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Nutritive Compounds from Flours of *Borassus aethiopum* New Shoots Enriched with *Moringa oleifera* Leaves and *Vigna unguiculata* Beans Powders

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Authors' contributions

This work was carried out in collaboration between all authors. Author BGHM supervised the whole investigation. Author MMR designed the study, performed the experiment and wrote the manuscript assisted with authors KNY and AYO. Authors DMV, KNY and MMR performed the statistical analysis of the results and checked the revised manuscript. Authors SD and CA participated in interpretation of the results. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this study is to contribute to a better valorisation of Palmyra by determining the nutritive compounds of the flours of its young shoots enriched with *Moringa oleifera* leaves and Cowpea beans powders, also evaluate the nutritional contributions of the consumption. The samples were collected between August and December 2015 from 3 big regions (Bélier, N'Zi and

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District of Yamoussoukro), in the center of Côte d'Ivoire. Once acquired, from the samples, 250 Kg, 75 Kg and 75 Kg of Palmyra new shoot tubers, cowpea beans and moringa leaves respectively, were sorted, washed dried and processed into flour. For this purpose, the nutritive compounds of formulations obtained using the central composite design and two industrial infantile flours (ET1 and ET2) were determined. The analysis of the nutritive compounds gave the following contents: proteins (8.27 ± 0.09 – 15.07 ± 1.74 g/100 g), ash (1.65 ± 0.23 - 2.67 ± 0.20 g/100 g), lipids (1.33 ± 0.18 - 8.70 ± 1.71 g/100 g), carbohydrates (68.07 ± 0.48 – 82.13 ± 0.96 g/100 g), soluble carbohydrate (4.55±0.37 - 30.71±1.27 g/100 g), reducing sugars (0.97±0.08 -8.07±0,48 g/100 g), and fibers (1.58±0.09 – 5.50±0.19 g/100 g). Of the formulations, nine had high protein content to that of the control flour ET1 and therefore had protein values in accordance with the FAO/WHO recommended standards for weaning foods. The caloric energy values of these flours are high (301.43 ± 3.80 to 352.58 ± 0.50 kcal/100 g). The average daily quantity of flour consumed by children under 5 in Africa is 250 g. The contributions estimated in nutritive compounds of 250 g of EF07 or EE09 flours are higher than those obtained with *B. aethiopum* flour. They contributed to more than 100% of needs in proteins and caloric energy, and 50% of fibers in children under 5. Similar results are obtained with the reference flours used. The popularization of these composite food formulations could help to ensure the food security of populations, preserve biodiversity and promote the fight against poverty and the advancement of the desert.

Keywords: Enriched flours; B. aethiopum; M. oleifera; V. unguiculata; nutritive compounds daily intake.

1. INTRODUCTION

The challenge of fighting malnutrition on a global scale is one of the most pressing issues of our time. Widespread food shortages have resulted in persistent hunger and malnutrition, particularly among low-income groups in developing countries. Indeed, Food and Agriculture Organization (FAO) estimated that more than 868 million people didn't meet their energy needs in the world, 98% of them in developing countries where at least 225 million children were affected [1,2]. Otherwise, 26% of children in the world were stunted, 2 billion people suffered from one or more micronutrient deficiencies and 1.4 billion people were overweight, of whom 500 million were obese [2,3].

In developing countries as those of the Sub-Saharan African, lack of dietary diversity and food availability has led to malnutrition due to an overall deficit in energy intake and micronutrient deficiencies [4,5]. Maternal and child undernutrition is the underlying cause of 3.5 million deaths [6].

In Côte d'Ivoire, there is a problem of the double burden of undernutrition and the emergence of overweight, and chronic non-transmissible diseases related to nutrition [7]. The situation of socio-economic and political crisis has contributed to the deterioration of the nutritional state of populations, in particular, children under 5 and women representing the most vulnerable groups. The prevalence of malnutrition in children under 5 years is 30% with 12% severe form with underweight affecting 15% of children, [8].

Although efforts have been made by the Government and its partners with a downward trend in recent years, the nutritional situation remains a national concern, especially in most of the regions (North, North-East, North-West, West, South West and Central) where rates of stunting are higher than 30%, with profiles of chronic malnutrition considered serious [8].

Faced with this situation, which particularly affects the future of many children, the actors (public services, NGO) working in the field of health and nutrition are in need of food supplements (in particular infant flours) more easily available and inexpensive to integrate them into the different programs of action in nutrition [9]. Thus, the enrichment of staple foods remains one of the important ways to combat malnutrition [10].

In addition, the exceptional nutritional value of legumes (soybeans, cowpeas and moringa) and the ease with which they can be produced are all factors that make it a potential asset to fight this curse in Côte d'Ivoire. In fact, legumes contribute to meeting protein, fiber, fat, essential minerals, vitamins and functional constituents requirements for the well-being of consumers and therefore, their absence in diets have important implications in this regard [11]. They play an inescapable role in the population's food security strategy and contribute to the nutritional balance by providing a significant income to the producer families [12,13]. Among legumes, cowpeas and moringa, which are recognized as highly nutritious [14,13], are increasingly used to improve the nutritional content of starch-based foods (maize, rice, millet) Tubers (yams, potatoes) and roots (cassava) low in proteins, fat and micronutrients.

Thus, *Borassus aethiopum* whose young shoots are tuberous and edible foods highly valued by the local populations as energetic food resource attracted our attention [15]. Palmyra young shoots are often processed into flour for the preparation of porridge or local fufu (food found in Côte d'Ivoire), especially during the lean season [16]. Some previous work has described the nutritional composition of this plant material [17,18]. The results of these studies have shown that young shoots of *Borassus aethiopum* are poor in protein and micronutrients like most starchy foods. This nutritional deficit is a threat to the public which could cause health problem. The dishes enrichment based on these young shoots of *B. aethiopum* with other local edible vegetable sources, notably cowpeas and *Moringa oleifera*, referring to the recommendations of FAO/WHO [10] would contribute to solve the problem.

