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Sensory evaluation and digestibility of moringa enriched Attiéké/cashew kermels composite flours

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Abstract

Flour enrichment is a strategy for improving the nutrient content of these flours. The in vitro digestibility study showed a higher quantity of reducing sugars in moringa-enriched Attiéké/cashew kermels composite flours than in the control infant flour. Hedonic and descriptive tests were carried out by untrained and trained panelists respectively. The hedonic evaluation showed that moringa-enriched Attiéké/cashew almond composite flour porridges were accepted by tasters. However, after 10% incorporation of moringa, the acceptability of the porridges declined. The descriptive test showed that after 10% incorporation of moringa, the bitter taste and green color were perceived more strongly, leading to a reduction in the acceptability of the porridges

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Introduction

In Côte d'Ivoire, Attiéké, a product derived from cassava (*Manihot esculenta* Crantz), is the most widely consumed (Koffi-Nevry *et al.*, 2007). Production of Attiéké is estimated at between 18,965 tonnes and 40,000 tonnes. Annual consumption varies between 28 kg and 30 kg per capita (FAO, 2001). Attiéké is essentially an energy food, with a total carbohydrate content of over 90%. Dietary fiber content is 2-3%. Protein content is generally less than 2% and lipids less than 1% (Sahoré *et al.*, 2010). Despite the dietary and socio-economic importance of Attiéké, it must be combined with protein-, lipid- and mineral-rich foods such as oilseeds and legumes to form a balanced diet. In addition, other sources such as cashew kernel powder (*Anacardium occidentale* L.), rich in protein, and Moringa oleifera powder, a source of micronutrients, could enrich Attiéké flour for the production of supplementary foods.

Recognized as highly nutritious, cashew kernels and moringa are increasingly used to improve the nutritional content of cereal-based energy foods (maize, rice, millet, etc.) and tubers (yam, sweet potato, manioc, etc.) that are low in protein, lipids and micronutrients. In view of the above, it would be advisable to evaluate in vitro digestibility and determine the acceptability of Attiéké/cashew kermels /moringa composite flours.

Materials and methods

The biological material used in this study consists of various flours based on dehydrated Attiéké, cashew kernels (*Anacardium occidentale*) and moringa leaves (*Moringa oleifera*). The attiéké, cassava semolina (*Manihot esculenta* Crantz), was purchased from local producers in the village of Djahakro, opposite the Institut National Polytechnique Houphouët Boigny (INP-HB) in the town of Yamoussoukro, Lake District. Cashew kernels obtained from cashew nuts (*Anacardium occidentale*) were supplied by the laboratories of the Institut National Polytechnique Houphouët-Boigny (INP-HB). Moringa (*Moringa oleifera* L) leaves were harvested in the town of Yamoussoukro (city of ivory coast).

Production of attiéké flour

The attiéké collected from the producers was brought to the laboratory to be dried in an oven at 60°C for 24 h and ground using a grinder. The flour obtained was stored in polyethylene bags. Cashew nut processing Cashew nut processing was inspired by the Falade *et al.* (2004) process. A batch of healthy dried cashews was steamed in a steamer at 115°C for 45 min, then left to dry at room temperature for 48h. The cashews were manually shelled into two equal halves using a hand operated huller.

The kernels were then separated from the shells using small knives. The almonds were dried in an oven at a temperature of 85°C for 2 hours, then dehulled. The depelleted almonds were dried at 65°C for 6 hours to reduce the moisture content to between 5 and 6%, then packed. Production of de-oiled and unfermented cashew kernel flour The kernels were obtained after shelling, drying and trimming the nuts. Cashew kernel flour was produced using the method described by Sze-Tao and Sathe (2004), modified. Dried kernels were crushed using a semi-handcrafted grinder and placed in a stainless steel vat. Hexane was added 1:1 (W/v) to the flakes for oil extraction. The mixture was macerated for 30 min before being heated at 130° for 50 min and left to stand for 24 h at room temperature. The pellet was then separated from the supernatant (oil and hexane). This operation is performed twice. The oil cakes are pressed for 24 h to extract the remaining oil. The de-oiled cakes are oven-dried at 70°C for 12 hours. They are ground in a mill and the flour obtained is stored in polyethylene bags. Production of de-oiled and fermented cashew kernel flour.

