moisture content. It seems that the incorporation of legume flours contributed to increasing the dry matter content of the enriched *attiéké*. The moisture content values are close to those of Krabi et al.[33] whose contents are respectively 46.60% and 50% for fresh *attiéké*. The high moisture content of fresh *attiéké* would increase their perishability. Indeed, a high-water content would promote the growth of microorganisms [34]. In addition, *attiéké* enriched with 20% red beans and 20% *voandzou* would have the best conservation potential given their low water content compared to other formulations. In addition, the enrichment of *attiéké* with legumes considerably increases their ash content ranging from 1 to 1.4%. *Attiéké* with 20% red bean has the highest ash content (1.4%) (Fig. 3). As for the total ash content, the values obtained are like those of Guira[8] who had found 0.31 to 1.61% for *attiéké* made from dough imported from Côte d'Ivoire to neighbouring countries. However, the values obtained for enriched*attiéké* with cowpea, red bean and *voandzou* are higher than those (0.45±0.01) produced with sweet cassava called "Bonoua" [35]. The values recorded (1 to 1.4%) agree the value recommended by Codinorm[29] which is 1.4% of dry matter. This high ash content of enriched *attiéké* could be advantageous because their consumption would provide more mineral elements.

Table 1.Moisture and dry matter content of the different *attiéké* formulations

Samples	Moisture (%)	Dry Mater (%)

Control	51.90±0.32[a]	48.10±0.32[h]
Cowpea10%	49.00±0.36[c]	51.00±0.36[f]
Cowpea15%	46.86±0.13[f]	53.13±0.13[c]
Cowpea20%	46.067±0.25[g]	53.93±0.25[b]
Voandzou10%	49.96±0.36[b]	50.03±0.36[g]
Voandzou15%	48.86±0.31[c]	51.13±0.31[f]
Voandzou20%	46.133±0.49[g]	53.86±0.49[b]
Red bean10%	47.96±0.49[d]	52.03±0.49[e]
Red bean15%	47.16±0.60[e]	52.83±0.60[d]
Red bean20%	44.967±1.06[h]	55.03±1.06[a]

Values are mean ± standard deviation of three measurements (n = 3). The different case letters (a, b, c) in the column indicate significant differences (*p*< 0.05) in the respective values.

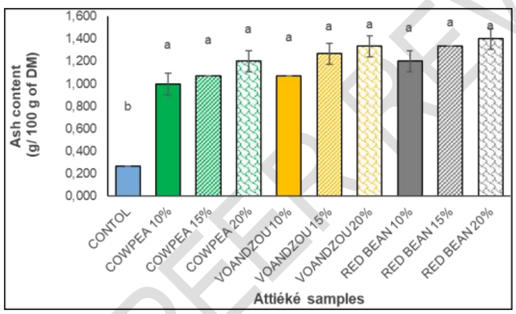

Fig. 3. Ash content of the different *attiéké* formulations

3.1.3. Protein content

Fig. 4 depicts the results of protein contents. These protein contents increased significantly due to the enrichment of *attiéké* with legume flours. The control *attiéké* showed a very low protein content (1.133%) than those of the enriched *attiéké* which vary from 4.002% (for the *attiéké* enriched with 10% cowpea) to 9.93% (for the *attiéké* enriched with 20% red bean and 20% *voandzou*). Indeed, the addition of legumes in the *attiéké* improves considerably its protein content. The enriched *attiéké* with the proportions of 20% red bean and *voandzou* have the highest protein values 9.9% and 9.93% DM, respectively. The protein amounts obtained are very satisfactory and can provide 80% of the recommended daily protein requirements. The results obtained agree with those of Kouakou et al. [20] who reported an increase in protein content with the addition of soy flour. *Attiéké* enriched with 20% beans and 20% *voandzou* could therefore be recommended as growth foods given their high protein content [36]. Moreover, the consumption of these *attiéké* could largely contribute to covering the protein needs of children over 2 years old, which are estimated between 12 to 13.5 g/day [37]. Also, according to Kasprowicz-Potocka et al. [38],legume proteins are generally rich in essential amino acids particularly in lysine. Therefore, the incorporation of cowpea, *voandzou* and red bean could improve the quality of *attiéké* protein content. Increasing the protein content of *attiéké* would prevent protein-energy malnutrition.

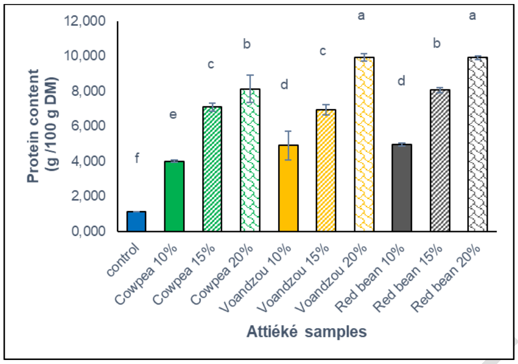

Fig. 4. Protein content of the different *attiéké* formulations

3.1.4. Crude fat content

Enrichment of *attiéké*increases their lipid content compared to the control. The highest lipid contents are formulations with 10%, 15% and 20% of *voandzou* (1.9, 1.96 and 2.06%) while the enriched*attiéké* with 10% of cowpea and 10% of red bean, although having higher values than the control, have lower lipid contents (0.1 and 0.133% of DM) compared to the other formulations (Fig. 5). These results agree the values recommended (1 to 3%) by Codinorm[29].

