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Nutritional value and microbiological quality of potential complementary foods formulated from the combination of fonio, soybean and mango flours

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ABSTRACT: The present study was initiated to evaluate the nutrient composition and microbiological quality of composite flours based on fonio, soybean and mango for possible use as complementary food for children aged 6-24 months. For this purpose, four composite flours CF1 = 90: 10: 0, CF2 = 80: 15: 5, CF3 = 70: 20: 10 and CF4 = 60: 30: 10 were formulated from fonio, soybean and mango flour ratio respectively. Chemical analyses showed that these composite flours contain 6.18-15.25% crude fat, 10.73-11.35% crude protein, 48.60-66.55% carbohydrates and 355.37-384.39 kcal of energy, which are close to the standard recommended by World Health Organization. However, the composite flours had levels of calcium (13.46-22.78 mg/100 g), vitamin C (12.40-32.70 mg/100 g) and iron (4.27-7.73 mg/100 g) lower than standard values. The *in vitro* digestibility of the formulations showed that CF2 was more hydrolyze than the other composite flours with 301 µg of glucose released in 3 hours. With regard to the results of microbiological analyzes, all germs of hygienic interest (mesophilic aerobic germs, total coliforms, yeasts and molds, enterobacteria and *Staphylococcus aureus*) were found with loads below the recommended microbiological standards. However, CF3 was outside of the recommended limits in terms of *Staphylococcus aureus* loads. This study revealed that the formulated complementary foods from local products have great potential in providing nutritious foods for children. This is promising for regions where protein-energy malnutrition is prevalent.

KEYWORDS: Infant food, *Digitaria exilis*, *Glycine max*, *Mangifera indica*, Food quality, Flours.

1 INTRODUCTION

The vulnerability of infants to problems associated with the weaning process is of global concern, but more especially in economically developing countries [1], [2]. The search for low-cost, nutritious, and easy-to-prepare locally available complementary foods will continue as long as protein–energy malnutrition still prevails in developing countries. This malnutrition can be related to the composition of the complementary foods introduced after the breastfeeding period [3]. Thus, the quality of the complementary foods used is therefore of great importance.

In Côte d'Ivoire, traditional Infant diets are generally poorly diversified and poor in certain key micronutrients such as calcium, iron and zinc [4]. In Daloa, in order to fight against malnutrition during weaning, the dietary service of the regional hospital proposed to mothers, food supplements produced from available local staple cereals and legumes, and composed of flours of millet, rice, maize and peanut or soybean. Such formulation of complementary foods based on available and accessible local products proves to be an effective alternative to industrial flours, generally made from imported products which are often too expensive for most of mothers.

Besides the use of these local and well known staple product in infant diets, several studies are exploring the use of others less known plants for their potential good nutritional values. Among these marginal plants is fonio (*Digitaria exilis*), a small grain cereal grown for consumption in savannah areas of West Africa, from Senegal to Lake Chad [5], [6]. In Côte d'Ivoire, fonio is practically an abandoned cereal. Traditionally produced and consumed in the north of the country, fonio contributes to the food seam before harvesting other crops [7].

Fonio is widely reported to be rich in methionine and cystine, two amino acids essential for human health that are lacking in many major cereals [8], [9]. According to [10], this cereal has the potential to improve the nutrition of children of weaning age. However, its nutritional value is limited by its low protein content. It is therefore necessary to add protein sources to infant meals based on this cereal. As soybeans are known to be a high source of protein, their use in combination with fonio can upgrade the protein level of such weaning diets. Moreover, the supplementary used of dried fruit rich in microelements can be of great interest. Since in Côte d'Ivoire, particularly in Daloa, fonio, soybean and mango are very available, they could be used to formulate infant diets. Mango is an excellent source of fiber and bioactive compounds such as provitamin A, carotenoids, vitamin C, calcium, iron and phenolics [11]. Fruits and vegetables, being rich sources of nutrients, have been of interest due to their potential health benefits in preventing several chronic diseases [12]. However, there is little information about any attempt to use fonio, soybean and mango for production of complementary foods.