To produce a flour from cashew kernel meal, the modified d'Ijarotimi *et al.* (2012) method was used. The resulting kernels are boiled at 100°C for 1 h. The boiled kernels are tightly wrapped in plantain leaf for 72 h for fermentation. Fermentation is carried out using micro-organisms naturally present on the surface of the plantain leaves. The fermented seeds are dried in a 60°C oven for 48 hours. The fermented kernels are crushed and hexane added as described above. After extraction, the oil cakes were dried at 70°C for 12 h to evaporate the hexane. The cakes were ground in a mill and packed in polyethylene bags. Moringa powder production M. oleifera leaflets are detached from their petioles, sorted to remove damaged leaves and sanitized for five minutes in bleach water. After rinsing in distilled water and draining for 30 minutes, the leaflets are soaked for 12 hours and dried in a ventilated room away from the sun for three weeks, then ground in a hammer mill and packed in polyethylene bags. Formulation of infant flours: attiéké / cashew almonds/moringa.

The attiéké/cashew almond/moringa composite flours are obtained by incorporating respective proportions of 10%, 15% and 20% moringa flours in the two composite flours most appreciated in the study made by Koné *et al.* (2017), (FAFCF15: 85% attiéké flour/15% fermented cashew kernels; FAFCNF10: 90% attiéké flour/10% unfermented cashew kernels). Each formulation is carefully mixed in a blender, then divided into 250 g fractions in polyethylene plastic bags, and stored for analysis.

Formulations and their abbreviations

A: 90% FAFCF15 + 10% moringa
B: 85% FAFCF15 + 15% moringa
C: 80% FAFCF15 + 20% moringa
D: 90% FAFCNF10 + 10% moringa
E: 85% FAFCNF10 + 15% moringa
F: 80% FAFCNF10 + 20% moringa

FAFCF15: Attiéké flour + 15% fermented cashew almond flour
FAFCF10: Attiéké flour + 10% fermented cashew almond flour

In vitro digestibility of composite flours

To a tube containing 7.5 mL of 20 mM acetate buffer, pH 5 was added 3 mL of the α-amylase suspension. The whole was pre-incubated for 10 min at 37°C and 4.5 mL of 1% flour gel was added. The resulting reaction mixture was incubated at 37°C in a water bath for 140 min. At different time intervals, 250 µL of reaction medium was withdrawn and 300 µL of DNS added to stop the reaction. The mixture was incubated in a boiling water bath for 5 min and allowed to cool to room temperature before the addition of 2 mL distilled water. Enzyme-free controls were made under the same conditions. Absorbance was measured at 540 nm using a UV-Force spectrophotometer (Uv-100, Cyberlab, USA). The amount of sugar released was determined using a calibration line obtained with a glucose solution (1 mg/mL). Tests were carried out in triplicate on each sample. Flour digestibility was measured in terms of reducing sugars/min. Sensory evaluation of porridges prepared from Attiéké-cashew kernel-moringa composite flours.

Preparation of porridges from attiéké/cashew kermel/moringa composite flours

The porridges were prepared by diluting 50 g flour in 300 mL tap water. Cooking took 5 min over low heat. At the end of cooking, 18 g of sugar were added to the mixture. The porridges were cooled to room temperature in the preparation room before being served. Hedonic test.

