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BIOCHEMICAL CHARACTERIZATION AND FUNCTIONAL PROPERTIES OF WEANING FOOD MADE FROM CEREALS (MILLET, MAIZE) AND LEGUMES (BEANS, SOYBEANS).

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ABSTRACT

From the sixth month, nutrient intakes of breast milk become inadequate. In order to prevent various forms of malnutrition, a supplement food balanced in nutrients with appropriate organoleptic characteristics was developed. Formulation of flour was carried out in the following proportions: 95% millet flour, 5% trade sugar for flour called FM (millet flour); 65% millet flour, 30% beans flour and 5% trade sugar for flour called FC1 (composite flour 1); 25% millet flour, 25% yellow corn flour, 45% soybean meal and 5% trade sugar for flour called FC2 (composite flour 2). The physico-chemical, rheological and functional properties and the lysis of amylase of these flours were determined. FC1 and FC2 contained respectively 5 and 8.66% of minerals, 38.21 and 50.48% of carbohydrates, 27.86 and 40.83% of starch, 14 and 24.5% of protein, 7.63 and 12.1% of fat, 277.87 and 408.98 kcal. The swelling and solubility of these flours increased with temperature. The solubility and swelling of FC1 were become more important than those of FC2 respectively from 70 to 85°C. On the other hand, the water absorption capacity, the oil absorption capacity, the foaming capacity and the water absorption index of FC2 were higher than those of FC1. However, the solubility index in water, the digestibility percentage, consistency and viscosity of porridge made from FC2 were lower than those of FC1. The rheological characterization showed that the FC2 porridge was less consistent and less viscous. Taken together, our findings indicated that FC2 seems to be much richer in nutrients with a high energy value and has functional properties up to standard, which suggest potential use as the best formulation in infant food.

Keywords: Consistency, viscosity, digestibility, solubility, swelling, best formulation.

INTRODUCTION

In Côte d'Ivoire, local raw materials frequently used for the preparation of complementary infant feeding such as porridge, are cereals and tubers which are accessible to the most disadvantaged populations. Cereals are introduced as slurries in the child feeding beyond six months ago, age at which the nutrient content of breast milk (protein and micronutrients) is not sufficient to cover the nutritional needs for child (WHO, 2002). However, the nutritional quality of porridge from cereals is insufficient (Blandino *et al*., 2003). Indeed, these foods under normal cooking and consumption conditions cannot effectively complement breast milk energy intake deficits, because of their low energy density. These porridges not undergoing any technologic treatment have a viscosity increasing rapidly according to dry matter content. Even so, the porridge interest, at early period of supplementary feeding, is their liquid or semi-liquid consistency (Trèche, 1996), given the low gastric capacity of children. In addition, level and bioavailability of micronutrients in the porridge are low to cover the nutritional needs of the infant. There is evident that anti-nutritional factors, such as phytates present in cereal grains, chelating minerals namely iron, zinc, and calcium limit highly micronutrients absorption and use by the body (Gibson *et al*., 1998).

The proteins in cereals whose content varies from 7 to 13% of dry matter do not have an adequate profile of amino acids, because of their poverty in some essential amino acids such as lysine and tryptophan (Latham, 1979). In view of these short comings presented by this type of complementary foods, there is a risk of malnutrition that may occur in young children who

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consume them. So in order to prevent various forms of malnutrition, many food ingredients with consistent and appropriate functional properties are used (Hermansson, 1973). However, given the high price of animal proteins, other protein sources like plant proteins relatively less expensive have been explored by several researchers in Africa for the enrichment of infant cereal flour (Besançon, 1978; Mensa-Wilmot *et al.*, 2001).

It has been reported that vegetable seeds and plant proteins sources could improve the balance diet in Africa, if their consumption is increased. They are used to combat the protein malnutrition effects, particularly in children. However, for effective use and acceptance of legume or cereals flours by consumers, it is desirable to study their functional properties (Besançon, 1978; Mensa-Wilmot *et al.*, 2001; Adebowale and Lawal, 2004). This study aims to develop a supplement food balanced nutrients with appropriate organoleptic characteristics. Specifically, the idea is to develop formulas based on cereals and legumes flours and determine the physico-chemical, rheological and functional properties of these foods, to study their digestibility.

MATERIAL AND METHODS

Cereals used are millet (*Pennisetum glaucum*) and maize (*Zea mays*). Legumes used are soybean (*Glycine max*) and beans (*Phaseolus vulgaris*). These cereal grains and legumes used were bought at Abobo (Abidjan) market, 2008.

Different flours production: The grains of cereal were cleaned manually, soaked in water in ratio of 1:3 (p/v) for 24 h, dried in an oven (Gallenkamp Plus 11) at 65ºC for 24 h and then milled using a hammer mill (Christy & Norris Ltd., Chelmsford, England), to pass through a 250 µm stainless sieve (W. Styler Co., Mentor, Ohio, USA). The cereal flours obtained were dried at 45°C. The seeds of legume were cleaned manually to remove broken seeds and other extraneous materials before soaking in distilled water in ratio of 1:5 (p/v) for 24 h. The soaked seeds were drained and then grounded in the same conditions as previously described and resulted flours were dried at 45°C. The legume and cereal flours were sifted in respectively 80 and 60 mesh for flours (Figure 1). They were kept in plastic bag until analysis. The proportions of raw materials for the composition of different flours are given in Table I.