Therefore, the objective of the present investigation is to contribute to make Fonio a valuable cereal in the formulation of complementary foods by studying new formulations of complementary foods based on fonio (*Digitaria exilis*), soybean (*Glycine max*) and mango (*Mangifera indica*) flours and assessing their nutritional and microbiological quality.

2 MATERIALS AND METHODS

2.1 MATERIALS

The biological material used in this study was constituted of fonio seeds (*Digitaria exilis*), yellow soybean (*Glycine max*) flour and dried mango (*Mangifera indica*) pulps. Fonio seeds were purchased from the Lobia market (Daloa, Côte d'Ivoire), dried mango pulp (kent variety) were purchased from supermarket SOCOCE (Daloa, Côte d'Ivoire) and soybean flour was purchased from the dietary service of Regional Hospital of Daloa.

2.2 PREPARATION OF FONIO AND MANGO FLOURS

The fonio seeds (1 kg) were sorted to remove defect seeds and any other foreign materials. They were peeled with a porcelain mortar and then vanned in order to rid them of non-consumable parts. Several washes with tap water and finally with distilled water are performed to remove the sand grains. After washing and draining, fonio seeds were ground using blender. The crude flour obtained was sieved with 500 µm mesh sieve, sun-dried for up to 48 hours. The flour was kept in plastic airtight container and was stored in a desiccator until required for further analysis.

The dried mango pulps were powdered using blender and sieved through the same mesh size to obtain fine flour and finally stored as above. All chemicals used were of analytical grades.

2.3 FORMULATION OF FLOURS BLENDS

The composite flours (CF) were formulated by the mixing of flours made from fonio, soybean and mango pulp. Four sample were therefore formulated in the following proportions of 90: 10: 0, 80: 15: 5, 70: 20: 10 and 60: 30: 10 to produce respectively CF1, CF2, CF3 and CF4. The flours were uniformly blended in a domestic mixer before analysis.

2.4 BIOCHEMICAL ANALYSIS OF THE INGREDIENTS (SIMPLE FLOURS) AND COMPOSITE FLOURS

Samples were analyzed for their pH and dry matter [13]. One hundred (100) mL of distilled water was homogenized with 10 g of sample, and the pH was measured with a combined glass electrode pH-meter (Hanna Instruments, Romania). Dry matter was determined by hot oven (Memmert, Schwabach, Germany) drying at 105°C for 24 h to constant weight. Crude fat was carried out by Soxhlet extraction of a 10 g sample, with hexane as solvent [14]. Ash content was determined using the muffle furnace at 550°C during 12 h according to AOAC method [15]. Crude protein was determined by using Kjeldahl method and was calculated as N × 6.25 [16]. Crude fiber was determined by digestion method [17]. Two g of sample was accurately weighed and transferred into beaker containing 50 mL of H_2SO_4 (0.25 N). After boiling for 30 min under reflux refrigerant, 50 mL of NaOH (0.31 N) was added and boiled. After 30 min, the solution was filtered. Residues were washed with hot water and transferred to crucible. Crucible containing residue was dried at 105°C for 8 h to a constant weight. The crucible was then cooled in a desiccator and weighed. The residues were placed in muffle furnace at 550°C for 3 h and then the sample was cooled in a desiccator and weighed. Crude fiber content was taken as difference between residues before and after incineration.