The objective of this study is to produce composite flour made from *B. aethiopum* young shoots enriched with high nutritive compounds *Moringa oleifera* leaves and *Vigna unguiculata* beans needed by the population.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material was the flour processed from *Borassus aethiopum* new shoots, *Moringa oleifera* leaflets and *Vigna unguiculata* beans powders. Some industrial infantile flours were used as reference during the study

2.2 Sampling

The acquirement of the raw material samples were done between August and December 2015 from 3 big regions (Bélier, N'Zi and District of Yamoussoukro) in the Centre Region, which are the natural habitat accommodating Palmyra in Côte d'Ivoire and where large quantities of *Vigna unguiculata* and *Moringa oleifera* are also produced. To achieve this study, 90 kg of Palmyra new shoots, 30 kg of Cowpea beans and 50 kg fresh leaves of *Moringa oleifera* were purchased from the retailers in each of the three regions, giving total amount of 270 kg Palmyra new shoots, 90 kg of Cowpea beans and 150 kg of *Moringa oleifera* leaves. Once acquired the samples were taken to the lab for analyses. Thus, a pool was constituted by mixing samples by plant species. Finally, 250 kg, 75 kg and 75 kg of respective samples from Palmyra new shoots, Cowpea beans, and *Moringa oleifera* leaves were deducted, sorted, washed meals.

2.3 Processing of Palmyra Flour and Powders from Cowpea and Moringa

The study was conducted in Laboratory of Biochemistry and Food Sciences, Biosciences Unit, at Félix Houphouet-Boigny University, Côte d'Ivoire, between June 2015 and February 2016.

Palmyra flour and powders from Cowpea beans and *Moringa oleifera* leaves were processed according to previous reports of Mahan et al. [18]. The Palmyra new shoots tubers were washed, boiled, peeled, carved, rinsed, and then to fermentation with, allowed to ferment inside a tank for 24 hr [19]. The fermented tubers pieces were dried at 65°C in a ventilated oven (Minergy Atie Process, France) for 6 hr, and ground using a hammer mill (Forplex).

The moringa leaves were disinfected for 5 min with chlorinated water (50 mL of 8% sodium hypochlorite in 30 L of water), rinsed, and fermented inside a tank for 24 hr. Then, fermented leaves were dried at 30°C for 14 days with shade ambient temperature and powdered.

Regarding Cowpea, beans were washed, soaked, drained, and submitted to sprouting at 30°C during 48 hr. The seeds were dried at 40°C using the oven for 96 hr, and the resulted malt was sprout out, heated for 15 min in boiling water and submitted to 24 hr fermentation inside a tank. The fermented Cowpea beans were strained, roasted, dried at 50°C in the oven for 24 hr, and ground.

Finally, flour and powders were filtered using sieves with 250 µm diameter and the resulting products were put in polyethylene hermetic bags and kept dry place till analyses.

2.4 Preparation of Composite Flours

From the flours obtained, 15 formulations in different proportions were constituted according to the method used by Mahan et al. [20]. Indeed, these authors used a central composite design taking into account 3 variables (quantities of *B. aethiopum*, cowpea and *Moringa oleifera* leaves). Referring to Feinberg [21], the combination of the 3 variables led to 20 formulations with 8 factorial essays, 6 star essays and 6 essays in the central experimental domain. The 6 essays in the center were reduced to a formulation because they had the same proportions of the ingredients. The different composite flours, the reference flours and their code are presented in the Table 1.

Table 1. Different composite flours, references flours and their code

Flour code	Quantity of flour (%)		
	BAM	**VUW**	**MOL**
EF01	72	18	10
EF02	78	14	8
EF03	62.5	28.5	9
EF04	70	23	7
EF05	65	16	19
EF06	71.6	12.8	15.6
EF07	57	26	17
EF08	64.5	21.5	14
EE09	61	24	15
EE10	72	17	11
EE11	75	11	14
EE12	61.4	27.3	11.3
EE13	73	21.6	5.4
EE14	62.8	18.6	18.6
EC15	67.5	20	12.5
ET1	Control 1		
ET1	Control 2		

BAM, Borassus aethiopum Mart.; VUW, Vigna unguiculata Walp ; MOL, Moringa oleifera Lam; EF, factorial essay; EE, star essay; EC, essay at the centre ; ET1, sample control 1; ET2, sample control 2

2.5 Determination of the Nutritive Compounds

The nutritive assessment concerned the contents of moisture, proteins, lipids, carbohydrates, ash and fibers. The caloric energy values of the flours were also calculated.

2.5.1 Moisture content

The moisture content was determined by drying 5 g of meal at 105°C in an oven till constant weight upon a two-digit scale. The weight loss after ovening allowed deduction of the water content [22].

2.5.2 Proteins content

The proteins content was based on the total nitrogen of each flour sample according to Kjeldhal method. Thus, 1 g of flour was mineralized at 400°C for 2 h, with adding of concentrated sulfuric acid and potassium sulfate catalyst. The outcome solution was diluted with distilled water and sodium hydroxide was added to, then, distilled for ten min. Thereafter, the distillate collected in a flask containing boric acid and methylen bromocresol reagents, was taken to titration of the total nitrogen with a 0.01 N sulfuric acid solution. A factor of 6.25 was used to convert the total nitrogen into proteins content [22], according to the equation hereafter.

$$PC\ (g/100\ g) = TNC\ (g/100\ g) \times 6.25$$

With: PC, Proteins content; TNC, Total nitrogen content

2.5.3 Lipids content

Lipids were quantified by solvent extraction using hexane and Soxhlet device for 7 h [22]. The hexan-oil mixture resulted from the extraction was separated with a rotavapor and the sample's weight difference before and after the essay stated on the lipids content.