Table I: Proportion of raw maters (based on percentage of dry mater).

Ingredients	FM (% MS)	FC1 (% MS)	FC2 (%MS)
Flour of millet	95	65	25
Flour of maize	-	-	25
Flour of soybean	-	-	45
Flour of bean	-	30	-
Sugar (Saccharose)	5	5	5

FM = 95 % Millet + 5 % Sugar;
FC1 = 65 % Millet + 30 % Bean + 5 % Sugar;
FC2 = 25 % Millet + 25 % Maize + 45 % Soybean + 5 % Sugar.
Symbol: (FM) Flour of millet; (FC1) Composite flour 1; (FC2): Composite flour 2.

Evaluation of some biochemical characteristics of flours: The dry matter and ash contents were determined by the standard method (AOAC, 1990). Total sugars extracted with chilled 80% ethanol were assayed by the method of Dubois *et al*. (1956). The determination of total carbohydrates was performed according to the methodology described by Bertrand and Thomas (1910). The content of starch was determined by difference between the rate of total carbohydrates and that of total sugars. The proteins content was assayed by the Kjeldahl (1976) method. The fat was extracted and measured by the Soxhlet apparatus using n-hexane. The flour energy value (EV) was calculated using the method of Arwater and Benedict (1902) with the following equation:

$$\mathrm{EV} = (9 \times \%Lipid) + (4 \times \%\mathrm{Pr}otein) + (4 \times \%Glucid)$$

Determination of functional properties: Solubility and swelling powers of the samples were determined in triplicate according to the following procedure: 1 g of each sample was suspended in 20 ml of deionized water and heated at 90°C for 1 hour in a bath under constant stirrings. Then resulted suspension was cooled at 30°C and centrifuged at 4000 rpm for 15 minutes. The supernatant was poured into aluminum dishes, decanted and the swollen granules were weighted. The supernatant was dried at 110°C for 12 hours and the weight of dry solids was determined.

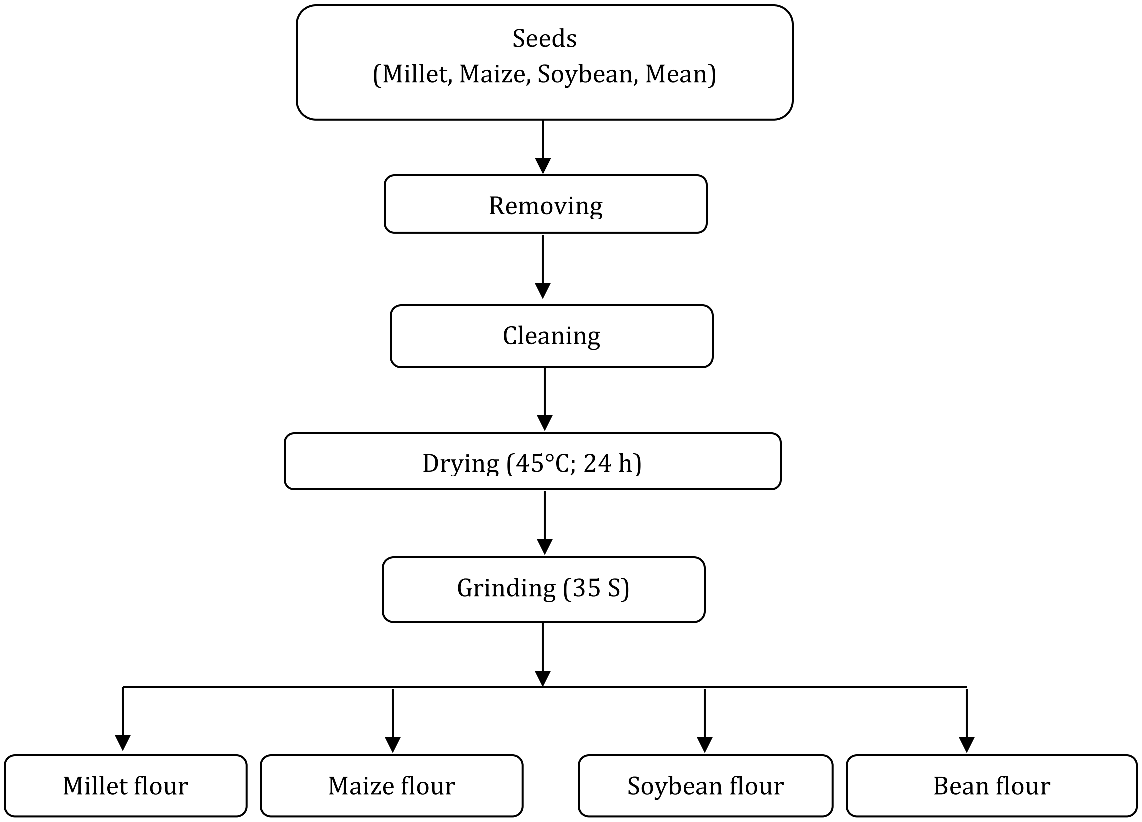

Figure 1: Experimental design showing the different process to produce different flours from a millet/soybean/maize/bean.