Total carbohydrate content was calculated adding the total values of crude protein, crude fat, crude fiber and total ash contents of the sample and subtracting it from 100% according to this equation [18]:

$$\text{Total carbohydrate (\%)} = 100 - (\text{\% protein} + \text{\% ash} + \text{\% fat} + \text{\% crude fiber})$$

The energy value (EV) of the flours was calculated with 4 kcal/g for carbohydrates, 4 kcal/g for proteins and 9 kcal/g for lipids according to [19]:

$$EV = (9 \times \text{Lipids (\%)}) + (4 \times \text{Proteins (\%)}) + (4 \times \text{Carbohydrates (\%)})$$

The ascorbic acid (vitamin C) content was determined according to the 2, 6-dichlorophenol – indophenols dye method [20]. Five g of each sample was mixed with 40 mL of 2% metaphosphoric acid at room temperature. The mixture obtained was centrifuged at 3000 rpm for 20 min. The supernatant was introduced into a 50 mL flask and adjusted with distilled water. Test sample of the diluted sample was titrated with 2,6-dichloroindophenol (2,6-DCPIP, 0.5 g/L) until it turns pale pink.

Mineral (Ca and Fe) content was determined by titrimetric and TPTZ (2,4,6 tripyridyl-5 triazine) methods respectively. Twenty mL of 1% nitric acid was added to the ash (0.25 g). The mixture obtained was filtered into a 250 mL standard flask. This was made up to the mark with deionized water. This solution was used to determine the calcium and iron content. A 50 mL aliquot of ash solution was pipette into a beaker and 2 mL of NaOH (2 N) was added to adjust the pH to 12-13. An indicator calcone carboxylic acid (0.2 g) was then added, mixed and immediately titrated with a 0.01 M EDTA solution to the blue end-point. For the iron, before testing, the pH of ash solutions should be between 3 and 4, not exceed pH 5 as iron may precipitate. The wavelength of the spectrophotometer (HACH DR 3900) was fixed at 590 nm. Ten mL of aliquot was pipette into a sample cell and TPTZ iron reagent powder was added. The cell was caped and shaked for 30 sec. The reading was compared with blank. All results for biochemical analysis are recorded on the dry weigh basis.

2.5 In Vitro Digestibility Of Composite Flours

In vitro digestibility of composite flours was determined using the digestive juice of the snails (*Archachatina marginata*) collected according to the method described by [21]. The reaction medium was constituted as follow: 100 µL of acetate buffer (100 mM, pH 5), 20 µL of enzymatic solution diluted 50 times and 80 µL of 1% of flour gel. The mixture was then incubated at 37°C over a period of 3 h. The sugars released was quantified according to the method of [22] using the 3-5 dinitrosalicylic acid. All determinations were carried out in duplicate. Results were expressed as the amount of glucose released per hydrolysis time.

2.6 Microbiological Analysis Of Composite Flours

The composite flours were subjected to a microbiological analysis to count microorganisms such as mesophilic aerobic flora (MAF), total coliforms (TC), yeast and molds, enterobacteria (ETB) and *Staphylococcus aureus* (SA). Ten grams of each sample was taken aseptically and homogenized in 90 mL sterile peptone water for about 2 min. Serial dilutions (using 1 mL of homogenates) were made in 9 mL sterile physiologic water and 1 mL of each decimal dilution was inoculated in duplicate on specific culture media for the numbering of the germs retained. The different culture media used were prepared according to the manufacturers' instructions. MAF were counted on Plate count agar (PCA) after incubation at 30°C for 72 h as recommended in NF/ISO 4833: 2003; TC were numbered on violet red neutral bile lactose (VRBL) agar after incubation at 30°C for 24 h as described in ISO 4832: 2006. Yeasts and molds were counted on Sabouraud agar chloramphenicol medium after incubation at 25°C for 5 days according to the NF/ISO 16212: 2011. ETB were counted on violet red neutral bile glucose (VRBG) agar after incubation at 37°C for 24 h according to ISO 21528-2: 2004 and SA were counted on Baird-parker agar with telluride egg yolk and 0.2% sulphamethazine after incubation at 37°c for 48 h according to the French standard NF/ISO 6888: 2004. Counts of visible colonies were made and expressed as colony forming units per gram of sample (CFU/g).