2.5.4 Ash content

The ash contents were determined by incineration in an electric muffle oven. Five grams of sample were beforehand carbonized on a Bunsen burner, and then placed into the oven at 550°C for 12 h. Thereafter, the white derived residue was weighed expressed in ash percentage.

2.5.5 Fibers content

The determination of the crude fibers percentage consisted in treatment of 2 g of flour with 50 mL of 0.25 N sulfuric acid and 50 mL of 0.31 N sodium hydroxide and filtration of the outcoming solution upon Whatman paper. The residue was dried for 8 h at 105°C then incinerated at 550°C for 3 h into ovens [22]. The crude fibers content was deducted according to the equation below:

$$CFC\ (\%) = (W1-W2) \times 100/We$$

With: CFC, Crude fibers content; W1, weight of the residue ovened (g); W2, ash weight after incineration (g); We, weight of the essay (g).

2.5.6 Contents of total glucides, total soluble carbohydrates and reducing sugars

Total glucides were quantified accounting the contents derived with proteins, moisture, lipids, fibers and ash as indicated by FAO [23] in the following formula:

TGC (%) = 100 – [Prot + Lip + Moi + Ash + Fib]

With TGC, Prot, Lip, Moi, Fib:of total glucides content, proteins, lipids, moisture and fibers.

Ethanosoluble glucides were extracted from 1 g of flour with 20 mL of 80% (v/v) ethanol, 2 mL of 10% (m/v) zinc acetate and 2 mL of 10% (m/v) oxalic acid. The extract was centrifuged at speed of 3,000 rpm for 10 min. The ethanol residue was evaporated from the extract upon a hot sand bath. Then, the extracted total soluble sugars were measured out with the method of Dubois et al. [24]. That consisted in adding 0.9 mL of distilled water, 1 mL of 5% (m/v) phenol and 5 mL of 96% sulfuric acid into 100 µL of extract, then measuring the absorbance at 490 nm with a spectrophotometer (PG instruments). For the reducing sugars, 1 mL of extract was processed with 0.5 mL of distilled water and 0.5 mL of 3, 5-dinitrosalycilic acid [25] prior to the recording of the absorbance from the final solution at 540 nm with spectrophotometer. Calibrations were performed with standard solutions of glucose and sucrose.

2.5.7 Caloric energy value

The caloric value of nutritive energy outcoming from the meals samples was calculated using coefficients related with the main macronutrients, especially proteins, lipids and glucides [23] as stated below:

CE = (2.44xProt) + (8.37xLip) + (3.57xGlu)

With CE, Prot, Lip, Glu, contents of Caloric Energy, proteins, lipids and total glucides.

2.6 Evaluation of the Nutritive Contribution

The contributions in nutritive compounds were estimated according to the method of Codex Alimentarius that takes into account the concentrations in nutritive compounds recovered in the food and the daily consumption of a child under-5s of this food [26].

Estimated Daily Intake (EDI) = C × Q

With: C, nutritive compound concentration measured; Q, food daily consumption;

2.7 Statistical Analysis

The data were recorded with Excel file and statistically treated with Statistical Program for Social Sciences (SPSS 22.0 for Windows). The statistical test consisted in a one-way analysis of variance (ANOVA) with the type of meal assessed basis. From each parameter, means were compared using Student Newman Keuls post-hoc test at 5% significance level. In addition, Multivariate Statistical Analysis (MSA) was performed through Principal Components Analysis (PCA) and Hierarchical Ascending Clustering using STATISTICA software (version 7.1) for structuring correlation between the samples studied and their nutritive compounds traits.

3. RESULTS

3.1 Moisture Contents of the Flour

The moisture differentiates ($p < 0.001$) the composite flours studied from the control flours. The composite flours show the moisture content statistically identical ($p > 0.05$) and range between 7.88 ± 0.78% (EF03) and 8.44 ± 0.44% (EF04). The industrial infantile flours ET1 and ET2 provide 6.03 ± 0.24% and 5.98 ± 0.16% of respective moisture percentage (Table 2).

3.2 Nutritive Compounds of Flours

The protein contents vary from 8.27 ± 0.09 g/100 g in composite flour EF02 to 13.21 ± 0.75 g/100 g in composite flour EF07 ($p < 0.001$). Control flours ET1 and ET2 provide respectively 10.02 ± 0.33 and 15.07 ± 1.74 g/100 g of protein contents. The results indicate that composite flours EF03, EF04, EF05, EF07, EF08, EE09, EE12, EE14 and EC15 have higher protein contents than commercial ET1 flour (Table 2).