The solubility and swelling power were determined using the following formulas:

$$S_0 = \frac{\text{Weight of dried supernatant}}{\text{Weight of fresh sample}} \times 100$$

$$Sp = \frac{\text{Weight of sediment}}{\text{Weight of fresh sample } \times (100 - S_0)}$$

The flour water absorption was measured by the centrifugation method previously described (Sosulski, 1962). For determination of oil absorption as described by Lin *et al.* (1974), the foaming capacity and foam stability were determined. The water solubility and water absorption indexes were determined as described by Anderson *et al*. (1969). The water absorption index (WAE) was calculated using the following formula:

$$WAE = \frac{\text{Remaining gel waight (sediment)}}{\text{Weight of dry matter}}$$

For studies about starch digestion, α-amylase from *Bacillus licheniformis* (E.C.3.2.1.1; Megazyme, Wicklow, Ireland) supplied at a concentration of 3000 U/mL and glucoamylase from *Aspergillus niger* (E.C. 3.2.1.3; A7095, Sigma, St Louis, MO) obtained at a concentration of 300 U/mL, were used. After appropriate dilution, each enzyme was added to a flour suspension. The rates of hydrolysis of starch were measured. Both were pretreated with a "cocktail" of hydrolytic enzymes (Sopade and Gidley, 2009) including porcine pancreas α-amylase (A4268, Sigma), porcine mucosa pepsin (P7000, Sigma), porcine pancreas pancreatin (P7545, Sigma) and glucoamylase. The mixture was incubated under stirring in a water bath at 37°C for 100 min. The glucose released as a result of starch digestion was measured with an AccuCheck® Performa® glucometer (Roche Diagnostics Australia Pty. Ltd., Caste Hill NSW 2154, Australia), and digested starch (g per 100 g of dry starch) at a measurement time (min) was calculated as described by Sopade and Gidley (2009).

Study of some rheological properties: Consistency and viscosity of the porridge were made by the method using the Stable Micro System tetrameter TAX- T2i ®. The different porridges were prepared in 20% (w/v) of dry matter.

Twenty grams (20 g) of flour were added to 100 ml of distilled water. Resulted mixture was homogenized manually using a spoon. Homogenization was continued on the hot plate until boiling. The porridge was poured in appropriate containers for cooling. At general consumption temperature (45°C), sample was placed on the measuring device basis. The consistency was measured during the penetration of the probe in the porridge, while the viscosity was measured during the withdrawal of the probe (Ospina and *al*., 2007).

Statistical analysis: Results are expressed as mean ± standard deviation from triplicate measurements. The non-parametric test of Duncan is used to analyze the difference between the means at 5% risk, using SPSS 11.5.

RESULTS AND DISCUSSION

Biochemical composition of flours: High contents of dry matter and ash in all flours were recorded (Table II). The proportions of dry matter are not significantly different for these three (3) types of flour with respective values of 96.64%, 93.72% and 94.67% for flour FC1, FC2 and FM. The ash proportions were not significantly different. They are higher in flours FC1 (2.33%) and FC2 (2.66%) than FM (2.5%) (Table II). The results showed that the dry matter content is very high in the different flours. These values could be explained by low moisture content. Indeed, the raw materials used for the production of these flours were from dried crops. This characteristic indicates that the resulted flours could be stored safely for long time without risk of microbial growth. Concerning the total ash, their high concentration in the composite flour could be linked to the addition of legumes during formulation. Indeed, Gibson *et al*. (1998) demonstrated that legumes are rich in minerals. Therefore, supplementation of these foods in cereals could lead to the increasing of the mineral elements content.

The ethano-soluble total sugar, total carbohydrate and starch contents of FC1 and FC2 were significantly lower than those of FM. In fact, FC1 presented 3.81% of total sugars, 38.21% of total carbohydrate and 27.86% of starch; FC2 showed 5.11% of total sugars, 50.48% of total carbohydrate and 40.83% of starch, while FM recorded 7.34%, 72.56% and 58.70% for total sugars, total carbohydrates and starch respectively (Table II). The concentrations of total sugars, total carbohydrates and starch were significantly lower in composite flour than millet flour. Indeed, gravimetrically starch is the main part of cereal and represents 70 to 85% by dry matter weight (Redhead, 1990) and according to Latham (1979), carbohydrates represent 69% of millet and maize composition, while the soybean contains only 15%.