2.7 Statistical Analysis

Results are expressed as mean ± standard deviation and Analysis of Variance (ANOVA) was used to test the level of significance at $P < 0.05$. Duncan test was used to compare and separate means. STATISTICA software 7.1 was used for these analyses.

3 RESULTS

3.1 PROXIMATE COMPOSITION OF THE INGREDIENTS (SIMPLE FLOURS) AND COMPOSITE FLOURS

Biochemical analyses were carried out to determine the macro and micronutrient of all the flours. The proximate nutrient compositions of the fonio, soybean and mango pulp flour are presented in Table 1. Results show that pH values differed significantly and varied between 3.62 (mango flour) and 6.76 (soybean flour). Mango pulp flour was more acidic than other flours. The dry matter contents of the flours ranged from 85.64 to 92.64%. The lowest dry matter content was observed in mango pulp flour which was significantly different from the other two flours. The fat contents reported in table 1 varied from 6.40 to 26.71% on the dry weight basis. The highest value of 26.71% was obtained for soybean flour. Total ash contents were also variable in the flour (0.36-4.46% on dry weight basis) with highest values in soybean flour. The crude fiber of different flours ranged from 4.44 to 8.26% on dry weight basis. Only the mango pulp flour differed significantly from the other. In terms of proteins, the contents obtained varied from 8.24 to 38.77% on the dry weight basis with significant difference ($P < 0.05$). Soybean flour had the highest protein contents. Results also indicated that flours contained high values of carbohydrate (74.32% for fonio flour and 77.49% for mango pulp flour), excepted soybean flour with 21.8%. The results of the energy values showed significant difference ($P < 0.05$) between soybean flour and the other two flours. The energy values ranged from 400.35 kcal/100 g to 482.65 kcal/100 g. Soybean flour had the highest energy value.

Concerning the micronutrients, results show significant differences ($P < 0.05$) between the flours (Table 1). The vitamin C content of the simple flours varied from 13.40 to 54.90 mg/100 g on the dry weight basis. Mango pulp flour had the highest value (54.90 mg/100 g DW) which was different from fonio flour (13.40 mg/100 g DW) and soybean flour (21.16 mg/100 g DW). The calcium content ranged from 13.39 mg/100 g DW for soybean flour to 24.12 mg/100 g DW for mango pulp flour. For the iron content, the values ranged between 2.62 mg/100 g DW (mango pulp flour) and 9.22 mg/100 g DW (fonio flour).

Table 1. Macro and micronutrient contents of simple flours

Nutrients (100 g sample)	Fonio flour	Mango pulp flour	Soybean flour
Macronutrients			
pH	$6.23^b \pm 0.01$	$3.62^a \pm 0.17$	$6.76^c \pm 0.02$
Dry matter (%)	$92.53^b \pm 0.01$	$85.64^a \pm 0.01$	$92.64^b \pm 0.01$
Crude fat (%)	$6.40^a \pm 0.01$	$6.75^a \pm 0.02$	$26.71^b \pm 0.01$
Ash (%)	$0.36^a \pm 0.12$	$2.65^b \pm 0.14$	$4.46^c \pm 0.31$
Crude fiber (%)	$8.10^b \pm 1.43$	$4.44^a \pm 1.65$	$8.26^b \pm 1.59$
Crude protein (%)	$11.37^b \pm 0.05$	$8.24^a \pm 0.02$	$38.77^c \pm 0.22$
Total carbohydrate (%)	$74.32^b \pm 0.21$	$77.49^c \pm 0.27$	$21.80^a \pm 1.09$
Energy value (kcal/100 g)	$400.35^a \pm 12.07$	$403.67^a \pm 16.30$	$482.65^b \pm 8.05$
Micronutrients			
Vitamin C (mg)	$13.40^a \pm 0.83$	$54.90^c \pm 2.44$	$21.16^b \pm 0.10$
Calcium (mg)	$22.32^b \pm 0.14$	$24.12^c \pm 0.21$	$13.39^a \pm 0.07$
Iron (mg)	$9.22^c \pm 0.25$	$2.62^a \pm 0.11$	$5.01^b \pm 0.12$

Values are averages ± standard deviation of replicate determinations (n = 3). Means not followed by the same superscript letters in the same row are significantly different (P < 0.05).