The hedonic test panel was made up of 60 untrained students (men and women) who are regular consumers of porridges, recruited on the basis of their availability. The different porridge samples of unfermented Attiéké/cashew almond composite flours enriched with 10%, 15%, 20% moringa powder coded with three-digit random numbers, were presented simultaneously to each subject in randomized order. Then, samples of fermented Attiéké flour/cashew almonds slurries enriched with 10%, 15%, 20% moringa powder were presented under the same conditions to the tasters, so that they could indicate for each type of formulation (fermented and non-fermented) the sample they liked best. Next, the pleasure experienced by each panelist after tasting each sample was marked on a nine point hedonic scale. Scores ranging from 9 (extremely pleasant) to 1 (extremely unpleasant) were assigned to the different modalities of the scale to determine the level of acceptability of each formulation (Meilgaard *et al.*, 1999).

Descriptive analysis quantitative

For quantitative descriptive analysis, a panel of 15 students from the Biochemistry and Food Science laboratory of the Biosciences UFR of the Félix Houphouët-Boigny University were recruited and trained in the methodology of quantitative descriptive analysis (AFNOR, 1984). They were then familiarized with the vocabulary used to evaluate infant meal slurries (AFNOR, 2000). The different coded slurry samples of unfermented attiéké/cashew kernel composite flours enriched with 10%, 15%, 20% moringa powder were presented simultaneously to each subject in randomized order. Then, coded samples of attiéké/cashew kernel composite flours enriched with 10%, 15%, 20% moringa powder were presented to each subject following the same procedure. After the training phase, the slurries were evaluated for each organoleptic attribute using a 100 mm linear scale, with the left-hand end showing the lowest intensity and the right-hand end showing the highest intensity. Each panelist then marked the perceived intensity with a line on the scale.

Results

In vitro enzymatic digestibility of moringa-enriched Attiéké/cashew nut composite flours

Fig. 1 shows the specific activity as a function of different dilutions of the enzyme extract (α-amylase present in digestive juice). The 1/200 dilution shows the highest specific activity. This dilution was used to determine the amount of reducing sugars produced by enzymatic hydrolysis of flour. Fig. 2 shows the enzymatic hydrolysis curves for Attiéké flour, moringa-enriched composite flours and Blédine commercial infant flour. Both moringa-enriched composite flours have higher quantities of reducing sugars released than commercial infant flour. Nonetheless, unfermented moringa-enriched Attiéké-cashew almond composite flour (E) and Attiéké flour (FA) have virtually the same reducing sugar content up to 50 min. Composite flour (Attiéké/fermented cashew almonds) enriched with moringa (A) had the highest reducing sugar content, and commercial flour the lowest.

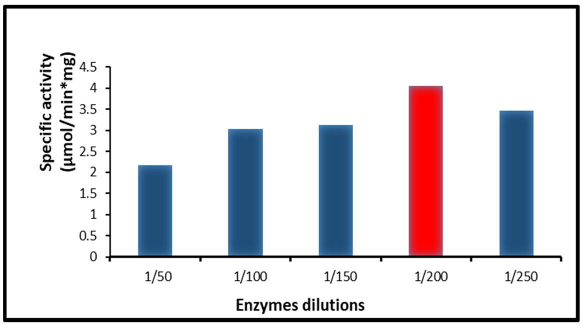

Fig. 1. Specific activity (µmol/min*mg) of digestive juice enzyme extract of the snail

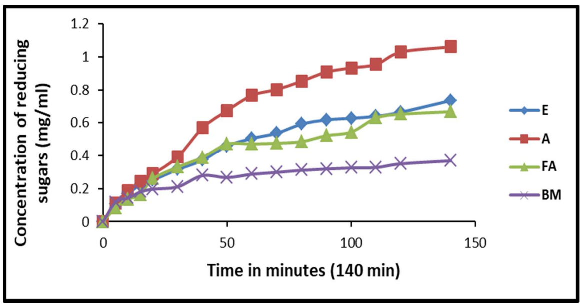

Fig. 2. Enzymatic digestibility curve for attiéké flour, wheat flour and wheat bran. attiéké/cashew kermels/moringa composites and commercial infant flour

