**Proximate composition, functional, and sensory characteristics of complementary instant flours from yellow maize soya bean and baobab pulp blends**

**Abstract**

This study aimed to formulate an instant complementary flour from yellow maize, soya bean, and baobab pulp. To achieve this, maize was germinated and cooked, and soya beans soaked and roasted. The three food materials were ground, and their proximate composition was determined. The instant complementary flours were formulated following the World Food Program specifications. Gruels were prepared from these flours and a sensory analysis was carried out. The selected gruel was analyzed for viscosity, water absorption capacity (WAC), solubility index (SI), particle size, and energy value and density. Sprouted yellow maize, soaked/roasted soybeans, and baobab pulp are good sources of carbohydrates, protein, and iron respectively. Amongst the eleven complementary flours formulated, F2 (80.5 % yellow maize, 17.2% soya bean, 2.3% baobab pulp), was the most accepted with 71.32% carbohydrate, 12.75% protein, 7.83% lipid, 6.26 mg/100g DM iron. Functional properties indicate that it's suitable for the preparation of an energy-dense gruel suitable for complementary, with an energy density of 111.49 Kcal/100ml. Thus, the pretreated yellow maize and soya bean are good ingredients for the formulation of complementary food when combined with baobab pulp.

**Keywords:** Food formulation; Complementary Food; Instant Complementary Flour; Energy Dense Gruel, Sensory Evaluation.

1. **Introduction**

Diet plays a key role in the various developmental processes by providing food in the quality and quantity required to meet its nutritional needs during a child's normal growth and development [1]. During the first six months of life, all the child's nutritional needs are covered by breast milk which is no longer sufficient to fully cover its energy and protein requirements after this age, hence the importance of supplementing the child's diet with foods known as complementary foods [2]. Complementary foods are the first new foods to be given to children in liquid or semi-liquid form to supplement their mother's milk to fully meet their nutritional needs [3]. They are designed to provide balanced proportions of proteins, lipids, and carbohydrates, as well as certain vitamins and minerals [4].

In sub-Saharan Africa, complementary foods are mainly porridges prepared from flour [5]. Specially designed to cover nutritional needs, taking into account the intake of breast milk and the daily frequency of meals, complementary flour is a composite flour that is given in the form of gruel to babies from four to six months [6]. It should provide for 100 g of flour, 400 kcal for 60 – 70% carbohydrates (81% of which should be soluble sugars), 8 – 16% protein (with a minimum digestibility of 70%), 7 – 13% fat, less than 5% fiber, 11.6 – 23 mg iron and 300 –400 µg vitamin A [7]. It should be safe, accessible to as many children as possible, and have particles with a diameter below 500 µm [8]. Gruels prepared from these flours should have an energy density > 80Kcal/100ml, with a viscosity of 2.5 to 3.5 Pa.s, making them easy to swallow for complementary and toddlers [9].

To improve accessibility of complementary floursusing locally available foodstuffs as recommended [10], many researchers in Sub-Saharan Africa have used local crops, mainly starchy products as sources of energy, which have been combined with legumes and seeds as a source of protein and fat, and fruit and vegetables as a source of vitamins and minerals in the complementary food formulation [11-14]. However, as these matrices are generally rich in antinutrients and starch, they also need to be treated to improve nutrient bioavailability and digestibility [15].

Treatments such as soaking, germination, fermentation, and roasting have been applied to some of these foodstuffs to improve their nutritional quality [15]. It is the case of fermented melon and steam-bleached spinach [16,17], cooked plantain, roasted sesame and cashew nut, soaked/roasted soya bean [14], maize and roasted soybean [18], yam and soaked/roasted soya bean [19]. However, most of these formulated complementary flours are to be cooked by the mothers or caregivers of the child, and are energy and time consumers, compared to instant complementary flours which are ready-to-use flours that simply need to be diluted in warm water to obtain a gruel [20]. There is a growing interest in instant complementary flours with and increasing demand compared the flours that need to be cooked before consumption. This is due to the convenience, improved nutritional and organoleptic qualities, and longer shelf life of instant flours [21]. Imported instant complementary flours are overwhelmingly dominant in Cameroon, accounting for over 85% of the market, but they are out of price for the major part of the rural populations which for the majority are stripped and vulnerable. The consequence of this state of cause is the persistence of undernutrition in children under 5 years with prevalences of 29% for protein-energy malnutrition, 57% for anaemia caused by iron deficiency and 35% for vitamin A deficiency [22]. Yet, the country has a variety of raw food materials that can be used in the formulation of complementary flours more accessible for vulnerable households, and the technology can be forwarded to the populations during programs of sensitizing and nutritional intervention.

