Influence of Baobab Leaf Enrichment on the Physicochemical, Sensory and Nutritional Characteristics of Plantain/Cashew kernels Composite Flours

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Abstract— *The purpose of this study is to determine the nutritional value and sensory acceptance of Baobab leaf enriched plantain- cashew kernel meal. Composite flours formulated from plantain and cashew almond were enriched with baobab leaf powder at substitution levels of 10%, 15% and 20%. The biochemical composition, minerals, vitamin C, antioxidant activity, sensory properties and nutritional parameters of the enriched composite flours were measured. The addition of baobab leaf powder evidenced significant (p <0.05) increase in protein, fiber, vitamin C, main mineral elements, total polyphenols contents and antioxidant activity; but dropped the lipids and carbohydrates contents. With sensory evaluation, cashew-almond-based composite meal formulas substituted for 10% by baobab leaf powder showed a similar overall sensory acceptance to non-enriched cashew-nut kernels. In addition, the ingestion of these meal formulas by the young rats was favorable to their growth. Thus, diets incorporating 10% baobab leaves are more suitable for consumption and growth of young rats.*

Keywords— Flour, plantain-cashew nut, enrichment, Baobab, leaves.

I. INTRODUCTION

Vitamin and mineral deficiencies are among the major nutritional problems affecting populations, especially those with low incomes. Even in developed countries, the micronutrient deficit is not negligible since the affected population sometimes exceeds 30% (Gallan *et al*., 2005). Such nutritional deficiencies cause serious health concerns, specifically among vulnerable people such as children and pregnant and lactating women (FAO/WHO, 1994; FAO/WHO, 1992). Worldwide, half of pregnant women and one-third of under five children suffer from various degrees of anemia due to iron deficiency (UNACC/SCN 1997; Frossard *et al*., 2000). Strategies for addressing these nutritional deficiencies include pure protein supplementation and dietary approaches including the fortification of staple foods with functional foods from the traditional foods often richer in micronutrients (Gibson *et al*., 2000, West, 2002). Improving public health through food biofortification has thus the advantage in promoting natural resources such as highly widespread fruits and vegetables that are generally available even in developing countries.

Fruits and vegetables are products of great importance in terms of food and health. They have many natural flavors and contain nutritional and functional compounds such as carbohydrates, proteins, vitamins, minerals, dietary fiber, antioxidants and other bioactive substances (FAO/WHO, 1992; Traore *et al*., 2015; UNACC/SCN, 1997). These products are part of the Africa's vast reservoir of natural forest resources products exploitable for the well-being of people (Honfo *et al*., 2007; Magdi *et al*., 2004). Thus, the plant species *Adansonia digitata* L. (Malvaceae) locally known as "baobab" is among the vegetables commonly used in Africa. It is a hundred-year life span plant providing multiple uses for populations. Indeed, the different parts of the plant are widely used as food and medicine (Sidibe & Williams, 2002). By the season, fresh and/or dried leaves are important source of protein and minerals for families using this plant as a staple (Sidibe & Williams, 2002). Previous studies highlighted the nutritional features of this fresh leafy vegetable (Oulai *et al*., 2014). As every leafy vegetable, it contains higher levels of magnesium, potassium, calcium, iron and records a significant amount of protein (FAO, 2012; Oulai *et al*., 2014). The micronutrient richness of leafy vegetables is therefore an advantage usable for the biofortification of staple foods during specific periods and diets such as growth, breastfeeding and weaning characterized by increased needs and requiring adaptation of food contributions. The development of composite food formulas enriched with leafy vegetables is an application to meet nutritional needs. In this sense, formulations based on starchy foods enriched in vegetables such as cowpea beans and moringa leaflets have been successfully investigated by Mahan *et al*. (2016a). However, there are scanty data regarding the baobab leaf vegetable in improving the nutritional value of local starchy products used during weaning. Earlier reports have highlighted the nutritional limits of plantain/cashew kernels composites flours (Fofana *et al*., 2017). The purpose of this study is to evaluate the effects of baobab leaf enrichment on the nutritive, sensory and nutritional value of composite flours produced on plantain and cashew kernel basis for use as weaning foods.

II. MATERIAL AND METHODS

2.1 Biological material

The study was conducted on composite flours made from banana plantain (*Musa paradisiaca* sp) and cashew kernels (*Anacardium occidentale* L.). Fresh leaves of baobab (*Adansonia digitata* L.) were used for the enrichment of composite flours. Two infantile commercial flours, namely infantile flour of Bledine® (ETB) and infantile flour of Farinor® (ETF), were used as a reference.

2.1.1 Production of plantain / cashew kernel composite flours

The raw flours were obtained after treatment of ripening plantain at stage 4 and cashew nuts according to the methods of Fofana *et al*. (2017). Then, two composite flours were processed by substitution of part of the plantain flour by the cashew kernel flour. Indeed, a composite flour A was worked by incorporation of 15% unfermented cashew kernel flour, and a composite flour B was filled by incorporation of 10% fermented cashew kernel flour. Each formulation was thoroughly blended, and then divided into 250 g fractions in polyethylene plastics and kept at room temperature till analyses.

2.1.2 Production of baobab leaf powder

The leaves powder from *A. digitata* L. was produced according to the processing reported by Soro *et al*. (2014). The collected leaves were disinfected in a diluted sodium hypochlorite solution (1/1000) for 15 min and thoroughly rinsed with tap water. Thereafter, the leaves were sunny drained for 2 hours (30 ± 5 ° C), immersed in a boiling water bath for 15 min, dripped, and sunny dried for 48 hours resulting in an unvarious weight. Afterwards, the dried leaves were ground using a grinder with a mesh size of 200 μm. The resulted powder was batched in 250 g, hermetically packaged into polyethylene plastic bags each, and then stored at room temperature till incorporation into the plantain/cashew kernels composite flours.