E: 85% FAFCNF10 / 15% Moringa; A: 90% FAFCF15 / 10% Moringa; FA: Attiéké flour; BM: BLEDINE commercial infant flour

Table 1 presents the overall acceptability and organoleptic properties of the slurries of the composite Attiéké/cashew almond flours enriched with moringa powder, and of the commercial control infant flours Blédine and Farinor. All porridges were moderately accepted by panelists. Statistical analysis showed that the appreciation of the composite flour porridges differed significantly ($P < 0.05$). The Blédine commercial flour porridge was the most accepted, with a score of 8/9. However, the Farinor (FP) commercial flour porridge and the Attiéké/cashew almond composite flour porridges enriched with 10% and 15% moringa powder (A, D and E) had statistically identical scores (7/9) ($P > 0.05$). All slurries of the different formulations of attiéké/cashew nut composite flours enriched with moringa powder have values between 7/9 and 5/9.

Table 1. Average values for acceptability and organoleptic properties of porridges based on moringa-enriched Attiéké/cashew kernel flours and commercial infant flours

	Organoleptic descriptors								
Flour porridges	**Color Green (mm)**	**White color (mm)**	**Yellow color (mm)**	**Sweetness (mm)**	**Bitter taste (mm)**	**Smooth texture (mm)**	**Viscous texture (mm)**	**Appearance in the mouth (mm)**	**Overall assessment**
A	$56,2\pm1,05^{c}$	$10\pm0,00^{b}$	$10\pm0,00^{b}$	$62,6\pm1,03^{a}$	$21,2\pm0,45^{d}$	$68,8\pm0,75^{b}$	$68,6\pm0,55^{b}$	$55,5\pm0,27^{c}$	$7\pm0,89^{b}$
B	$68,3\pm1,35^{b}$	$10\pm0,00^{b}$	$10\pm0,00^{b}$	$48,5\pm1,43^{c}$	$25,5\pm0,53^{c}$	$64,4\pm0,68^{bc}$	$61,6\pm0,52^{cd}$	$43,7\pm0,30^{d}$	$6\pm0,76^{c}$
C	$72,5\pm1,06^{a}$	$10\pm0,00^{b}$	$10\pm0,00^{b}$	$47,1\pm1,36^{c}$	$30,9\pm0,14^{a}$	$57,7\pm0,80^{d}$	$52,3\pm0,58^{e}$	$37,9\pm0,59^{e}$	$5\pm0,41^{d}$
D	55 ± 0103^{f}	$10\pm0,00^{b}$	$10\pm0,00^{b}$	$61,1\pm1,65^{ab}$	$18,4\pm0,41^{f}$	$68,2\pm0,64^{b}$	$67,4\pm0,85^{bc}$	$48,1\pm0,89^{d}$	$7\pm0,90^{b}$
E	$61,2\pm0,93^{d}$	$10\pm0,00^{b}$	$10\pm0,00^{b}$	$62,6\pm01,12^{a}$	$19,4\pm0,58^{e}$	$68,1\pm0,70^{b}$	$61,5\pm1,13^{cd}$	$56,3\pm0,61^{c}$	$7\pm0,83^{b}$
F	$66\pm1,60^{c}$	$10\pm0,00^{b}$	$10\pm0,00^{b}$	$56,1\pm1,34^{b}$	$28,6\pm0,50^{b}$	$58,3\pm0,92^{d}$	$56,8\pm0,77^{de}$	$37,5\pm0,64^{e}$	$5\pm0,61^{d}$
BM	$10\pm0,00^{g}$	$73,3\pm1,04^{a}$	$10\pm0,00^{b}$	$61,0\pm0,65^{ab}$	$10\pm0,00^{g}$	$86,6\pm0,41^{a}$	$87,7\pm0,25^{a}$	$75\pm0,50^{a}$	$8\pm0,26^{a}$
FP	$10\pm0,00^{g}$	$10\pm0,00^{b}$	$72\pm0,26^{a}$	$55,9\pm0,44^{b}$	$10\pm0,00^{g}$	$62,3\pm0,57^{c}$	$53,8\pm0,67^{e}$	$61,1\pm0,34^{b}$	$7\pm0,57^{b}$

Scores in the same column with different superscript letters are statistically different at (P < 0.05), according to Duncan's test.