Table 2 shows the mean values of proximate composition and micronutrient of the different composite flours formulated from fonio, soybean and mango pulp flour at varying ratio. The pH values of the different composite flours were between 5.67 (CF3) and 6.54 (CF1). This parameter was significantly different ($P < 0.05$). The dry matter content was very high and comparable in the different composite flours. It varied from 90.65 to 92.16%. The results show no significant differences between dry matter content of the composite flours. The fat content of the composite flours was also very high ranging from 6.18 to 15.25% on dry weight basis. Among the different composite flours, the highest fat content was observed in CF4. The ash content of the composite flours varied from 0.90 to 1.82% on dry weight basis. There were significant differences between all the composite flours. The ash level in the composite flours increased when the proportions of soybean and mango flour in the mixture increase. The composite flours contained high fiber content. Values varied between 14.29 to 24.84% on dry weight basis. CF3 had the highest value while CF2 had the lowest value. There was significant difference between CF1, CF2 and CF3, CF4. The protein contents of the composite flours were also high and they were significantly different. Values ranged from 10.73 to 11.35% on dry weight basis. Results also indicated that composite flours contained high carbohydrate contents with significant differences (P < 0.05) between CF1, CF2 and CF3, CF4. Total carbohydrates ranged from 48.58 to 66.55% on dry weight basis. The energy value of the four lots of composite flour ranged from 355.37 to 384.39 kcal (Table 2). CF2 had the highest while CF3 had the least.

The micronutrient composition of the composite flours is also presented in Table 2. The vitamin C content of these flours ranged from 12.40 mg / 100 g to 32.70 mg/100 g on dry weight basis. CF1 had the highest value which was significant different (P < 0.05) from the other composite flours. The calcium content varied from 13.46 mg/100 g to 22.78 mg/100 g on dry weight basis. CF2 had the lowest value which was significantly different from the other composite flours. The iron content of the composite flours varied from 4.27 mg/100 g to 7.73 mg/100 g on dry weight basis. There were significant differences (P < 0.05) between all the composite flours.

Table 2. Macro and micronutrient contents of composite flours

Nutrients (100 g sample)	CF1	CF2	CF3	CF4
Macronutrients				
pH	$6.54^d \pm 0.11$	$6.00^c \pm 0.07$	$5.67^a \pm 0.05$	$5.84^b \pm 0.05$
Dry matter (%)	$91.63^a \pm 0.01$	$92.16^a \pm 0.03$	$90.65^a \pm 0.01$	$91.64^a \pm 0.01$
Crude fat (%)	$6.18^a \pm 0.01$	$9.43^{ab} \pm 0.01$	$11.75^{bc} \pm 0.01$	$15.25^c \pm 0.03$
Ash (%)	$0.90^a \pm 0.35$	$1.30^{ab} \pm 0.04$	$1.62^{bc} \pm 0.14$	$1.82^c \pm 0.25$
Crude fiber (%)	$15.46^a \pm 0.52$	$14.29^a \pm 0.60$	$24.84^b \pm 1.74$	$23.28^b \pm 1.21$
Crude protein (%)	$11.35^c \pm 0.04$	$10.73^a \pm 0.09$	$10.83^a \pm 0.13$	$11.03^b \pm 0.03$
Total carbohydrate (%)	$66.55^b \pm 0.96$	$64.15^b \pm 0.12$	$51.56^a \pm 2.96$	$48.60^a \pm 4.19$
Energy value (kcal/100 g)	$367.21^{ab} \pm 4.97$	$384.39^b \pm 8.48$	$355.37^a \pm 4.37$	$375.67^b \pm 8.64$
Micronutrients				
Vitamin C (mg)	$32.70^b \pm 6.31$	$12.40^a \pm 1.00$	$14.35^a \pm 2.00$	$13.10^a \pm 0.10$
Calcium (mg)	$22.54^b \pm 0.31$	$13.46^a \pm 0.41$	$22.78^b \pm 0.27$	$22.53^b \pm 0.15$
Iron (mg)	$7.73^d \pm 0.16$	$4.27^a \pm 0.16$	$5.42^b \pm 0.07$	$6.76^c \pm 0.59$