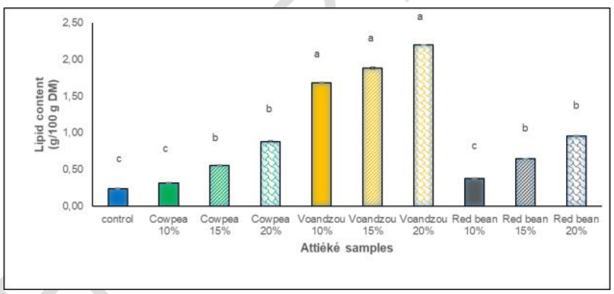

Fig. 5. Lipid content of the different *attiéké* formulations

3.1.5. Total sugar, total carbohydrate, and starch contents

Concerning the total sugar contents and the energy values of the enriched *attiéké*, they gradually increase compared to the control. The highest values of total sugars (from 0.833% to 0.9%) were obtained with the formulations red bean 15%, cowpea 15% and 20% of all legumes (Fig. 6).
The carbohydrate contents of formulated *attiéké* decrease gradually compared to the control. the formulation with the lowest total carbohydrate content was *attiéké* enriched with 20% *voandzou* (78.13g/100 g DM) (Fig.7). Also, the addition of legume flours gradually influences the amount of starch contained in the *attiéké*. Indeed, the higher the level of enrichment, the lower the starch content. The starch contents of the different enriched *attiéké* formulations vary from 69.79 to 77.91% respectively for the formulation with 20% *voandzou* and the control *attiéké*. (Fig.8).

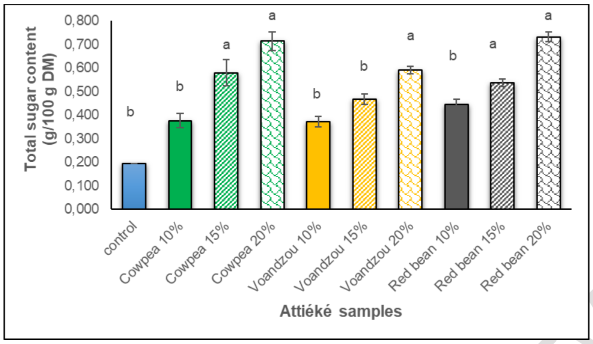

Fig. 6. Total sugar content of the different *attiéké* formulations

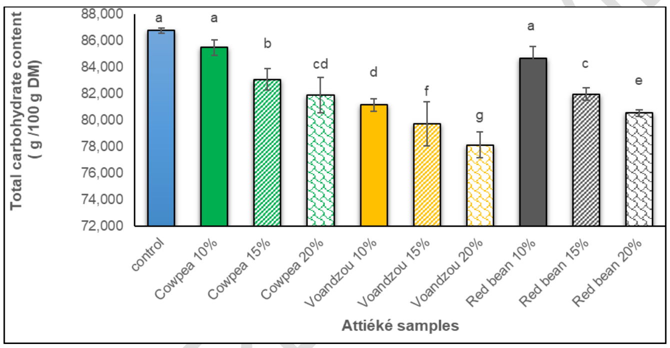

Fig.7. Total carbohydrate content of the different *attiéké* formulations

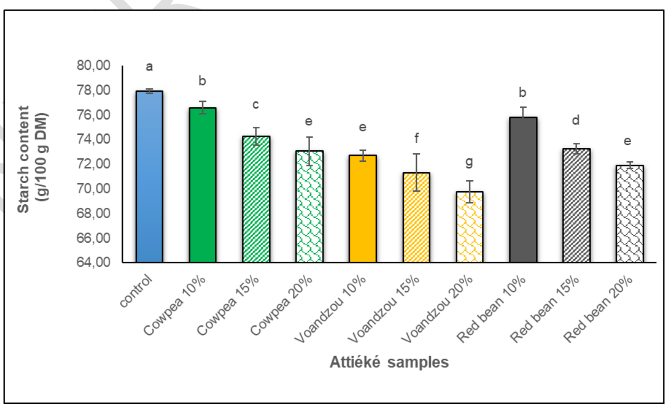

Fig. 8. Starch content of the different *attiéké* formulations

3.1.6. Energy value

The enrichment with legume flours allowed us to obtain energy values varying from 353.75 to 372.06 Kcal /100 g DM (Fig. 9). The results corroborate those (377.20 and 414 Kcal / 100 g) of Kouakou et al. [20] determined during a study of *attiéké* fortification with soy in Côte d'Ivoire. So, the values obtained are higher than those (156.46 and 215.26 Kcal/100 g) of Guira [8] who worked on the evaluation of the nutritional and health values of *attiéké* in Burkina Faso.