2.1.3 Formulation of enriched composite flours: plantain- cashew kernel -baobab

Formulas enriched with plantain-almond cashew-baobab were obtained by incorporating various ratios of baobab powder into the plantain-almond cashew meals. Thus, samples of plantain + 15% unfermented cashew kernel and plantain + 10% fermented cashew kernel flour were substituted with 10%, 15% and 20% baobab leaf powder weight. So, three enriched flours were formulated from each plantain-cashew composite flour: A10BP, A15BP, and A20BP (from composite flour A), and B10BP, B15BP, and B20BP (from composite flour B). Each final formulation was thoroughly blended, divided into 250 g fractions in polyethylene plastic bags, and stored at room temperature until analysis.

2.2 Physico-chemical analyzes of flours

The physicochemical investigation of the enriched composite formulations consisted in determination of their contents in moisture, macronutrients (proteins, lipids, carbohydrates, and fibre) and micronutrients (minerals, vitamin C, total phenols and antioxidant activity). Thus, the moisture content was determined by drying 5 g of each sample in an oven (Memmert 854 Schwabach, Germany) at 105 ° C for 24 h (AOAC, 1995).

The crude protein content was determined according to the Kjeldahl method using a Kjeltec 8400 (FOSS, Sweden) unit of the analyzer and the resulting nitrogen (% N) allowed the deduction of the percentage of crude protein (% P) using the relation: % P =% N x 6.25 (AOAC, 1995).

The lipid content was determined by extraction using hexane as extraction solvent and a Soxhlet device (Unid Tecator, System HT2 1045, Sweden) (AOAC, 1995). For the crude fibres, 1 g of flour sample was first digested with 1.25 N sulfuric acid and 1.25 N sodium hydroxide. The insoluble residue obtained was washed with hot water and dried in an oven

(Memmert 854 Schwabach, Germany) at 105 ° C for 24 h. The dried residue was then incinerated into a muffle furnace (Nabertherm GmbH Babnhofstrasse 20, 28865 Lilienthal / Bremen, Germany) at 600 ° C for 6 h and weighed for the determination of the crude fiber content. The total carbohydrate content and energy value were estimated from the following formulas provided by AOAC (1995):

Total Carbohydrate Content (%) = 100 - (% moisture +% protein +% fat +% ash)

Total Energy Value (kcal/100 g) = (% of protein * 4) + (% of carbohydrates * 4) + (% of fat * 9)

The flours ash was estimated by incineration of 5 g of each sample in a muffle furnace (Nabertherm GmbH Babnhofstrasse 20, 28865 Lilienthal / Bremen, Germany) at 600 ° C for 6 h (AOAC, 1995), and the resulting ash allowed the minerals evaluation using Pelkin Elmer type of atomic absorption spectrometry (PE 3110, Norwalk USA) according to the AOAC method (1995).

Vitamin C was quantified from the samples by extraction using metaphosphoric and acetic acids and 2,6-dichlorophenol indophenol solutions against a standard vitamin C solution (Poncracz *et al*., 1971). The total polyphenols were extracted according to the AOAC method (Christensen, 1974) using Folin Ciocalteus reagent. The full antioxidant activity of the studied flours was assessed on the anti-radical activity basis, according to the method reported by Choi (2002) and deriving from the bleaching of a DPPH reagent by antioxidant components previously extracted using methanol.

2.3 Sensory analyzes of dishes derived from enriched composite flours

2.3.1 Preparation of the porridges

From each sample, 50 g of flour was added with 275 ml of tap water and then prepared accordingly to indications from both selected reference flours. The porridges were gently cooked for 10 min and table sugar was thereafter added at a rate of 6%. They were then cooled at room temperature before being dished up for analysis about the sensory acceptance and description against both infant flours taken as controls.

2.3.2 Porridges analysis for sensory acceptance

The full acceptance of the porridges prepared from the enriched composite flours was estimated by a group of 60 tasters selected for their availability and regardless of gender and age (18 to 35 years). Twenty (20) ml of porridge samples, identified by individual 3-digit codes, were simultaneously presented to each panelist in a random order. The pleasure perceived by the panelist after tasting each sample was expressed with a quantitative mention on a 9-points hedonic rating scale, ranged from 1 (when the sample is extremely unpleasant) to 9 for the extreme pleasance (Meilgaard *et al*., 1999).

2.3.3 Quantitative sensory description of the porridges

Descriptive sensory analysis of porridges consisted in quantifying appropriate descriptors, such as odor, flavor, consistency, color, and texture. The tests were achieved according to a category scale. The enriched composite meal flours and the commercial infant flours were presented to a jury of 15 people duly trained to sensory analysis methodology (AFNOR, 1984). The porridge samples were then 3-digits coded and presented simultaneously in a random order to quantify their sensory parameters (Meilgaard *et al*., 1999).

2.4 Animal experimentation

2.4.1 Animals and housing

Wistar rats with mean weight of 60 g and at the growth stage were housed in individual metabolism cages. These cages were built with racks and bottles for providing feed and water to animals.

2.4.2 Distribution of animals

Three batches of 7 rats were submitted to a particular diet each resulting from the formulations successfully enjoyed by tasters after the sensory acceptance analysis. Animal experimentation was achieved according to the method reported by previous authors (Adrian *et al*., 1991; Meité *et al*., 2008).

The investigation ran over sixteen days including an adaptation period of two days where animals were fed pellets (standard food) and a 14-day growth period.

2.4.3 Implementation of the experimentation

The experimental animal room temperature was 26 °C, with moisture between 70% and 80%. The food formulas retained at the end of the sensory analysis were distributed *ad libitum* to animals one a day between 8 AM and 10 AM in the form of mash. Drinking water was also provided at will and renewed every day. The animals were weighed at the beginning of the experiment and then at two-day intervals; the last weighing took place at the end of the experiment.