Table II: Chemical composition of flours (% DM ± SD[a])

	FC1	FC2	FM
Dry matter (%)	96.64 ±1.30[a]	93.72 ±0.80[a]	94.67 ±0.30[a]
Ash (%)	2.33 ±0.00[b]	2.66 ±1.70[c]	2.50 ± 0.10[a]
Total sugars (%)	3.81 ± 0.10[b]	5.11±0.10[c]	7.34 ±0.00[a]
Carbohydrates (%)	38.21 ±0.90[b]	50.48 ±0.60[c]	72.56± 0.50[a]
Starch (%)	30.96 ±0.80[b]	40.83 ±0.50[c]	58.70 ±0,50[a]
Protein (%)	14.00 ± 0.90[b]	24.50 ±0.90[c]	10.21 ±0.50[a]
Lipid (%)	7.63 ± 0.20[b]	12.10 ±0.10[c]	8.10 ± 0.10[a]
Energy value (kcal/100g)	277.87[b]	408.82[a]	403.98[a]

Values are the mean ± standard deviation of three measures (n = 3). The same letter of index in the same line indicate that it doesn't have significant difference in the samples for the parameter concerned (P<0, 05). Symbol: (FM) Flour of millet; (FC1) Composite flour 1; (FC2): Composite flour 2.

The proteins content was on contrast significantly higher in composite flours, especially in FC2 with 24.50% than FC1 (14%) and FM (10.21%) (Table II). The results showed that the proteins content increases significantly in composite flours added of legumes. In fact, legumes are rich in proteins with the content ranged from 20 to 50% according to Singh *et al*. (2004). So adding legumes to cereals contributes strongly to increase protein content in the final flour. In this way, Shuey and Tipples (1982) reported an increase in protein content of food by adding soybeans. Also, the amino acids profile of legumes would be complementary to that from cereals (Watier, 1982). Foods formulated from composite flours, especially FC2, would cover the protein needs of children as recommended by the World Health Organization (WHO, 2003).

Flours FC1, FC2 and FM have also a high fat content with 7.63%, 12.1% and 8.1% respectively. FC2 contained more fats than the other two flours (Table II). The value of fats content in FC2 is similar to those previously reported in millet (Robert *et al*., 2003). This similarity could be explained by the presence of soybeans in flour composition. In fact, soybean is richer in fats than other beans so that enrichment millet flour by addition of soybean could lead to the increase of lipid content. These results are previously obtained by Salunkhe *et al*. (1992) and the content of fats in composite flour FC2 could cover fat needs of children. According to WHO (2003) standards, complementary foods lipids should provide energy in the proportions ranged from 0 to 42% of the total energy produced. Effectively, the lipid content of all formulations of flours analyzed in the present study provided 24.79%, 26.63% and 18.05% for FC1, FC2 and FM respectively.

The energy amount was very high in all mixed flours namely 277.87 kcal/100g for FC1, 408.82 kcal/100g FC2 and 403.98 kcal/100g for FM. Energy value recorded for formulation FC1 was lower than those of formulations FM and FC2 which had similar energy values (Table II). The sources of high energy level in FM and FC2 were linked to the high carbohydrates content in the FM, proteins and lipids contents in the FC2, given energy value was calculated on these components rate. The FC2 energy value of 408.98 Kcal/100g, is greater than recommendation of WHO (2003) for an infant complementary food in developing countries which is ranged from 200 to 300 kcal/day for infants under one year. Compared to FC1, FC2 presented abundant nutrients jointed to a high energy density.

Flours functional properties: Swelling of different flours increased with temperature. The swelling values varied from 3.50 to 15.67 g/g for flour FC1, from 4.21 to 12.87 g/g for FC2, and from 2.1 to 17.3 g/g for FM. FM flour swelled much more quickly from 60°C and from 85°C, the swelling of FC1 became more important than that of FC2 (Figure 2). The starch behavior in water depended on both its concentration and water temperature. Generally, the starch absorbed very little water at room temperature; hence, it leads to low swelling capacity. As the starch absorption and swelling increased according to the increasing of temperature it would explain swelling power at low temperature but high with increasing of temperature. From 75°C, the swelling of flour FM was higher than one of composite flours FC1 and FC2. This difference could be explained by the high content of starch, low contents of protein and fat into the millet flour contrary to supplemented legumes flour. Wang and Seib (1996) have reported that amount of protein and fat could inhibit the starch granules swelling. These findings were recently confirmed by those of Hathaichanock and Masubon (2007) who have shown that the presence of protein in the flour could reduce or inhibit the starch granules swelling.