Values are averages ± standard deviation of replicate determinations (n = 3). Means not followed by the same superscript letters in the same row are significantly different (P < 0.05). CF= Composite flour

3.2 COMPOSITE FLOURS DIGESTIBILITY

The amounts of glucose released during the *in vitro* enzymatic hydrolysis of composite flours are shown in the figure 1. The amount of glucose increased with the time of hydrolysis and then begin to stabilize from 120 min. These amounts are higher for CF2 (44-301 µg of glucose) than those of CF1 (17.5-239 µg), CF3 (12-265 µg) and CF4 (6-194.5 µg). The composite flours can be classified according to an increasing sensibility to the digestive juice of snail in the following order CF4 < CF1 < CF3 < CF2. Significant differences were observed between the amount of glucose released by the different composite flours.

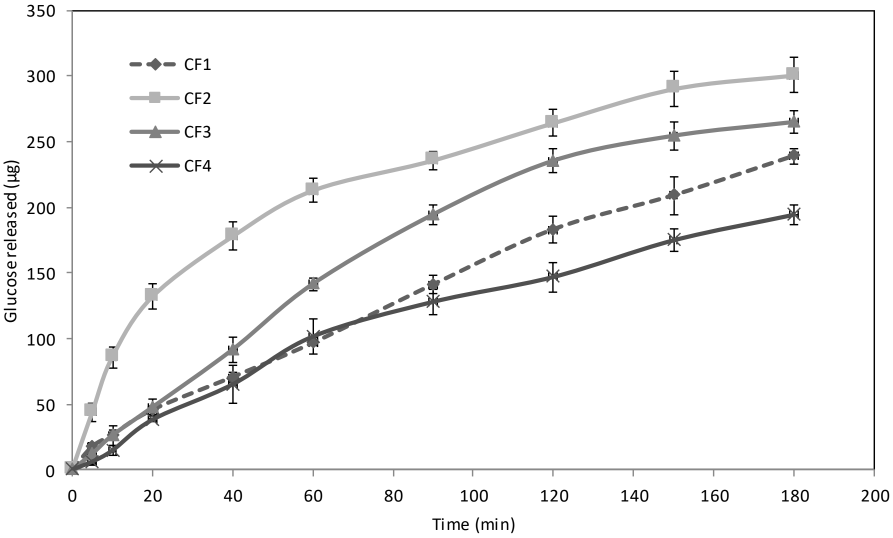

Fig. 1. In vitro digestibility of different composite flours

3.3 Microbiological Characteristics Of Composite Flours

presents the results of the enumeration of mesophilic aerobic germs (MAG), total coliforms (TC), yeast and molds, enterobacteria (ETB) and *Staphylococcus aureus* (SA) found in the different composite flours. All these microorganisms were present in the composite flours except enterobacteria (absent in CF1 and CF2) and total coliforms (absent in CF1). The load of MAG ranged from 3.05×10^4 (CF4) to 7.18×10^4 CFU/g (CF1). The number detected for the yeast and molds ranged from 3.40×10^3 (CF2) to 4.22×10^3 CFU/g (CF4). The load of TC and enterobacteria ranged from 0.00 (CF1) to 6.45 CFU/g (CF4) and 0.00 (CF1) to 9.68 CFU/g (CF3) respectively. The SA counts varied from 15.5 (CF4) to 115 CFU/g (CF3) and only the composite flour CF3 was outside of the recommended limits. Both the TC and SA counts were significantly different between the composite flours.