2.4.4 Expression of the nutritional parameters of the studied flours

The chemical analyzes performed regarding the nutritional parameters are consistent with those defined by AOAC (1975), namely the total ingested dry matter (TIDM) which is the total quantity of feed dry matter ingested during the experimentation period, the animals weight gain (WG), the food efficiency coefficient (FEC), the total ingested protein (TIP), and the protein efficiency coefficient (PEC). These parameters are worked with the following mathematical expressions:

TIDM (g) = Total feed dry matter provided – remaining dry matter after the experimentation period

WG (g) = Animal Final weight after experimentation – animal initial weight before experimentation

FEC = WG / IDM

TIP (g) = IDM * % Crude Protein

Protein Efficiency Ratio (PER) = GP / TIP

2.5 Statistical analysis

The data recovered were treated using the Statistical Program for Social Sciences software (SPSS 7.1, SPSS for Windows, USA). The statistical analysis consisted in evaluating the variability of the parameters through a one-way analysis of variance (ANOVA-1) at 5% statistical significance. The enrichment rate was the ANOVA criterion. The averages were classified using the Duncan post-ANOVA test.

III. RESULTS

Table 1 shows the physicochemical composition of the various flours. The moisture content of the flours oscillates between 5.66 ± 0.11% for the plantain flour enriched with 15% unfermented cashew kernel flour (composite flour A) and 4.63 ± 0.60% for the Baobab leaf raw powder. The protein, ash and fibre contents of baobab powder are measured at respective means of 16.90, 9.24, and 29.83 g/100 g. The results attest that incorporation of Baobab raw powder into the composite flours A and B resulted in a successful significant ($P<0.05$) increase in the final protein, ash, and fiber contents. The protein contents of the formulated flours range from 10.11 g/100 g (A10PB) to 12.54 g/100 g (B20PB), while the ash contents vary from 3.15 g/100 g (B10PB) to 5.26 g/100 g (A20PB). These amounts are over that of the ETB control sample (3.33 g/100 g). The fiber contents of composite flour A increase significantly from 1.40 g/100 g to 5.66 g/100 g with 20% incorporation of baobab leaf powder (A20PB). For the composite flour B, the 20% incorporation of Baobab powder increases the fiber content from 0.84 g/100 g to 4.16 g/100 g.

The baobab leaf powder mean content in total fat and carbohydrates are 2.48 g/100 g and 66.75 g/100 g, respectively. Unlike proteins, ashes and fibers, the substitution of proportions of composite flours with baobab powder leads to a significant decrease ($P<0.05$) in fat and carbohydrates levels, respectively from 4.92 g/100 g and 79.62 g/100 g to 3.87 g/100 g and 72.70 g/100 g for the composite flour A and from 3.69 g/100 g and 79.85 g/100 g to 2.99 g/100 g and 75.57 g/100 g for the composite flour B. In addition, Table 1 shows that the overall formulated flours are lower in fat (2.99 to 4.15 g/100 g) than the control infant flour (6.01 g/100 g). Regarding carbohydrates, the experimental infant flours (72.70 g/100 g and 78.59 g/100g) are as provided as the control infant flour (72.81 g/100 g). The results also show that baobab powder has a low energy value (281.42 kcal/100 g) compared to the flours produced. Thus, enrichment with baobab leads to a significant decrease in the energy value of the flours according to the rate of incorporation. The mean energy values of the formulated flours range from 375.35 to 385.85 kcal/100 g, which are statistically lower ($P<0.05$) than that of the ETB control sample (400.09 kcal/100 g).

TABLE 1
CHEMICAL PROPERTIES OF COMPOSITE FLOURS PROCESSED FROM PLANTAIN, CASHEW KERNELS AND FORTIFIED WITH BAOBAB LEAVES POWDER

Flours	Moisture (%)	Protein (mg/100g)	Fat (mg/100g)	Carbohydrate (mg/100g)	Fiber (mg/100g)	Ash (mg/100g)	Energy (kcal/100g)
PB	4.63±0.60^{f}	16.90±0.32^{a}	2.48±0.65^{i}	66.75±0.50^{h}	29.83±0.28^{a}	9.24±0.57^{a}	281.42±1.06^{g}
A	5.26±0.05^{a}	8.03±0.3^{h}	4.92±0.02^{b}	79.62±0.04^{a}	1.40±0.03^{g}	2.15±0.01^{e}	394.92±0.40^{b}
B	5.66±0.11^{f}	8.75±0.22^{g}	3.69±0.29^{f}	79.85±0.12^{a}	0.84±0.64^{h}	2.04±0.23^{e}	387.63±0.51^{c}
A10PB	4.83±0.79^{c}	10.11±0.20^{f}	4.15±0.51^{c}	76.49±0.95^{c}	3.41±0.38^{e}	3.27±0.57^{d}	385.85±0.80^{cd}
A15PB	4.40±0.51^{d}	11.04±0.10^{e}	3.95±0.34^{d}	74.90±0.45^{f}	4.83±0.28^{c}	4.37±0.32^{c}	380.23±2.28^{e}
A20PB	4.21±0.17^{e}	12.42±0.25^{c}	3.87±0.46^{e}	72.70±0.76^{g}	5.66±0.28^{b}	5.26±0.69^{b}	379.45±2.33^{e}
B10PB	4.90±0.42^{b}	11.16±0.98^{e}	3.42±0.25^{g}	77.59±0.15^{b}	2.50±0.57^{f}	3.15±0.00^{d}	383.79±2.68^{d}
B15PB	4.77±0.37^{c}	11.90±0.98^{d}	3.03±0.35^{h}	76.32±0.66^{d}	3.33±0.36^{e}	4.26±0.57^{c}	379.31±2.61^{e}
B20PB	4.33±0.23^{d}	12.54±0.17^{c}	2.99±0.28^{h}	75.57±0.50^{ef}	4.16±0.57^{d}	4.86±0.76^{c}	375.35±2.43^{f}
ETB	4.16±0.23^{e}	13.69±0.33^{b}	6.01±0.02^{a}	72.81±0.28^{g}	2.29±0.05^{f}	3.33±0.57^{d}	400.09±1.44^{a}