Table 2. Contents in nutritive compounds of the studied flours

Samples	Moisture (g/100 g)	Proteins (g/100 g)	Lipids (g/100 g)	Total glucides (g/100 g)	Total soluble carbohydrates (g/100 g)	Reducing sugars (g/100 g)	Ash (g/100 g)	Fibers (g/100 g)	Caloric energy value (kcal/100 g)
EF01	8.23 ± 0.55^{a}	9.72 ± 0.20^{fg}	1.45 ± 0.26^{bc}	77.60 ± 1.12^{bcd}	4.78 ± 0.32^{c}	1.08 ± 0.14^{c}	1.91 ± 0.05^{fgh}	1.77 ± 0.21^{bcd}	306.57 ± 2.33^{c}
EF02	8.38 ± 0.53^{a}	8.27 ± 0.09^{h}	1.34 ± 0.14^{c}	77.60 ± 0.92^{b}	4.86 ± 0.37^{c}	0.97 ± 0.08^{c}	1.65 ± 0.10^{h}	1.66 ± 0.08^{cd}	308.38 ± 4.05^{c}
EF03	7.88 ± 0.78^{a}	12.00 ± 0.21^{c}	1.53 ± 0.27^{bc}	73.43 ± 0.37^{e}	4.68 ± 0.55^{c}	1.32 ± 0.28^{c}	2.12 ± 0.15^{defg}	1.78 ± 0.04^{bcd}	304.20 ± 0.83^{c}
EF04	8.44 ± 0.44^{a}	10.21 ± 0.42^{efg}	1.40 ± 0.20^{bc}	75.58 ± 0.58^{cd}	4.78 ± 0.71^{c}	1.17 ± 0.35^{c}	1.82 ± 0.09^{gh}	1.66 ± 0.12^{cd}	306.48 ± 1.41^{c}
EF05	8.12 ± 0.81^{a}	11.14 ± 0.33^{cde}	1.72 ± 0.02^{bc}	73.20 ± 0.81^{e}	4.6 ± 0.45^{c}	1.14 ± 0.42^{c}	2.55 ± 0.21^{abc}	2.17 ± 0.15^{b}	302.89 ± 1.98^{c}
EF06	8.30 ± 0.45^{a}	9.70 ± 0.44^{g}	1.57 ± 0.36^{bc}	75.24 ± 1.01^{cd}	4.71 ± 0.63^{c}	1.03 ± 0.14^{c}	2.20 ± 0.16^{bcdefg}	2.05 ± 0.11^{bcd}	305.44 ± 1.05^{c}
EF07	8.07 ± 0.54^{a}	13.21 ± 0.75^{b}	1.76 ± 0.24^{bc}	71.27 ± 0.71^{f}	4.55 ± 0.37^{c}	1.36 ± 0.43^{c}	2.67 ± 0.20^{a}	2.13 ± 0.24^{bc}	301.43 ± 3.80^{c}
EF08	8.15 ± 0.42^{a}	11.44 ± 0.36^{cd}	1.61 ± 0.19^{bc}	73.51 ± 0.37^{e}	4.67 ± 0.86^{c}	1.22 ± 0.27^{c}	2.31 ± 0.17^{abcdef}	1.97 ± 0.14^{bcd}	303.88 ± 2.02^{c}
EE09	8.10 ± 0.46^{a}	12.28 ± 1.03^{bc}	1.67 ± 0.18^{bc}	72.50 ± 0.98^{ef}	4.62 ± 0.64^{c}	1.29 ± 0.15^{c}	2.46 ± 0.13^{abcd}	2.03 ± 0.06^{bcd}	302.80 ± 4.54^{c}
EE10	8.36 ± 0.42^{a}	9.67 ± 0.54^{g}	1.47 ± 0.26^{bc}	75.75 ± 0.75^{bcd}	4.78 ± 0.29^{c}	1.08 ± 0.35^{c}	1.96 ± 0.11^{fgh}	1.81 ± 0.11^{bcd}	306.32 ± 2.58^{c}
EE11	8.34 ± 0.43^{a}	8.90 ± 0.34^{gh}	1.50 ± 0.30^{bc}	76.28 ± 0.97^{bcd}	4.78 ± 0.92^{c}	0.98 ± 0.16^{c}	2.03 ± 0.14^{efg}	1.92 ± 0.32^{bcd}	306.59 ± 6.81^{c}
EE12	8.09 ± 0.50^{a}	12.23 ± 0.51^{bc}	1.59 ± 0.12^{bc}	72.93 ± 0.46^{ef}	4.66 ± 0.54^{c}	1.32 ± 0.26^{c}	2.26 ± 0.25^{bcdef}	1.88 ± 0.05^{bcd}	303.53 ± 1.75^{c}
EE13	8.41 ± 0.71^{a}	9.51 ± 0.50^{g}	1.33 ± 0.18^{c}	76.51 ± 0.56^{bc}	4.85 ± 0.81^{c}	1.13 ± 0.33^{c}	1.65 ± 0.23^{h}	1.58 ± 0.09^{d}	307.53 ± 1.72^{c}
EE14	8.11 ± 0.44^{a}	11.79 ± 0.90^{cd}	1.73 ± 0.24^{bc}	72.65 ± 0.83^{ef}	4.60 ± 0.72^{c}	1.19 ± 0.47^{c}	2.59 ± 0.16^{ab}	2.16 ± 0.31^{b}	302.63 ± 7.06^{c}
EC15	8.24 ± 0.46^{a}	10.74 ± 0.66^{def}	1.55 ± 0.13^{bc}	74.44 ± 0.98^{de}	4.71 ± 0.69^{c}	1.16 ± 0.18^{c}	2.16 ± 0.15^{cdefg}	1.90 ± 0.11^{bcd}	304.90 ± 4.06^{c}
ET1	6.03 ± 0.24^{b}	10.02 ± 0.33^{efg}	2.00 ± 0.12^{b}	82.13 ± 0.96^{a}	25.06 ± 1.15^{b}	$6.25\pm0,57^{b}$	2.43 ± 0.04^{abcde}	2.02 ± 0.16^{bcd}	334.41 ± 3.30^{b}
ET2	5.98 ± 0.16^{b}	15.07 ± 1.74^{a}	8.70 ± 1.71^{a}	68.07 ± 0.48^{g}	30.71 ± 1.27^{a}	$8.07\pm0,48^{a}$	2.37 ± 0.07^{abcde}	5.50 ± 0.19^{a}	352.58 ± 0.50^{a}
F	6.35	31.88	201.90	43.42	105.64	96.27	12.66	84.77	44.33
P-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