A : 90 % FAFCF15/10 % Moringa ; **B :** 85 % FAFCF15/15 % Moringa ; **C :** 80 % FAFCF15/20 % Moringa ; **D :** 90 % FAFCNF10/10 % Moringa ; **E:** 85 % FAFCNF10/15 % Moringa ; **F:** 80 % FAFCNF10/20 % Moringa ; **BM :** *BLEDINE* commercial infant flour ; ***FP*** : *FARINOR* commercial infant flour.

The scores (Table 1) for the various descriptors show significant differences ($p < 0.05$). The slurry color of BM commercial flour was judged white with a score of 73.3 mm, while that of FP was judged yellow with a score of 72 mm. Tasters rated moringa-enriched composite flours as green. The scores attributed to these flours were statistically different, ranging from 55 mm to 72.5 mm.

The intensity of green color in slurries of fermented Attiéké/cashew kernel composite flour formulations enriched with 10%, 15% and 20% moringa powder (A, B and C) is statistically higher ($P < 0.05$) than that of unfermented attiéké/cashew kernel composite flours enriched with 10%, 15% and 20% moringa powder (D, E and F). The sweetness of boiled Attiéké/fermented cashew almond composite flours enriched with 10% moringa powder (A) and unfermented attiéké/cashew almond composite flours enriched with 10% and 15% moringa powder (D and E) is significantly higher ($P < 0.05$) than that of commercial flours, with scores ranging from 47.1 mm (C) to 62.6 mm (A and E). In contrast to sweetness, bitterness is less perceived for all boiled products. Ratings ranged from 18.4 mm to 30.9 mm. The smooth texture scores of the composite Attiéké/fermented cashew almond flour porridges enriched with 10% moringa powder (A) and the composite Attiéké/unfermented cashew almond flour porridges enriched with 10% and 15% moringa powder (D and E) are statistically identical ($P > 0.05$). They are higher than those of slurries of fermented composite Attiéké/cashew kernel flours enriched with 15% and 20% moringa powder (B and C) and unfermented composite Attiéké/cashew kernel flours enriched with 20% moringa powder (F) (64.4 mm; 57.7 mm and 58.3 mm respectively).

However, these scores are still lower than those for Blédine and Farinor commercial flour porridges. The porridges of the Attiéké-cashew almond composite flours enriched with 10% moringa A and D were statistically the most viscous (68.6 mm and 67.4 mm) of the different formulations. The creamy texture of the porridges of the different moringa-enriched flours was moderately perceived by tasters. In addition, the creamy texture of Blédine and Farinor commercial porridges had intensities of 75 mm and 61.1 mm.

Structuring the variability of organoleptic characteristics of Attiéké/cashew nut composite flours enriched with moringa leaf powder

Principal Component Analysis (PCA) was used to group the different porridges of Attiéké/cashew kermels composite flours enriched with moringa powder according to organoleptic attributes (texture, aroma, taste, color and general acceptability) (Fig. 3).The projection of variables and samples enabled us to divide the samples into 4 groups. Group 1 is essentially made up of Blédine (BM) commercial infant flour, characterized by high values for organoleptic attributes such as aroma, viscous and smooth textures, mouthfeel, white color and good general acceptability. The second group is essentially made up of slurry from the other Farinor (FP) intantile commercial flour, which is characterized in particular by its yellow color. The third group is made up of slurries of the composite flour Attiéké/fermented cashew almonds enriched with 15% and 20% moringa powder (B, C) and the slurry of the composite flour Attiéké/unfermented cashew almonds enriched with 20% moringa powder (F). These porridges are characterized by a green color and a bitter taste. Boiled products based on the composite flour Attiéké/fermented cashew almonds enriched with 10% moringa powder (A) and boiled products based on the composite flour attiéké/unfermented cashew almonds enriched with 10% and 15% moringa powder (D and E) form the fourth group. They are distinguished from the other formulations by their more pronounced sweetness, in contrast to their bitter taste and green color (D and E).