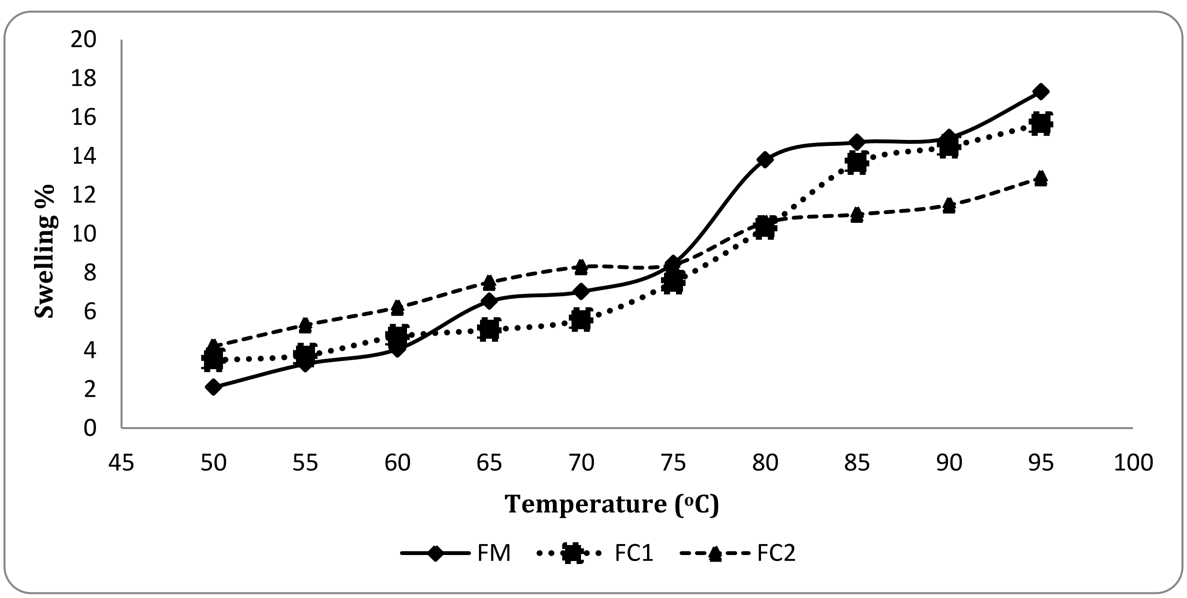

Figure 2 : Change in swelling power according to the increasing temperature. Symbol: (FM) Flour of millet; (FC1) Composite flour 1; (FC2): Composite flour 2.

The solubility percentages of different flours also increased with temperature. Values were comprised between 10 and 45% for FC1, 10 and 40% for FC2, 10 and 70% for FM.

The solubility percentage evolved much faster for the FM from 60°C. From 70°C, the FC1 solubility appeared more important than that of FC2 (Figure 3). Crystalline structure of starch was a veritable barrier to its solubility in cold water. During gelatinization, the destruction of crystalline structure and modification of initial swelling have been clearly observed at temperature ranged from 60 to 65°C.

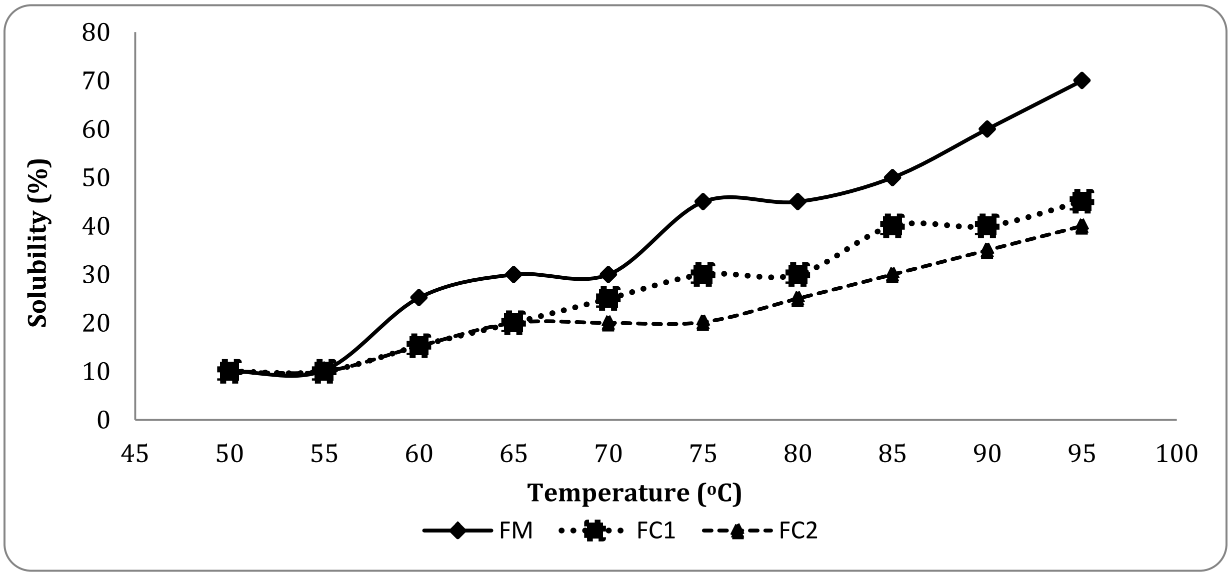

Figure 3 : Change in flour solubility percentage according to the increasing of temperature. Symbol: (FM) Flour of millet; (FC1) Composite flour 1; (FC2): Composite flour 2.

The intensity of swelling was proportional to the temperature increasing until the bursting granules released their contents which partially dissolved (Doublier, 2009). Therefore, high temperatures denature the flour starch granules by improving solubility which is closely linked to releasing of amylase from starch granules during the swelling (Hathaichanock and Masubon, 2007).