Values are expressed in dry matter; EF, factorial essay; EE, star essay; EC, essay at the centre; ET1, sample control 1; ET2, sample control 2 ; Composite flours with respective percentages of BAM, VUW and MOL: EF01, 72/18/10 ; EF02, 78/14/8 ; EF03, 62.5/28.5/9 ; EF04, 70/23/7 ; EF05, 65/16/19 ; EF06, 71.6/12.8/15.6 ; EF07, 57/26/17 ; EF08, 64.5/21,5/14 ; EE09, 61/24/15 ; EE10, 72/17/11 ; EE11, 75/11/14 ; EE12, 61.4/27.3/11.3 ; EE13, 73/21.6/5.4 ; EE14, 62.8/18.6/18.6 ; EC15, 67.5/20/12.5 ; BAM, Borassus aethiopum Mart. ; VUW, Vigna unguiculata Walp. ; MOL, Moringa oleifera Lam. From the same column, values differ statistically at P=5% according to the lowercase letter. F, value of the Ficher statistical test of ANOVA; P-value, value of the ANOVA probability test;

The composite flours contain low lipids (1.33 ± 0.18 g - 1.76 ± 0.24 g/100 g). Flours composite EF02 (1.34±0.14) and EE13 (1.33±0.18) have the lipids contents statistically different ($p < 0.001$) from the one of reference flour ET1 (2.00 ± 0.12 g/100 g). While the other composite flours (1.40±0.20 g - 1.76 ± 0.24 g/100 g) have the lipids contents statistically identical ($p > 0.05$) to the one of reference flour ET1 (2.00 ± 0.12 g/100 g). The largest amount of lipid is provided by the commercial flour ET2 (8.70 ± 1.71 g/100 g).

As regards ash, composite flour EF07 provided a higher content (2.67 ± 0.20 g/100 g) than other flour values and statistically identical ($p > 0.05$) to those obtained with EE14 (2.59 ± 0.16 g/100 g), EF05 (2.55 ± 0.21 g/100 g), EE09 (2.46 ± 0.13 g/100 g), ET1 (2.43 ± 0.04 g/100 g) and ET2 (2.37 ± 0.07 g/100 g). Thus, among the fortified flours, the sample EF07 has the highest protein, lipid and ash content. The fiber content of the studied flours is between 1.58 ± 0.09 and 5.50 ± 0.19 g/100 g. It distinguishes statistically the control flour ET2, which provides the highest value (5.50 ± 0.19 g/100 g) of the other studied flours. The composite flour EE13 has the lowest value (1.58 ± 0.09 g/100 g). The fiber contents of the other flours vary between those of the flours EE13 and ET2. The studied flours total glucides contents varied statistically from 68.07 ± 0.48 to 82.13 ± 0.96 g/100 g. The control flour ET1 provides the highest value (82.13 ± 0.96 g/100 g) whereas the control flour ET2 provides the lowest content (68.07 ± 0.48 g/100 g) of total glucides. Concerning composite flours, the carbohydrate contents are intermediate between those obtained with the two commercial flours, with values between 71.27 ± 0.71 and 77.60 ± 1.12 g/100 g. The ethanosoluble glucides and reducing sugars are more present in the reference flours ET1 (25.06 ± 1.15 and 6.25 ± 0.57) and ET2 (30.71 ± 1.27 g/100 g and 8.07 ± 0.48 g/100 g, respectively) compared to composite flours, which have statistically identical values (Table 2).

The studied flours provide energy values that vary from 301.43 ± 3.80 to 352.58 ± 0.50 kcal/100 g. Thus, the composite flours have energy values statistically identical ($p > 0.05$), included between 301.43 ± 3.80 kcal/100 g (EF07) and 308.38 ± 4.05 kcal/100 g (EF02) lower to those of control flours ET1 and ET2 (334,41 ± 3,30 and 352,58 ± 0,50 kcal/100 g, respectively) (Table 2).

3.3 Grouping of Samples According to Nutritive Compounds

Principal component analysis (PCA) was carried out by considering components F1 and F2 (Table 3), which have an eigenvalue greater than 1, according to the Kaïser statistical rule. Pronounced groupings of the PCA were then clarified by the hierarchical ascending classification (CAH) using the Unweighted Pair Group Method with Arithmetic Means (UPGMA).

3.3.1 Principal component analysis

Fig. 1A shows the Fact.1- Fact.2 factorial draw of the principal components analysis, which expresses 88.93% of the total variability of the studied parameters. The component F1 with an eigenvalue of 5.98, expresses 66.49% of the variance. It is predominantly established by a positive correlation with moisture content and negative correlations with protein, lipid, fiber, total soluble carbohydrate, reducing sugars contents and caloric energy value. The component F2, with its own value 2.02, expresses 22.44% of the variance and is mainly formed by the total glucides content with a positive correlation (Table 3).

The characteristics and samples projections in the formed plan by the components F1 and F2 highlight two classes of flour. Class 1 consists essentially of commercial flours ET1 and ET2. These are distinguished by higher contents of proteins, total glucides, total soluble carbohydrate, reducing sugars, lipids, fibers and in energy. Class 2 contains composite flours samples. They provide higher contents of humidity, and also contain flours containing high amounts of protein and carbohydrates. The flours EF05, EF07, EF08 and EE14 from this group present the highest ash content (Fig. 1B).