Values are casted with average ± standard deviation per parameter. In columns, values with different letters are statistically different at statistical probability value of 5%. ***PB****: Baobab raw leaf powder;* ***A****: Plantain flour with 15% unfermented cashew kernel flour;* ***B****: Plantain flour with 10% fermented cashew kernel flour;* ***A10PB, A15PB, A20PB****: Flour A enriched with respective 10%, 15%, and 20% Baobab leaf powder;* ***B10PB, B15PB, B20PB****: Flour B enriched with respective 10%, 15%, and 20% Baobab leaf powder;* ***ETB****: Control Infant flour from Bledine.*

Table 2 displays the mineral content of the flours investigated. These minerals consist of Na, K, Ca, Mg, Fe and Zn. The incorporation of baobab leaf powder results in significant contribution (P<0.05) for the mineral interest of the composite enriched flours. Thus, potassium is the major mineral, with contents ranging between 384.37 (B10PB) and 539.76 mg/100 g (A20PB). However, the ETB control flour provides higher potassium content (626.17 mg/100 g) compared to the formulated composite flours. Calcium contents range from 149.21 mg/100 g (B10PB) to 281.59 mg/100 g (A20PB) and iron levels range from 6.62 mg/100 g (A10PB) to 9.80 mg/100 (A20PB), whereas they are respectively lower than 30 mg/100 g and 3 mg/100 in non-enriched composite flours. Also, with at least 15% incorporation of baobab powder, the formulated composite flours have iron contents (8.02 to 9.80 mg/100 g) comparable to the ETB control (8.92 mg/100 g). However, the ETB control flour has higher calcium content (695.33 mg/100 g) than the baobab fortified composite formulations. The magnesium and zinc contents of the composite flours are respectively between 93.49 mg/100 g (B10PB) and 113.35 mg/100 g (A20PB) and between 1.88 mg/100 g (B10PB) and 3.01 mg/100 g (A20PB). The tests show a greater presence of magnesium in the formulated flours, compared to the ETB control flour (81.91 mg/100 g). Also, the fortified flours have zinc levels (1.88 to 3.01 mg/100 g) close to that of the ETB control flour (2.39 mg/100 g). With the sodium content, the averages range from 8.21 mg/100 g (B10PB) to 13.45 mg/100 g (A20PB), which are statistically lower (P<0.05) compared to ETB control flour (115.49 mg/100 g).

In addition, enrichment with baobab leaves powder resulted in an increase in the vitamin C content of the composite flours formulated according to the incorporation rate (Table 3). Indeed, the vitamin C contents of the flours vary from 4.03 mg/100 g (A10PB) to 7.13 mg/100 g (B20PB) whereas without baobab powder they are worth hardly 2.5 mg/100 g. However, fortified flours have significantly (p<0.05) lower vitamin C than the control infant flour (45.13 mg/100 g). With the polyphenols compounds, Table 3 also indicates a significant (p<0.05) increase with the addition of baobab powder in the composite flours. The total polyphenols contents are between 630.45 mg GAE/100 g DM (B10PB) and 809.84 mg GAE/100 g DM (A20PB). The overall flours formulations have more significant polyphenols compounds compared to the control flour sample. The antioxidant activity of composite flours (43.22% for A and 42.38% for B) is strengthened by the baobab powder. The fortified flours thus provide an antioxidant activity between 66.42% (B10PB) and 79.55% (A20PB), higher compared to the control flour (50.81%).

TABLE 2
MINERAL CONTENTS (mg/100 g) OF COMPOSITE FLOURS PROCESSED FROM PLANTAIN AND CASHEW KERNELS (FERMENTED AND UNFERMENTED), AND FORTIFIED WITH BAOBAB LEAVES POWDER

Flours	K	Ca	Mg	Na	Fe	Zn
PB	1672.54±1.10[a]	1375.25±1.51[a]	213.93±1.10[a]	35.41±0.45[b]	38.05±0.53[a]	10.22±0.74[a]
A	273.54±1.65[i]	25.24±0.60[f]	85.31±0.51[def]	6.95±0.57[ef]	2.78±0.02[f]	0.69±0.07[d]
B	248.68±0.90[j]	21.48±0.55[F]	78.27±0.63[f]	5.89±0.05[f]	2.60±0.01[f]	0.55±0.06[d]
A10PB	406.49±1.51[g]	151.92±1.08[e]	99.59±0.53[cd]	11.86±0.57[cd]	6.62±0.63[e]	2.08±0.63[bc]
A15PB	469.46±0.46[e]	212.23±1.21[d]	106.25±0.40[bcd]	12.65±0.32[cd]	8.54±0.06[cd]	2.50±0.17[bc]
A20PB	539.76±1.03[c]	281.59±1.73[c]	113.35±0.78[b]	13.45±0.21[c]	9.80±0.08[b]	3.01±0.32[b]
B10PB	384.37±1.06[h]	149.21±1.00[e]	93.49±0.40[cde]	8.21±0.48[ef]	6.43±0.57[e]	1.88±0.26[c]
B15PB	449.26±1.49[f]	210.44±1.51[d]	100.93±0.79[bc]	9.20±0.35[def]	8.02±0.15[d]	2.38±0.95[bc]
B20PB	516.81±1.58[d]	276.96±1.63[c]	107.72±1.02[bc]	10.20±0.62[cde]	9.64±0.05[b]	2.90±0.69[b]
ETB	626.17±0.51[b]	695.33±1.15[b]	81.91±0.62[ef]	115.49±0.64[a]	8.92±0.60[c]	2.39±0.01[bc]