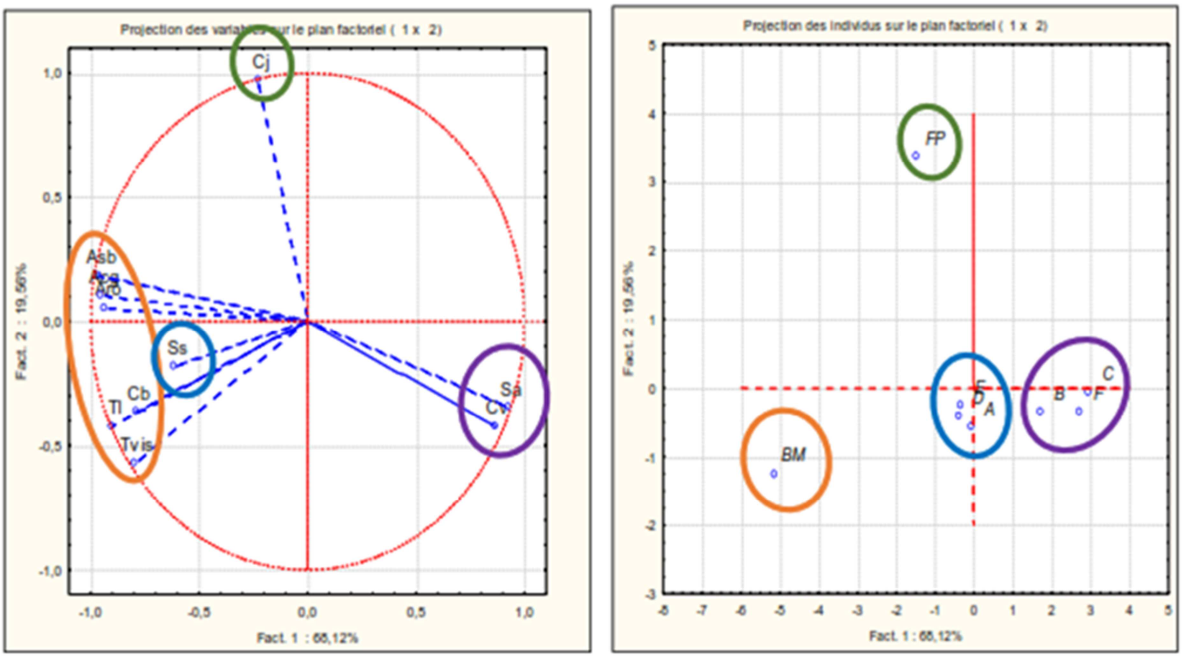

Fig. 3. Projection of the organoleptic parameters and slurry samples of the flours studied in the factorial plane 1-2 of the principal component analysis (PCA).

CJ: Yellow color; Cv: Green color; Cb: White color; Ss: Sweet taste; Sa: Bitter taste; Arô: Flavor; Tvis: Viscous texture; TI: Smooth texture; Aspb: Mouthfeel; Acg: General acceptability.