3.3.2 Hierarchical ascending classification

Hierarchical classification corroborates the variability observed in the Principal Component Analysis. Indeed, at the Euclidean aggregation distance of 25.5, the UPGMA dendrogram shows two classes of flour sample. Class 1 consists of reference flours ET1 and ET2 with high protein, carbohydrate, lipid, fibers, total soluble carbohydrate, reducing sugars and energy values. The second class contains composite flour samples that provide the highest moisture content and also high amounts of protein and

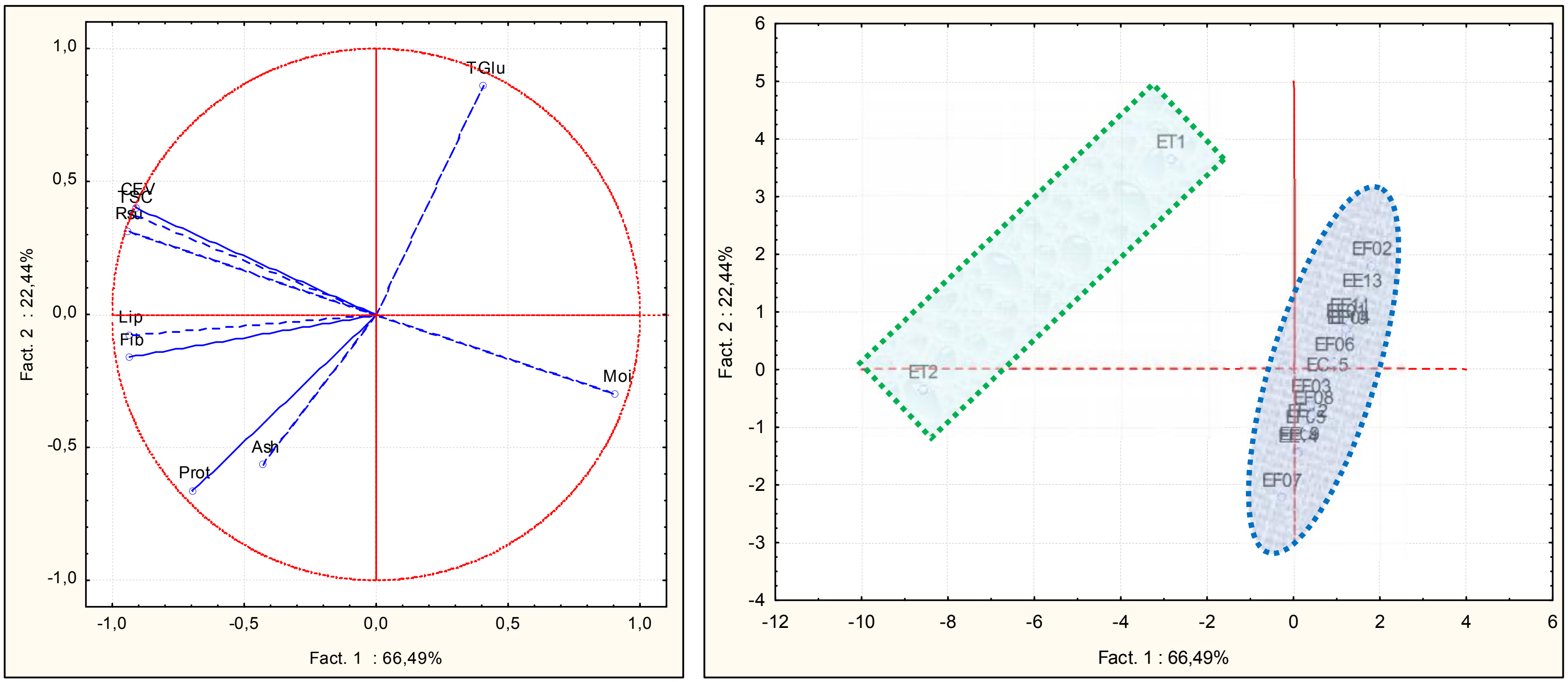

Fig. 1. Correlations between the factorial F1 et F2 draw of the principal components analysis and the nutritive compounds (A) and the samples (B) of the studied flours

With: Moi, Prot, Lip, TGlu, TSC, RS, Fib: respective contents of moisture, proteins, lipids, total glucides, total soluble carbohydrates, reducing sugars and fibers; CEV: Caloric energy value, EF, factorial essay; EE, star essay; EC, essay at the centre ; BAM, Borassus aethiopum Mart. ; VUW, Vigna unguiculata Walp. ; MOL, Moringa oleifera Lam.; Composite flours with respective percentages of BAM, VUW and MOL: EF01, 72/18/10 ; EF02, 78/14/8 ; EF03, 62.5/28.5/9 ; EF04, 70/23/7 ; EF05, 65/16/19 ; EF06, 71.6/12.8/15.6 ; EF07, 57/26/17 ; EF08, 64.5/21,5/14 ; EE09, 61/24/15 ; EE10, 72/17/11 ; EE11, 75/11/14 ; EE12, 61.4/27.3/11.3 ; EE13, 73/21.6/5.4 ; EE14, 62.8/18.6/18.6 ; EC15, 67.5/20/12.5;

total glucides. The highest ash contents are provided by flours EF05, EF07, EF08 and EE14 from this group (Fig. 2).