TABLE 3
CONTENTS IN POLYPHENOLS COMPOUNDS, VITAMIN C, AND ANTIOXIDANT ACTIVITY OF THE STUDIED COMPOSITE FLOURS

Flours	Total polyphenols (mg GAE/100g DM)	Vitamin C (mg/100g)	Antioxydant activity (%)
PB	1003.07±0.59[a]	22.35±0.26[b]	85.33±0.05[a]
A	387.01±0.60[e]	1.29±0.44[h]	43.22±0.51[g]
B	388.65±0.71[e]	2.58±0.44[g]	42.38±1.29[g]
A10PB	637.61±0.00[d]	4.03±0.56[h]	66.62±1.10[e]
A15PB	742.66±0.00[bc]	5.29±0.74[e]	72.78±0.68[c]
A20PB	809.84±0.98[b]	6.06±0.61[d]	79.55±0.37[b]
B10PB	630.45±0.00[d]	5.58±0.25[de]	66.42±0.45[e]
B15PB	697.34±1.06[cd]	6.10±0.49[d]	70.47±0.02[d]
B20PB	765.56±0.83[bc]	7.13±0.45[c]	79.27±0.62[b]
ETB	173.87±0.60[f]	45.13±0.98[a]	50.81±1.14[f]

*Values are casted with average ± standard deviation per parameter. In columns, values with different letters are statistically different at 5% significance. **PB**: Baobab raw leaf powder; **A**: Plantain flour with 15% unfermented cashew kernel flour; **B**: Plantain flour with 10% fermented cashew kernel flour; **A10PB**, **A15PB**, **A20PB**: Flour A enriched with respective 10%, 15%, and 20% Baobab leaf powder; **B10PB**, **B15PB**, **B20PB**: Flour B enriched with respective 10%, 15%, and 20% Baobab leaf powder; **ETB**: Control Infant flour from Bledine; **GAE**: gallic acid equivalent; **DM**: dry matter.*

From the sensory analysis, the overall porridges acceptances are shown in Table 4. The formulations are variously appreciated. Thus, the enrichment with baobab powder decreases the full acceptance of the porridges the more the incorporation rate. Flours supplemented with 10% baobab leaf powder (A10PB and B10PB) record acceptance rating of 6.96/9 and 6.67/9 close to that of commercial flour ETB (7.28/9), and are the most preferred in both batches of composites flours formulations A and B. With the same rate of baobab incorporation, the slurries containing unfermented cashew meal (A) is statistically more enjoyed than the porridge with fermented cashew kernel flour.

The descriptive sensory parameters are exhibited by the sensory profiles drawn in Figures 1 and 2. The flours enrichment with baobab powder generates new sensory parameters (green color, bitter taste and glutinous aspect) which are globally not appreciated by the tasters. These descriptors are perceived accordingly to the rate of incorporation of the baobab leaf powder. Thus, the green appearance is rated from the composite porridges formulated between 3.68/9 (B10PB) and 5.25/9 (A20PB), while control flours (ETB and ETF) do not reveal any obvious green appearance (1.00/ 9). Regarding the flavors, the bitterness of the porridges is rated between 2.58/9 (A10PB) and 5.37/9 (B20PB); which is relatively lower compared to the sweet flavor perceived with indices of 6.18/9 (B20PB) to 6.75/9 (A10PB). The sticky texture is also mentioned from the formulations having baobab leaf powder, with scores ranging from 3.06/9 (B10PB) to 6.06/9 (A20PB). In addition, the more the rate of incorporation of baobab powder, the more the aroma and smooth texture are decreasing. The smooth texture of enriched composite porridges is rated with indices ranging from 6.82/9 (A10PB) to 4.81/9 (B20PB). The aroma records a sustained decrease in the perception degree from the composite flour A with scores dropping from 6.43/9 (A10PB) to 5.62/9 (A20PB), whereas the scores recorded from the flour B formulations range from 6.88/9 (B10PB) to 4.75/9 (B20PB). On the other hand, the incorporation of the baobab leaf powder accentuates the fluidity of the formulated meal mixes. The fluid texture is perceived with indices increasing from 6.95/9 to 7.42/9 and 6.88/9 to 7.13/9 for the respective enriched formulations deriving from flour A and flour B, according to the incorporation rate.

TABLE 4
SENSORY ACCEPTANCE OF PLANTAIN/CASHEW KERNELS COMPOSITE FLOURS PORRIDGES ENRICHED WITH BAOBAB LEAVES POWDER

Porridges	Overall sensory acceptance (/9)
A	7.07±1.51^{c}
B	6.98±1.46^{c}
A10PB	6.96±0.93^{c}
A15PB	6.25±1.54^{e}
A20PB	5.17±0.68^{g}
B10PB	6.67±1.43^{d}
B15PB	5.81±1.45^{f}
B20PB	5.05±0.56^{h}
ETB	7.93±0.26^{a}
ETF	7.28±0.39^{b}

*Averages± standard deviations with different superscripts are statistically different at 5% significance. **A**: Plantain flour with 15% unfermented cashew kernel flour; **B**: Plantain flour with 10% fermented cashew kernel flour; **A10PB**, **A15PB**, **A20PB**: Flour A enriched with respective 10%, 15%, and 20% Baobab leaf powder; **B10PB**, **B15PB**, **B20PB**: Flour B enriched with respective 10%, 15%, and 20% Baobab leaf powder; **ETB, ETF:** Control Infant flours from Bledine and Farinor.*

Since the porridges A10PB and B10PB are more enjoyed par tasters, they were used for the nutritional *in-vivo* analysis with rats. The nutritional values of the various diets provided to animals are recorded in Table 5. Rats fed with the ETB control diet have a more significant daily consumption (9.01 g/day) than those fed respectively with A10PB diets (5.16 g/day) and B10PB (5.89 g/day). The A10PB and B10PB diets provide the same daily amounts of total dry matter ingested. The highest levels of protein intake are achieved with the ETB control diet (1.22 g/day); and both A10PB and B10PB investigated diets result in similar amounts of protein ingestion (0.52 g/day and 0.65 g/day, respectively). All animals fed with the different diets gain weight. Animals fed at the A10PB and B10PB diets display respective mean weight gains of 0.68 g/day and 0.79 g/day. The rats with the highest growths are those subjected to ETB control diets (2.07 g/ day).