Table 3. Microbiological evaluation of composite flours

Composite flours	Microorganisms (CFU/g)				
	MAG	TC	ETB	Yeast-Molds	SA
CF1	$7{,}18.10^4\pm0{,}89.10^{4a}$	$0{,}00\pm0{,}00^a$	$0{,}00\pm0{,}00^a$	$3.63.10^3\pm0{,}12.10^{3a}$	$19{,}5\pm2{,}12^a$
CF2	$6{,}95.10^4\pm0{,}06.10^{4a}$	$3{,}45\pm0{,}25^b$	$0{,}00\pm0{,}00^a$	$3{,}40.10^3\pm0{,}19.10^{3a}$	$23{,}5\pm0{,}70^b$
CF3	$3{,}11.10^4\pm0{,}10.10^{4b}$	$4{,}40\pm0{,}19^c$	$9{,}68\pm0{,}06^b$	$3{,}50.10^3\pm0{,}19.10^{3a}$	$115\pm1{,}41^c$
CF4	$3{,}05.10^{4b}\pm0{,}07.10^{4b}$	$6{,}45\pm0{,}25^d$	$9{,}36\pm0{,}38^b$	$4{,}22.10^3\pm0{,}19.10^{3b}$	$15{,}5\pm0{,}70^d$
Microbiological criteria	$<10^5$	$<10^3$	<10	$<10^4$	$<10^2$

Values are averages ± standard deviation of replicate determinations (n = 2). Means not followed by the same superscript letters in the same column are significantly different (P < 0.05). MAG: Mesophilic aerobic germs, TC: Total coliforms, ETB: Enterobacteria, SA: Staphylococcus aureus

4 Discussion

The nutritional quality of infant flours largely depends on their chemical composition. Macronutrients (fats, proteins and carbohydrates) and micronutrients (vitamins and minerals) are the most important nutrients and must be present in quantity and quality necessary for the development of the child [23]. The mixture of various ingredients is therefore helpful in meeting this requirement.

The chemical composition of simple flours used in the formulation of infant flours appear to be rich in nutrients. The dry matter, crude fat, ash and crude protein contents found in fonio and soybean flours agreed with other previous researchers [10], [24], [25]. Simple flours have high fiber and carbohydrate contents. The high carbohydrate contents of fonio and mango were approximate to those of [26] and [27]. Soybean had the lowest carbohydrate content (21.80%), but its value was higher than the value of 15.99% reported by [28]. The energy values indicated that the simple flours studied can serve as good source of energy for the body. Regarding micronutrient contents, simple flours are sources of bioactive compounds, particularly for mango pulp flour in vitamin C.

The nutritional value of composite flours made with fonio, soybean and mango flour reveals that they have significant nutritional potential. The slightly lower pH value observed in composite flours may be a result of incorporation of mango flour in the formulations. The dry matter contents were high, this indicate their long shelf life. These values are consistent with prior studies [29], [30], which found 90.95% (for composite flours made from maize, sorghum and soybean) and 95% (cassava and soybean) respectively. Ash contents also increased with the amount of soybean and mango flour. These contents are lower than the value (2%) obtained by [30] in flours based on cassava and soybean, but close to the value (1.88%) reported by [31] in the formulation of flour based on yam and soybean.

Fats are relatively minor constituents in cereals. However, they play an important role in human nutrition as a source of energy and essential fatty acid [32]. Fat contents in composite flours were recorded in increasing order from CF1, CF2, CF3 to CF4. As simple flour analysis in the present study showed that soybean had the highest fat content, the results of CF1, CF2, CF3 and CF4 means that supplementing flours with soybean brings a substantial part of fat. The fat contents of CF2, CF3 and CF4 are within the range of the recommended values 10-25% [33].