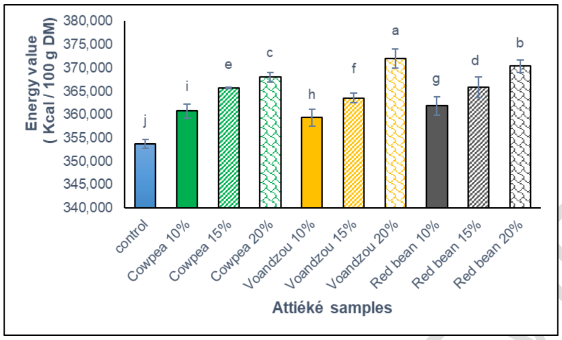

Fig. 9. Energy value of the different *attiéké* formulations

3.2. Sensory characteristics of enriched *attiéké*

It has been observed that consumers generally judge the *attiéké* quality based on its appearance, colour, aroma, and taste. The addition of 10, 15 and 20% legume flours modifies the appearance, aroma, taste, colour and overall acceptability of the formulations compared to the control. Fig.10 shows that the formulations are generally appreciated when 10% legume flours are used for the fortification of *attiéké*. On the other hand, the addition of 15% and 20% pulse flours to *attiéké* is less appreciated. Enrichments with 10% flour are those whose taste is accepted. Those with rather pleasant aromas are the samples with 10% cowpea flour and 10% red bean compared to the control. However, the samples with 15% and 20% of the flours have neither unpleasant nor pleasant aromas. The samples whose colour and appearance are appreciated are those with 10% red bean flour. As far as colour is concerned, the samples with 10, 15 and 20% of cowpea flour and 10 and 15% of *voandzou* flour as well as with 15% of red bean flour were moderately appreciated. As for the 20% cowpea samples, 15 and 20% *voandzou* and red bean had an appearance not appreciated by the panel. Samples with 10% flour are closest to the witness in terms of all sensory parameters. The observations made during our studies differ from the conclusions of Oluwamukomi et al[39] who found that there was no difference between the witness and gari enriched with soy flour up to 10%, and Banjo and Ikenebomeh [40] up to 15% enrichment.
Enrichment with cowpea, *voandzou* and red bean flour in this study reduced the score of the panel showing that they were less accepted than the control sample. The average of the panel scores is 7.64 for the control *attiéké* and ranges from 4.45 to 6.62 for the formulations enriched with legume flours. The formulation enriched with 20% of the voandzou flour had the lowest score of 4.45 for appearance. Regarding scores, the control was the best, followed by formulations enriched with 10% red bean, cowpea and *voandzou* flours, then formulations enriched with 15% and 20% of these flours. It seems that, the higher the enrichment level, the more the colour intensity increases. Taste is the main factor that determines the acceptability of a product [41]. The incorporation of flours also influences the flavour of formulated foods. The flavour of the enriched *attiéké* was significantly different from that of the control. Based on overall acceptability, the control *attiéké* was found to be the best, followed closely by the *attiéké* enriched with 10% flours. Formulations with 20% legume flours are the least accepted. These observations are like those made by Oluwamukomi and Adeyemi[42].

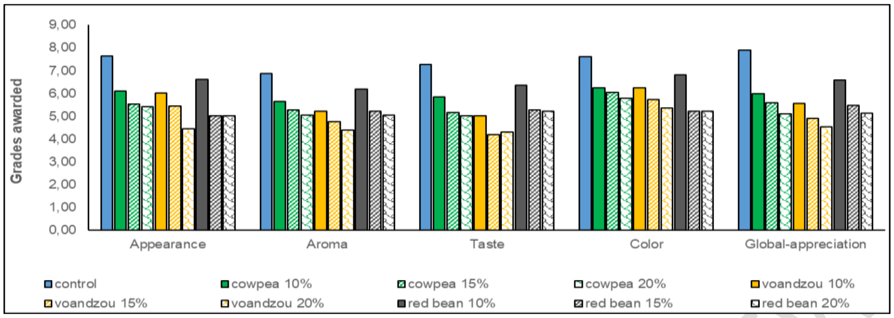

Fig. 10. Organoleptic characteristics of the different *attiéké* formulations

CONCLUSION

This study showed that the incorporation of legume flours at 10, 15 and 20% improves the nutritional properties of *attiéké*. The enrichment of attiéké with legume grain flours made it possible to significantly increase the physicochemical and biochemical parameters (proteins, lipids, energy value). *Attiéké* enriched with 20% red bean and *voandzou* presented the highest levels of protein and energy value. However, there was a slight decrease in total carbohydrates and starch of the fortified formulations compared to the control formulation. Regarding sensory parameters, the *attiéké* produced with 10% flour are the most appreciated after the control as concerned colour, appearance, taste, and aroma. The red bean flour incorporated into the *attiéké* before fermentation gave the best sensory aspect of the enriched *attiéké*. The enrichment of attiéké would make it possible to fight against protein deficiencies and provides 80% of the recommended daily protein needs.

Comment [M3]: It would have been better to add tables with curves to support the results

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Comment [M4]: Formatting references according to the terms of publication in the journal

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