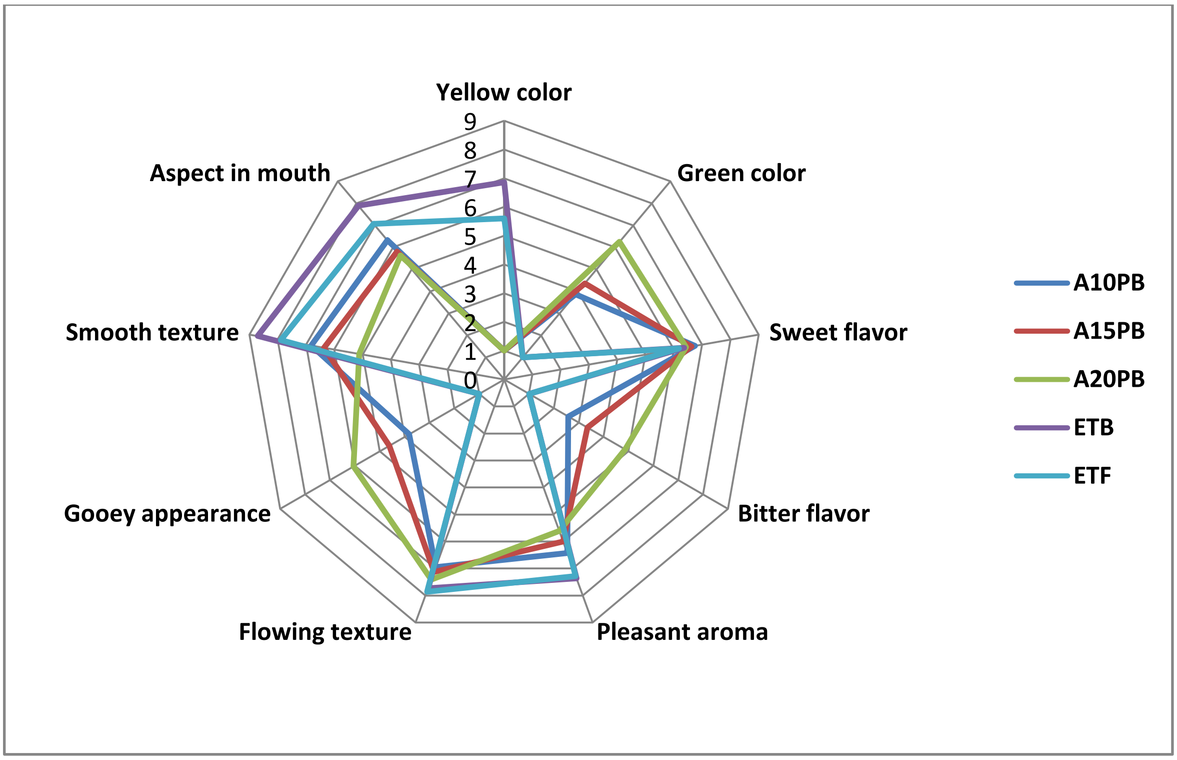

FIGURE 1: Sensory profiles of plantain/unfermented cashew kernels composite porridges enriched of baobab leaves powder and control flours

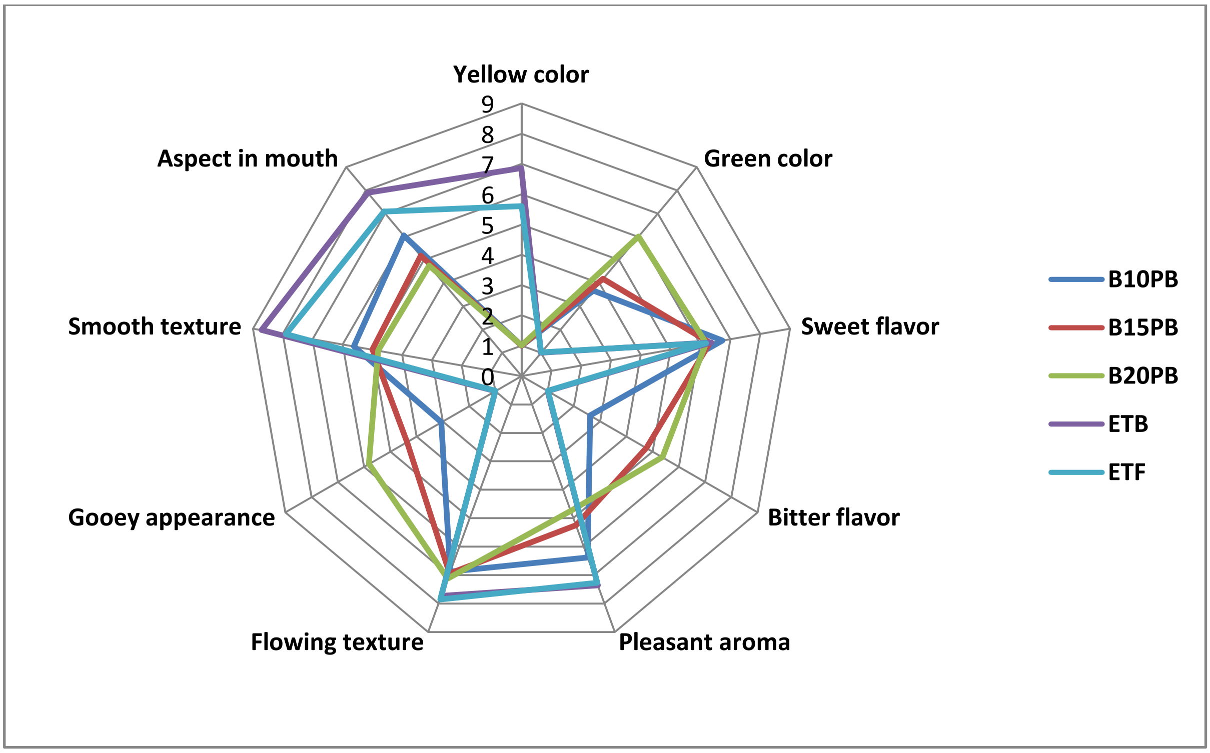

FIGURE 2: Sensory profiles of plantain/fermented cashew kernels composite porridges enriched of baobab leaves powder and control flours