According to these authors, soluble proteins and high hydrophobic amino acids content could also improve the grain products solubility. Table III presents functional properties of different formulated flours. Recorded results indicate a high water absorption capacity for composite flours and low ones for FM. Obtained experimental values were 0.95 g/g for FC1, 1.33 g/g for FC2 and 0.92 g/g for FM. The oil absorption capacity of all three meals was significantly different compared each to other. It was 1.1, 1.3 and 1.04 g/g respectively for FC1, FC2 and FM. Similarly to its water absorption capacity, the oil absorption capacity of flour FC2 was the highest among all obtained values. The increasing of water absorption capacity of flour could be due to the addition of legume flours which is rich in protein (Sefa-Dedeh and Afoakwa, 2001).

Table III: Functional properties values of flours

	FC1	**FC2**	**FM**
Water absorption capacity (g/g)	0.95 ±0.00[b]	1.33 ±0.00[c]	0.92 ±0.00[a]
Oil absorption capacity (g/g)	1.10 ± 0.00[b]	1.30 ± 0.00[c]	1.04 ±0.0 0[a]
Foam capacity (%)	4.00 ±0.00[b]	10.00 ±0.00[c]	0.00 ±0.00[a]
Foam stability (ml/5min)	0.00 ±0.00[a]	0.00 ±0.00[a]	0.00 ±0.00[a]
Water solubility index	20.34 ±1.00[b]	17.54±1.24[c]	2.41± 0.50[a]
Water absorption index (g/g)	2.92 ±0.10[b]	3.60 ±0,20[c]	3.22 ±0.20[a]

Values are the mean ± standard deviation of three measures (n = 3). The same letter of index in the same line indicate that it doesn't have significant difference in the samples for the parameter concerned (P<0, 05). Symbol: (FM) Millet flour; (FC1) Composite flour 1; (FC2): Composite flour 2.

These observations were made in the case of the FC2 which contained high protein content and presented best characteristics for water absorption. According to Kinsella (1976), the polar amino acid residues of proteins have an affinity for water molecules that explained easily water absorption of products having high amount of protein.

The value of the FC2 absorption capacity water was similar to those of legume flours previously studied including cowpea (1.28 g/g), chickpea (1.36 g/g) (Ghavidel and Prakash, 2006), and chickpea flour *kabuli* type (1.33 g/g) (Kaur and Singh, 2005a). In addition, it has been reported that hydrophilic constituents present in flours could increase water absorption capacity (Hodge and Osman, 1976). In partial conclusion, water absorption capacity of flour was closely linked to both amount of amino acids in different flours studied and availability of proteins functional groups in flour. However, high water absorption capacity was desirable in order to improve the viscosity reduction in food products (Oyarekua and Adeyeye, 2008). Related to oil absorption capacity of studied different flours, results of the present work were greatly superior to that reported for chickpea (0.79 g/g) (Ghavidel and Prakash, 2006) but close to that of *kabuli* chickpea (1.24 g/g) reported by (Kaur and Singh, 2005b). There is an advantage for best organoleptic characteristics of meal that high water and oil absorption capacity of the flour can positively influence the flavor, moisture and fat content in food (Yadahally *et al*., 2008). Flour FM presented no foaming capacity while low for FC1 and FC2 recorded respectively low values with 4 and 10%. Despite its low foaming capacity, flour FC2 rich in proteins was the best studied composite flour indicating the increasing of foaming capacity with protein content. Indeed, proteins were denatured and aggregated during agitation leading to foam formation (Yadahally *et al*., 2008). In opposite to flours FC2 and FM made from millet grains which are very poor in protein provided the proof of relation between foam formation and high protein content. In fact, the foam formed by the flour has no stability over time. This was due to the protein denaturation caused by grinding. It has been reported that the native proteins provide high foam stability than denatured proteins (Lin *et al*., 1974). Moreover, the low or absence of foaming capacity of certain meals could affect their stability during storage. At the end, water absorption index were high with values of 3.22 g/g, 2.92 g/g and 3.60 g/g respectively for flours FM, FC1 and FC2. Water solubility index was higher for composite flours FC1 (20.34%) and FC2 (17.54%) compared to flour FM which showed 2.41%. The lowest water absorption index obtained with the FC1 would indicate that the water occupied a small volume in starch content which was relatively low.

Amylolysis: Figure 4 showed the amylolysis evolution of the different flours over time. Amylolysis increased with time band stabilized after 90 min. It was higher for flour FM varying from 0 to 80% and lowest for FC2 ranged from 0 to 40%. For FC1, it was comprised between 0 and 60%.