Crude fiber is known to promote health as it aids the digestive system on human [34]. However, high fiber in infant foods is highly associated with gut irritation and affects the efficiency of nutrients absorption and protein digestibility [1]. The crude fiber contents of all the composite flours studied were higher than the *Codex Alimentarius* standard [33] which is less than 5%. These high fiber contents could be attributed to the amount of undehulled fonio and soybean, which are known to contain high fiber contents.

The protein contents of composite flours were comparable to that of fonio flour. Thus, the consumption of fonio alone can produce the necessary quantities. At the level of CF2, CF3 and CF4, protein content increased with soybean proportion. However, our results are lower than the 14% found by [30] with cassava flour enriched with soybean. The protein contents obtained in this study (10.73-11.35%) were below the recommended standard of 15% [35].

The carbohydrate contents obtained in the composite flours decrease when the percentage of soybean and mango pulp flours increased. According to [36] this can be explained by the fact that the addition of protein and lipid sources contributed to the reduction of carbohydrate source, represented here by soybean flour. The same observation was also reported by [10], [31]. The values of carbohydrate obtained (48.60-66.55%) were lower than the carbohydrate intake of infant flours of 68% [35].

The energy values of this study are close to the standard (400 kcal) recommended [37] and also close to those of infant flours produced and marketed in Benin (367-486 kcal/g) [29]. The addition of sucrose will not only improve the taste but also the energy content. This is very important for children who need high energy food to cover their energy due to the small size of their stomachs [38].

According to the results of micronutrients, the major element found were calcium followed by vitamin C and iron in all the composite flours. These values are higher than those reported in infant diet formulation [39], [40]. This could be attributed to the relatively higher micronutrients of soybean and mango pulp. However, the values of the micronutrients are lower than the standards (500 mg for calcium, 20 mg for vitamin C and 16 mg for iron) [37].

It is obvious that the nutritional value of foods depends on their digestibility. The differences in the *in vitro* digestibility observed between composite flours could be linked to the characteristics of flours. Indeed, the proximate composition (protein, fat, mineral…) and the physical form of the starch can affect the digestibility according to previous studies [10], [41], [42]. So, the fact that CF1 and CF4 had higher protein content than CF2 and CF3 could be responsible for their low digestibility. In addition, the protein-starch interactions and the formation of amylose-lipid complex limit the enzymatic attack and the hydrolysis of starch [43].

Microbiological analysis of composite flours was focused on the search for flora of contamination and pathogenic microorganisms. The load (CFU/g) of total mesophilic aerobic flora and yeasts and molds are below the microbiological standards. These low values can be explained by the drop in the humidity level in the various compound flours. Also, the enumeration of total coliforms, enterobacteria and *Staphylococcus aureus* gave values below microbiological standards. However, the composite flour CF3 showed a load higher than the standards in the case of *Staphylococcus aureus*. This is an indication that the packaging material used was compromised. However, the *Staphylococcus aureus* detected can be destroyed during cooking. The consumption of these composite flours cannot present a danger to the health of the child.

5 Conclusion

The study successfully formulated a new complementary food with good nutritional value from local products such as fonio, soybean and mango. High contents of fat, fiber, protein, carbohydrate, energy and micronutrients in the formulated composite flours were observed. These contents, for the most part, meet World Health Organization (WHO) recommended standards for complementary food. Moreover, the composite flours were found to be digestible and of satisfactory microbiological quality. These complementary foods formulated with fonio, soybean and mango have promising nutritional attributes for potential nutritional programmes aiming vulnerable children. In view of these results, utilization of fonio as a base cereal to produce complementary foods should be encouraged and special attention should be paid to this neglected and under-exploited cereal due to its exceptional nutritional properties.

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