***A10PB**, **A15PB**, **A20PB**: Flour A enriched with respective 10%, 15%, and 20% Baobab leaf powder; **B10PB**, **B15PB**, **B20PB**: Flour B enriched with respective 10%, 15%, and 20% Baobab leaf powder; **ETB, ETF:** Control Infant flours from Bledine and Farinor.*

The highest food efficiency coefficient (FEC) values are recorded from rats fed with the ETB diet (0.23). These values are significant ($p<0.05$) than those provided from fed diets A10PB (0.13) and B10PB (0.13). Similar to the FEC, the ETB control diet has the most protein efficiency coefficient (1.69).

TABLE 5
NUTRITIONAL VALUE OF PLANTAIN / CASHEW KERNEL COMPOSITE FLOURS ENRICHED WITH BAOBAB LEAVES POWDER

Parameters	ETB	A10PB	B10PB
TIDM (g)	126.14±2.01^{a}	72.26±1.00^{c}	82.46±1.04^{b}
DIDM (g/day)	9.01±0.50^{a}	5.16±0.11^{b}	5.89±0.50^{b}
TIP (g)	17.15±0.99^{a}	7.30±0.20^{c}	9.16±0.56^{b}
DIP (g/day)	1.22±0.21^{a}	0.52±0.50^{b}	0.65±0.53^{b}
FWG (g)	29.08±1.01^{a}	9.58±0.59^{b}	11.12±0.22^{b}
DWG (g/day)	2.07±0.29^{a}	0.68±0.58^{b}	0.79±0.30^{b}
FEC	0.23±0.35^{a}	0.13±0.70^{b}	0.13±0.97^{b}
PER	1.69±1.92^{a}	1.31±1.04^{b}	1.21±1.07^{c}

Per column, the averages ± standard deviations with different superscripts are statistically different at 5% significance. TIDM: total ingested dry matter, DIDM: daily ingested dry matter; TIP, total ingested protein; DIP, daily ingested protein; FWG: full weight gain; DWG: daily weight gain; FEC: food efficiency coefficient; PER: protein efficiency ratio.
***ETB:** Control Infant flour from Bledine; **A10PB, B10PB**: Respective Flours A and B enriched with 10% Baobab leaf powder.*

IV. DISCUSSION

The moisture of the flours studied is at the same range as the maximum limit of 5% required for the good preservation of infant flours (FAO/WHO, 2006). Indeed, the low moisture content of food products reduces the enzymatic and biochemical activities of the degradation microorganisms; with the advantage of preventing the deterioration of these products during storage (Kikafunda, 2006).

The incorporation of dried baobab leaf powder into composite flours A and B has significantly increased the protein, fibre and mineral contents in the formulated flours. These data strengthen previous studies considering baobab leaves as a natural reserve of minerals and proteins (Sidibé *et al*., 2002, FAO, 2012, Oulai *et al*., 2014). Regarding the protein content, the incorporation of baobab into composite flours A and B succeeded in infant flours with protein contents in accordance with the proteins amounts of 11-21 g/100g recommended by the FAO/WHO (2008) for weaning foods. These results are comparable to those obtained from the enrichment of *Ogi*, a corn and sorghum-based porridge in Nigeria, with moringa (*Moringa oleifera* L.) worked by Abioye and Aka (2015). Proteins being among the most important nutrients required in weaning foods, the high protein values observed in the current formulations are favorable for their valorization in the diet of young children. Thus, they could complete traditional foods mainly consisted of cereal and tuber porridges and causing protein-energy disorders among children weaned at low ages in developing countries (Anigo *et al*., 2009).

The dried baobab leaf powder used revealed fibre content (29.83g/100g) comparable to the value of 28.6 g/100 g reported by the FAO (2012). After enrichment, the fibre contents of the formulated flours comply with the international standard (≤ 5 g/100g) provided by FAO/WHO (2006) for complementary foods. Fibres regulate intestinal transit and capture some of the lipids and carbohydrates molecules, helping thereby the regulation of blood sugar levels and preventing the cholesterol excess (Ponka *et al*., 2016). They also have a positive effect against overweight and metabolic diseases due to their high degree of saturation (Henauer and Frei, 2008); and facilitate the hydration of feces (AFSSA, 2002).

The reduction of carbohydrate content in the formulated flours could logically be attributed to the lower presence of these molecules in the baobab powder, since the enrichment technique consisted in substituting a proportion of the composite flour by the baobab powder. Decreasing carbohydrate content, especially in starch, may reduce the water absorption from flours. Such a factor is advantageously used during preparation of the concentrate-based flours in dry matter (flour) to obtain a suitable fluidity for children. In addition, the decrease in lipid content is in accordance with many studies reporting that leafy vegetables are fat-free food resources (Ejoh *et al*., 1996). The lipid contents of overall formulated flours remain below the maximal limit of 8% admitted for the weaning foods (FAO/WHO, 2006). The low lipid content in foods could succeed in increasing their self-life by decreasing the rancidity ability.