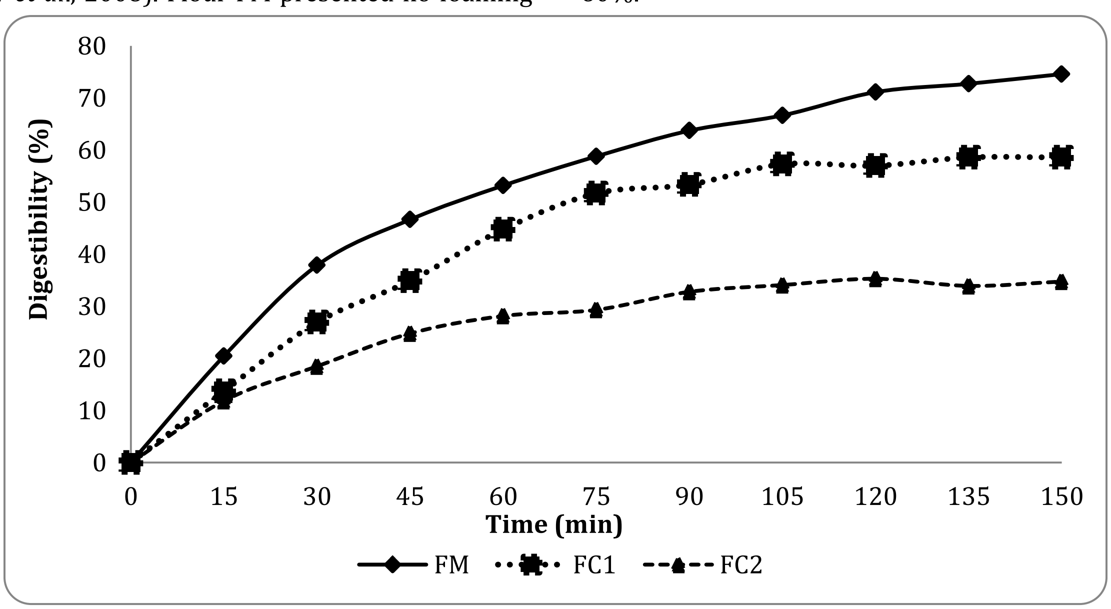

Figure 4: Change in digestibility in vitro of flours. Symbol: (FM) Flour of millet; (FC1) Composite flour 1; (FC2): Composite flour 2.

Among of the amylolysis percentage recorded in various studies flours, those of FC2 was very low. This could be explained by a potential enzymatic activity on starch fine particles by α-amylase during amylolysis following disaggregation cell walls and structure of the starch grain after grinding. Also, according to Sauvant (2000), this amylolysis evolves with the fineness of grinding. The results could be explained partly by a difference in particle size of studied flours and in other way by adding and content of legumes in the mixture. Indeed, the digestion of starch from supplemented flour with legumes is lower than that of FM.

Rheological properties of flours: Changes in porridge consistency in terms of flour type were highlighted in Figure 5 which has shown a low consistency for prepared porridge from FM (-1.443 N) and FC2 (-1.417 N). Consistency was higher for the porridge made from FC1 (-1.095 N). Figure 6 has shown change in the viscosity of porridge according to the type of flour. The viscosity of porridge made with FC2 was significantly lower (-4.281 N) than those of porridge made with FM (-3.438 N) and FC1 (-3.850 N).

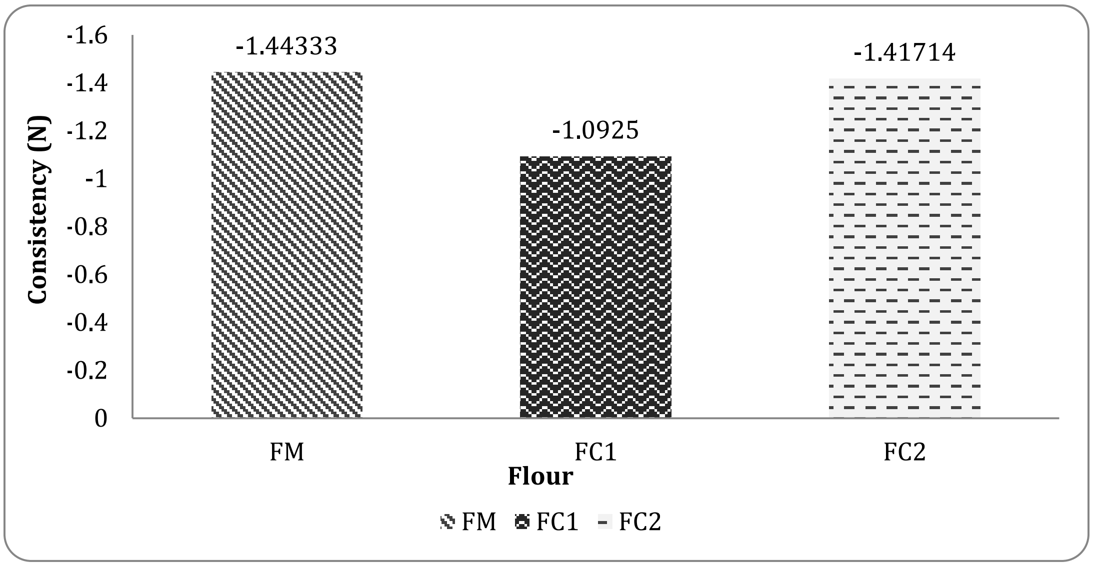

Figure 5: Change in consistency of porridge according to the type of flour. Symbol: (FM) Flour of millet; (FC1) Composite flour 1; (FC2): Composite flour 2.