A: 90% FAFCF15/10% Moringa; B: 85% FAFCF15/15% Moringa; C: 80% FAFCF15/20% Moringa;

D: 90% FAFCNF10/10% moringa; E: 85% FAFCNF10/15 % Moringa; F: 80% FAFCNF10/20% Moringa ;

BM: BLEDINE commercial infant flour; FP: FARINOR commercial infant flour

Discussion

The "in vitro" enzymatic digestibility over 140 min of moringa-enriched composite infant flours (A and E) and Blédine commercial infant flour (BM), showed that the rate of reducing sugars released was higher in the composite flours (A and E) than in the commercial flour. The digestibility of a starch resource is conditioned by a number of factors. Indeed, several factors can influence starch hydrolysis kinetics (Li *et al.*, 2014); in particular, changes in starch state that occur during processing steps. In this study, the formulated flours have finer sizes compared to the control flour. Indeed, it has been shown that flour digestibility depends on its granulometry (Mahasukhonthachat *et al.*, 2010). The finer the flour, the more susceptible it is to enzyme attack. Similarly, the heat treatment (cooking) employed would also serve to increase their digestibility (Singh *et al.*, 2010; Dhital *et al.*, 2015).

When starch is heated to around 80°C in an aqueous medium, it hydrates and swells. Part of the amylose, then of the amylopectin, passes into solution. The suspension then becomes viscous, and the gelatinized starch becomes more easily hydrolyzed. Furthermore, the fermentation process undergone by the cashew kernel flour present in formulation A could account for its greater digestibility (Elkhalifa *et al.*, 2004; Soro *et al.*, 2013).

The sensory evaluation of the different porridges revealed that the porridges of moringa enriched flours were moderately appreciated (5/9 to 7/9). The hedonic test, which focused on general acceptability, showed that the porridges of flours enriched with 10% and 15% moringa were the most accepted (7/9) of the other composite flours enriched with moringa. However, the Bledine control flour porridge was more appreciated. In fact, Bledine flour was made from corn, with sugar and milk added to improve acceptability. Above 15% incorporation of moringa powder, porridges are less acceptable. This is due to the darker green color and bitter aftertaste. According to Zongo et al, 2013, who pointed out that a high amount of moringa powder improves the nutrient content of porridges but could influence their organoleptic quality. In the same vein, Shiriki *et al.* (2015) demonstrated that the quantity, quality and bioavailability of nutrients improved with the level of fortification of supplemental foods with moringa powder, but acceptability moved in the opposite direction due to the increase in bitter taste.

Descriptive analysis revealed that the three accepted porridges had characteristics similar to those of commercial flours. Principal component analysis (PCA) showed that commercial flour porridges were highly appreciated over flours thanks to their pleasant aroma, sweet flavor, smooth and viscous textures and creamy appearance. Smooth and viscous textures are more noticeable in the three composite flours enriched with moringa A, D and E. The viscous texture is reduced as the incorporation rate of moringa powder increases. This is explained by the fact that the starch content, responsible for gel formation during baking, is reduced with increasing incorporation of moringa powder. The green color is more noticeable in flour porridges enriched with 20% moringa powder than in other porridges. This factor influences the acceptability of the porridges. The porridges of composite flours enriched with 10 to 15% moringa (B, C and F) are linked by the green color and bitter flavor, despite its low perception, which limits their acceptability to panelists. Boiled composite flours enriched with 5 to 10% moringa (A, D and E) are strongly associated with sweetness, while bitterness is less perceived. Indeed, sweetness is an important parameter in the usual appreciation of porridges. Consumers generally appreciate the sweet flavor, which is said to confer a delicious taste (Miallet-Serra *et al.*, 2005). Studies also show that the taste for sweet foods is acquired from birth (Nicklaus *et al.*, 2005).

Conclusion

The study of the incorporation of moringa powder in composite flours revealed that the various treatments carried out to obtain the flours contributed to improving the "in vitro" digestibility of these composite flours. Sensory evaluation of the slurries of the composite flours Attiéké/cashew almonds enriched with moringa powder showed that the different slurries were accepted by consumers. Descriptive analysis revealed a more pronounced bitter taste and green color with increasing levels of moringa powder. After 10% moringa enrichment, there was a decrease in the acceptability of the porridges. However, after 10%, the bitter taste and green color of the porridges were more perceived by the panelists.

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