The substitution of flour with baobab powder also resulted in a reduction of the energy value of the formulas obtained. Nevertheless, the energy values of the flours formulated in this work (375.35 to 385.85 kcal/100 g) are greater than the values of about 300 kcal/100 g resulting from the composite formulations worked by Mahan *et al*. (2016a) during enrichment trials of the flour deriving from young shoots tubers of Borassus aethiopum Mart with moringa leaves and cowpea beans. The energy values recorded from baobab-enriched flours are within the recommended range (344.4 to 473.81 kcal/100 g) for infant flours (Lutter, 2003); which is therefore favorable to the use of these flours against protein-energy malnutrition.

Moreover, the incorporation of baobab leaf powder increased the ash content of plantain/cashew nut flour, resulting in improvement of their mineral richness since minerals are the main ash components. The great minerals presence in baobab leaves has been highlighted by other works (FAO, 2012, Oulai *et al*., 2014) concluding on a good source of macroelements (potassium, calcium, magnesium) and oligoelements (iron, zinc, copper) for such a vegetable. The levels of potassium, magnesium and iron in baobab-enriched flours fill the recommendations of FAO/WHO (2006), even though their calcium and zinc contents remain below the standards. The food mineral nutrients are essential for the full metabolism in the body (Sowoola *et al*., 2002).

The ascorbic acid contents ran from 2.58 to 7.13 mg/100g, but remained significantly lower than the recommended value of 30 mg/100g (FAO/WHO, 2006). Ascorbic acid is an essential cofactor in various biological reactions and an antioxidant in the aqueous phase (Naziroglu and Butterworth, 2005). It participates in the absorption of iron in the gut and is necessary for the formation of collagen, the main protein of connective tissue that protects various organs (Shiriki *et al*., 2014). As a result, the consumption of fruit and vegetable juices, rich in this vitamin, in addition to the porridge is imperative for the well-being of children and infants.

The antioxidant properties of the methanolic extracts from the flours studied, although variable, forecast on the inhibitory ability of these flours against free radicals. The antioxidative ability of the composite flours is strengthened by the baobab leaf powder may because of its higher total polyphenol content (Oulai *et al*., 2014). Polyphenol compounds are important antioxidants known as protectors of biological macromolecules against degradation. Thus, they effectively fight against aging and the occurrence of cancer cells (Scalbert *et al*., 2005, Xia *et al*., 2011). Moreover, the affinity of polyphenols for free radicals is advantageous against the oxidation of low-density lipoproteins cholesterol (LDL-Cholesterol), which could conclude in the prevention of cardiovascular diseases (Kayodé *et al*., 2012). This antioxidant property is thus beneficial and helpful against carcinogenesis (Hooper and Cassidy, 2006). The regular consumption of these formulated flours as baby food-based could strengthen children's health.

The sensory evaluation showed a significant ($p<0.05$) influence of baobab fortification on the overall acceptance of the plantain-almond cashew composites meals (A and B). The maximum incorporation rate of 10% leafy vegetables is consistent with the work of Abioye and Aka (2015) when incorporating moringa leaf powder. Pleasant flavor and aspect are fundamental parameters in the appreciation of the porridge, especially from the children. Indeed, the sweet taste is an important parameter of habitual appreciation of the porridge. In addition, studies also indicate that taste for sweet foods is acquired as early as the birth (Nicklaus *et al*., 2005). Thus, the porridges of composite flours A10PB and B10PB, whose bitter taste is weakly expressed, are considered pleasant by overall consumers. The fair appreciation of the other porridges prepared could be resulted from the significant bitterness provided by the incorporation rates beyond 10% baobab leaf powder since baobab leaves displayed higher content of tannins, bitterness based compounds. These results are in agreement with those obtained by Mahan *et al*. (2016b), who showed that the bitterness is as strengthened as the porridges are incorporated with higher rate of moringa leaf powder. For the porridges texture, the glutinous aspect observed is due to the presence in the baobab leaves of mucilages which are hydrosoluble complex polysaccharides and lead to highly viscous solutions (Kerharo *et al*., 1974). The decrease of the aroma and taste of the porridges the more the incorporation rate are consistent with the work of Abioye and Aka (2015) and Ijarotimi and Oluwalana (2013). Thereby, the incorporation of natural aroma, natural flavor enhancers, and food grade oil could promoting infant formulas A10PB and B10PB as food support against child malnutrition. Such forecasting is as plausible as the ETB control commercial flour, which contains flavor and aroma, records a higher sensory acceptance and consumption compared to the formulated flours. These observations are consistent with the reports of Serna-Saldivar *et al*. (1999) who mentioned higher consumption values obtained by animals fed with casein diet (milk protein) compared to those receiving diets containing fortified breads with soy flour. The superiority of the rats' protein digestive use from the ETB control diet is explained by the good quality of the milk proteins. Indeed, these proteins have a good balance in essential amino acids with higher digestibility trait (Apfelbaum *et al*., 2004). However, despite the relative lower consumption index of the A10PB and B10PB formulations compared to the ETB control, they succeed in significant contribution in weight gain. These results confirm the nutritional and sensory quality recorded during biochemical and sensory tests of flours.

V. CONCLUSION

The results obtained in this study clearly indicate the nutritional benefits from the use of baobab leaf powder to enrich the plantain- cashew kernel composite meal. Among the substitution rates, the incorporation of 20% of baobab leaf powder into the composite flours of the plantain- cashew kernel meal improves significantly the protein, fiber, mineral and phytochemical contents of the formulated flours, but formulations with 10% substitution by baobab powder are more enjoyed as the non-enriched samples. They provide acceptable indicators of growth and nutritional use for rats; which parameters are extrapolable to the human race. Exploitation of plantain-cashew nut meal enriched with 10% baobab leaf powder could therefore be recommended in nutrition programs to deal with children malnutrition concerns.

DISCLOSURE OF INTEREST

The authors state that they have no competing interests.

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