Table 3. Matrix of eigenvalues and correlations between the nutritive compounds of the studied flours and both f1 and f2 factors of the principal components analysis

Factors	F1	F2
Eigenvalues	5.98	2.02
Variance (%)	66.49	22.44
Cumulative variance (%)	66.49	88.93
Moisture content	**0,91**	-0,3
Proteins content	**-0, 7**	-0,66
Lipids content	**-0,94**	-0,08
Total glucides content	0,41	**0,86**
Total soluble carbohydrate content	**-0,92**	0,37
Reducing sugars content	**-0,94**	0,31
Ash content	-0,43	-0,57
Fibers content	-0,93	-0,16
Caloric energy value	**-0,91**	0,40

3.4 Estimated Intakes of Nutritive Compounds in the Children under 5

Sensory evaluation tests of the slurries prepared from the composite flours studied made it possible to retain flours EF07 and EE09 having exhibited the most interesting sensory characteristics. The quantities of nutritive compounds provided by *B. aethiopum* flour, composite flours (EF07 and EE09), and reference flours (ET1 and ET2) are evaluated. Estimated nutrient intakes of flours EF07 and EE09 are comparable to those of reference flours, with the exception of the contributions in lipids (21.75 g/day) and fibers (13.75 g/day) which are more important in reference flour ET2. Reference flours ET1 and ET2 provide more also of total soluble carbohydrate (62.65 and 76.78 g/day), and reducing sugars (15.63 and 20.18 g/day, respectively). Palmyra new shoots flour has the lowest nutrient content except carbohydrates with the highest intake (210.25 g/day). The meals EF07 and EE09 provide the daily respective contributions in proteins, lipids, glucides, total soluble carbohydrate, reducing sugars, ashes, and fibers of (33.03 and 30.7 g/day), (4.4 and 4.18 g/day), (178.18 and 181.25 g/day), (11.38 and 11.55 g/day), (3.4 and 3.23 g/day), (6.68 and 6.15 g/day) and (5.33 and 5.08 g/day). The reference flours ET1 and ET2 provide daily 25.05 and 37.68 g of proteins, 5 and 21.75 g of lipids, 205.33 and 170.18 g of glucides, 62.65 and 76.78 of total soluble carbohydrate, 15.63 and 20.18 g of reducing sugars, 6.08 and 5.93 g of ash, and 5.05 and 13.75 g of fibers respectively (Table 3). Composite flours EF07 and EE09 contribute more than 100% as the reference flours ET1 and ET2, recommended daily intake of proteins, carbohydrates, and caloric energy in children under 5. Composite flours (EF07 and EE09) and reference flour ET1 provide more than 50% and less than 20% of the recommended daily intakes of fiber and lipids respectively for children under 5. The reference flour ET2 covers 72.5% and more than 100% of the daily intake of lipids and fiber in children (Table 4).

4. DISCUSSION

The moisture content of the studied flour is less than 12%, the maximum water content limit for good preservation of foodstuffs. A large amount of water in these flours would compromise their preservability. Indeed, water contributes to the proliferation of microorganisms capable of using their amylases, hydrolyzing the starch contained in the flours and thus facilitating the acidification of these [27].

The results presented in Table 3 show that the enrichment modifies considerably the nutritive characteristics of the Palmyra new shoots flours. It results in the increase of the proteins, lipids, ashes and fibers content and a reduction of the contents in total glucides as the substitution level increases. Indeed, Palmyra new shoots flour is rather low in protein, fat and ash [17,18]. The increase in the protein content of composite flours after enrichment could be attributed to the large amount of protein present in Cowpea powder [28,18]. Also, Moringa would contribute to improving the protein content of young shoots of *B. aethiopum* flour. The improvement in the fat, ash and fiber content of composite flours after enrichment would be due to the richness of the moringa powder in these constituents [29]. The slight decrease in total carbohydrate levels found in enriched flours may be due to the fact that fortifiers Cowpea and Moringa contain less carbohydrates than Palmyra new shoots [18]. The incorporation advantage of Cowpea and Moringa in the Palmyra new shoots flour is that they contain proteins with good biological values containing all the essential amino acids as well as vitamins and minerals [30,28,31]. In addition, the consumption of foods sources of vegetable proteins should be encouraged as they are

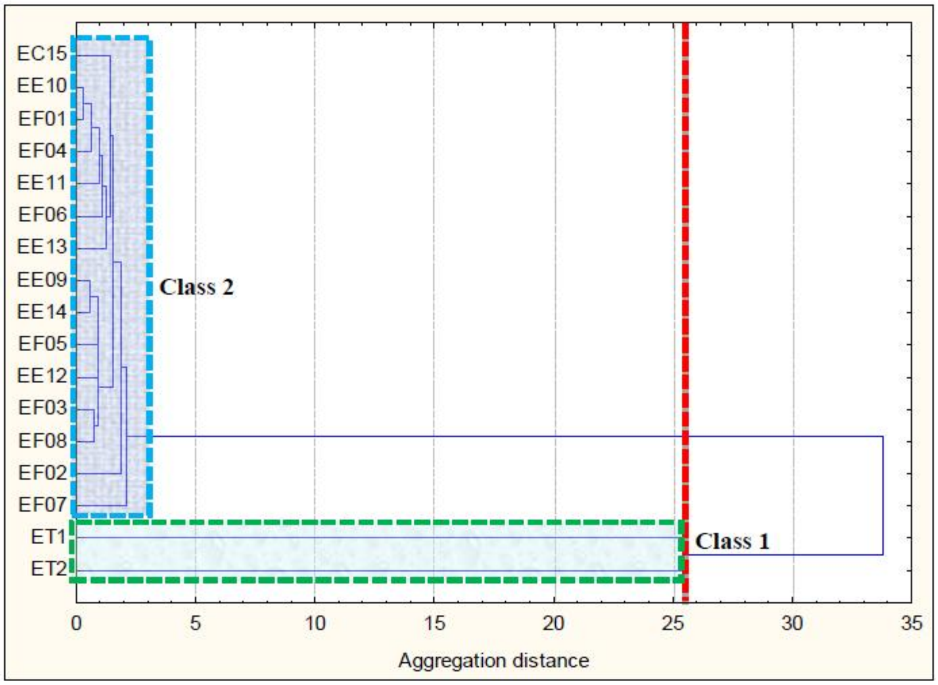

Fig. 2. Hierarchical classification of the studied flours according to nutritive characteristics