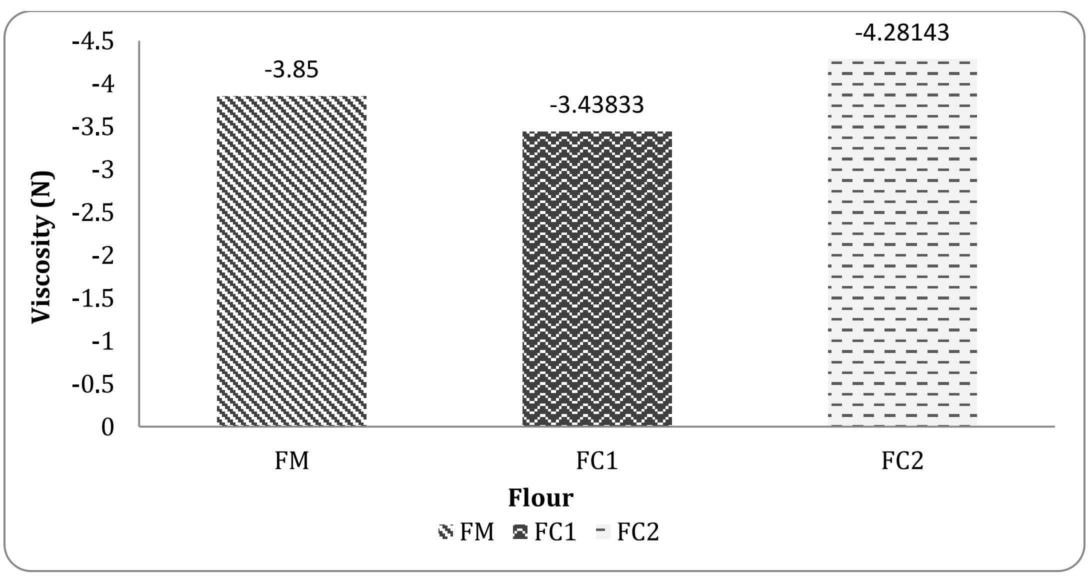

Figure 6: Change in viscosity of porridge according to the type of flour. Symbol: (FM) Flour of millet; (FC1) Composite flour 1; (FC2): Composite flour 2

Resulted porridges from FM and FC2 have lower consistency and higher viscosity because of their high dry matter concentration (20 g/100 g of porridge) and their high starch content. Indeed, with around 10 g, the porridge becomes too thick for young children consumption (Laurent and Sawadogo, 2002). According to these authors, the starch is the main component of flour. Cooking starch in water gives to the porridge thick consistency appearance, and viscous gel. However, young children, especially if they are malnourished, they haven't inadequate salivary and pancreatic amylase to digest starch. In addition to high values, the results showed that the porridge viscosity doesn't change with the consistency, whereas according to Mouquet *et al*. (1998), the most parameter often measured to assess the porridge consistency is the viscosity. Porridge made from flour FM is more viscous than that made from FC2, unlike their consistency. This could be explained by the water absorption capacity of flour. Indeed, higher water absorption capacity for FC2 could lead to reduce the viscosity of porridge resulted from this flour as reported by Oyarekua and Adeyeye (2008). More consistent porridge would not be the most viscous.

CONCLUSION

This study has developed two meals of complementary food and assessed their nutritional value. Relatively to physical and chemical parameters studied, it appears clearly that different produced flours contain various nutrients contents sufficient to cover the infant and young child needs, due to the presence of legumes. The energy value of flour FC2 (408.98 Kcal) was substantially similar to that of other complementary foods on the Ivorian market such as FARINOR (400 Kcal), BLEDINA NURSE (501.19 Kcal) and may therefore sufficient to cover the child energy needs. The functional properties and some physical and chemical properties of the flours, such as their high water and oil absorption capacities, and their low swelling power, supported their future use as convenient products for infant complementary food. However, resulted porridges from two composite flours were very thick and viscous, thus limiting their use.

Compared to flour FC1, flour FC2 was richer in nutrients with a high energy density and present acceptable functional properties. The porridge made from flour FC2 is less consistent and less viscous than that based on flour FM. This flour would meet the expectations of most young children.

For these reasons, it would be necessary to apply on these flours enzymatic treatments and/or hydrothermal appropriate such as fermentation, germination, cooking-extrusion in order to limit swelling during cooking, and therefore the viscosity of the resulted porridges. This could be then possible to reach the achievement porridge with density and mineral bioavailability even higher, enhanced nutritional quality, a suitable consistency. This porridge that which meets the standards would be used as the protein-energy source against children malnutrition in developing countries.

In addition, this study could be complemented by additives investigations on the in- vivo digestibility of starch in order to determine the energy ingested from these porridge according to the parameters that are the number of meals, the amount of each meal consumed.

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