available and inexpensive compared to animal proteins. Besides, *B. aethiopum* young shoots fortification made it possible to obtain composite flours EF03, EF04, EF05, EF07, EF08, EE09, EE12, EE14, and EC15 with proteins ranging from those of reference flours ET1 (10%) and ET2 (15%). These flours cover protein requirements. They constitute a considerable improvement in relation to the traditional porridge. In addition, composite flours EF05, EF07, EF08, EE09, EE12, EF03, and EE14 have protein values in accordance with recommended standards by FAO / WHO [10] for weaning foods.

Concerning the ash, EF07 composite flour has the highest content. This characteristic reveals its mineral richness compared to the other flours studied [32]. Except for the samples EF02, EF04 and EE13, ash contents of the studied composite meals are higher than those found by Soro et al. [33] (1.1 to 1.88 g/100 g) in yam-based infant flours fortified with soybean, vegetable sources of minerals and vitamins.

The composite flours fiber content ranging from 1.58 ± 0.09 to 2.17 ± 0.15 g/100 g appears to be low. These low fiber contents are due to the unit operations necessary for the production of flours, in this case in point germination, fermentation, grinding and sieving, which lead to the elimination of fibers. Moreover, these results are consistent with the Codex Alimentarius standard, which stipulates that the fiber content of supplementary food preparations for infants shouldn't exceed 5 g/100 g [34]. Indeed, fibers are of major importance in the protection of the body, against intestinal cancer, diabetes and cardiovascular diseases [35]. Thus, they regulate intestinal transit and capture a portion of lipids and carbohydrates, which partially regulate blood sugar levels and avoid excess cholesterol [36]. They also have a positive effect on overweight and metabolic diseases due to their high degree of saturation [37]. The studied composite flours have carbohydrate contents between those of the two reference flours used in this study. These meals could therefore be beneficial to children under 5. Carbohydrates have an essentially energetic role, they are the energy source that can be rapidly used by the body and are involved in the anabolism of proteins [36].

As for the energy values of composite flours, the averages vary from 301.43 to 308.38 kcal/100 g. These flours represent an important source of energy, due to their strong carbohydrate characteristic. Their consumption could be able to contribute significantly to the energy needs of the populations, especially during intense muscular activities.

Table 4. Estimated daily intake in nutritive compounds resulting from the consumption of 250 g of flour by children under 5

Flour	Proteins		Lipids		Total glucides		Total soluble carbohydrates		Reducing sugars		Ash		Fibers		Caloric energy value	
	DRI	VC	DRI	VC	DRI	VC	DRI	VC	DRI	VC	DRI	VC	DRI	VC	DRI	VC
	(mg/day)		(mg/day)		(mg/day)		(mg/day)		(mg/day)		(mg/day)		(mg/day)		(kcal/day)	
BAM		7.65		2.3		210.25		12.96		1.43		1.65		3.08		788.53
EF07		33.03		4.4		178.18		11.38		3.4		6.68		5.33		753.65
EE09		30.7		4.18		181.25		11.55		3.23		6.15		5.08		757.0
ET1	**12**	25.05	**30**	5	**130**	205.33	-	62.65	-	15.63	-	6.08	**10**	5.05	**750**	836.03
ET2		37.68		21.75		170.18		76.78		20.18		5.93		13.75		881.45

BAM: B. aethiopum Mart.; EF07: Flour composed of 57% B. aethiopum, 26% cowpea and 17% M. oleifera; EE09: Flour composed of 61% B. aethiopum, 24% cowpea and 15% M. oleifera; ET1: reference flour 1; ET2: reference flour 2; DRI, daily recommended intake; VC, valued contribution.
Sources (DRI): FAO/WHO (2010), EFSA (2012)

The average daily amount of flour consumed by children under 5 in Africa is 250 g [38]. During the intake of the same amount, the estimated daily intakes in children under 5 were much higher in composite meals (EF07 and EE09) and in reference meals compared to Palmyra new shoots flour with the exception of carbohydrates. This distribution shows the importance of the enrichment of *B. aethiopum* young shoots flour to the powders of *M. oleifera* leaves and cowpea seeds. Indeed, the incorporation of Moringa leaflets and cowpea beans powders into the Palmyra new shoots flour significantly contributed to increased levels of protein, fat, ash and fiber. Composite flours EF07 and EE09 have nutritive characteristics comparable to industrial infant flours. In addition, they cover recommended daily intakes of protein in children under 5 by FAO / WHO [39] and EFSA [40]. Furthermore, the studies of Mahan et al. [33] showed that flours EF07 and EE09 are also very rich in essential minerals. Composite flours EF07 and EE09 can meet the nutritional needs of populations, especially children. Healthy protein intakes could help meet the ever-increasing needs of children under 5, and be beneficial in combating malnutrition.

5. CONCLUSION

The studied flours in this study present very varied nutritive composition. Several composite flours have higher protein and ash contents than those of one of the reference flours found on the market. They constitute a considerable improvement over traditional porridge. The enrichment of *B. aethiopum* new shoots flour to the Moringa leaflets and Cowpea beans powders is a considerable improvement of the nutritive characteristics of flour. Among these composite flours, the EF07 and EE09 flours are distinguished by a high protein and ash content comparable to reference flours, and cover recommended daily intakes of protein and energy in children under 5. These flours are an asset in the fight against malnutrition which threatens populations during the lean season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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