To this end, yellow maize, with its high starch content (70%), is a staple food in many parts of the world including Cameroon, with an energy density of 365 kcal / 100g [23]. Yellow maize is also a source of provitamin A and can improve the vitamin A status of the population consuming it [24]. However, young children do produce enough enzymes to digest starch, thus maize intended for complementary foods formulation needs to be pre-treated to hydrolyze at least partially the starch before use. Malting has been used in this line to improve the nutritional value of cereals [25]. On the other hand, soya bean is a legume rich in good quality protein, fat, carbohydrate, fat-soluble vitamins, vitamin B, and various minerals [26], making it a good complement to yellow maize in complementary food formulations but lacks some important mineral like iron and calcium, present in baobab pulp. Dry baobab fruit pulp (100 g)may contain on average 1.1 to 10.4mg of iron, 390 to 701mg of calcium, up to 350mg of vitamin C, and 1.7mg of zinc [27]. The objective of the present study was to use germinated and roasted maize, soaked soya beans and baobab pulp to formulate and evaluate the functional properties and the composition of a fortified instant complementary flour suitable for complementary four to six months.

1. **Material and methods**
   1. **Sampling of raw materials**

Yellow maize (*Zea mays*) variety Coker 240 (SJ166), soya bean (*Glycine max*), and baobab fruit pulp (*Adansonia digitata*) were all purchased at the *Dakar* market in Douala (4°2’53.8”N, 9°42’15.4”E), Littoral Region of Cameroon, and then conveyed to the laboratory for the production of individual flours.

* 1. **Processing of the raw materials**

To produce yellow maize flour, maize grains were processed as presented in Figure 1A. They were sorted manually to remove undesirable materials (plant fragments and debris, stones and damaged grains), soaked in clean tap water at 1/3 (w/v) 24 hours at room temperature (25±2 °C), with the water changed every 6 hrs [28]. After soaking, the grains were drained in a colander and left to germinate for 48 hours. During germination, they were watered daily to maintain the high relative humidity required for good germination. The roots of the germinated grains were separated by abrasion on aluminium trays then the grains were cooked in a commercial SEB ACTUA 6L pressure cooker (SEB, Selongey, France) for 1 hour at 100°C and cooled at room temperature. The cooked grains were dried in a ventilated oven (Rivière & Bar QD105A, Paris, France) at 45⁰C for 24 hand ground using a hammer mill blender (Culatti Micro Hammer Mill DCFH 48, Lutoslawskiego Witolda, Poland) to obtain a malted yellow maize flour with a particle size ≤ 200 μm.

To obtain soya bean flour, grains were processed following the recommendations of the Codex Alimentarius [29] as presented in Figure 1B. After manual sorting to remove impurities, the beans were soaked for 24 h, dehulled, and then drained and dried in a ventilated oven at 45°C for 24 h. The dried soybeans were then roasted at 121°C for 15 min then cooked in a pressure cooker at 100°C for 1 hour, dried in a ventilated oven for 24 h at 45°C, and ground using a hammer mill to obtain fine soya flour (ϕ ≤ 200 µm).

Baobab powder was produced following the process described in Figure 1C. The baobab pulp was sorted to remove all impurities and stones, and then ultra-fine ground (≤ 50 µm) to obtain baobab pulp flour.

Sorting

Soaking

(25±2°C, 24 h)

Unwanted materials

Wastewater

Draining

Germination

(25±2°C, 48 h)

Rootlet removal

Cooking (100°C, 1hrs)

Drying

(45±1⁰C, 24hrs)

@

Grinding

(∅ 200 μm)

Rootlet

Sorting

Soaking

(25±2°C, 24hrs)

Unwanted materials

Hulls

Dehulling

Drying

(45±1°C, 2hrs)

Roasting (121°C, 15 mins)

Cooking (100°C, 1hrs)

Drying

(45±1⁰C, 24hrs)

Grinding

(∅ 200 μm)

Sorting

Pitting

Seeds

Unwanted materials

Grinding (≤ 50 µm)

**(A)**

**(B)**

**(C)**

**Fig 1** Process diagram of malted yellow maize (A), instant malted soybean (B), and baobab pulp (C) flours

* 1. **Determination of the proximate composition of individual flours**

Dry matter, moisture, ash, total and soluble sugar, protein, fat and fiber content of individual flours produced was determined using standard methods from the literature [14,16].

* 1. **Formulation of composite complementary flours**

The instant complementary flours were formulated using the World Food Program [30] specifications for complementary flours composition. Table 1 shows the domain of the ternary mixing plan used, with lower and higher levels of macronutrients.

**Table 1.** Domain of the ternary mixing plan for 100g of complementary flour

|  |  |  |
| --- | --- | --- |
| **Main nutrient** | **Lower level (g)** | **Higher level (g)** |
| **Carbohydrate** | 65 | 70 |
| **Protein** | 8 | 16 |
| **Fat** | 7 | 13 |

Preliminary sensory trials were done to determine the highest incorporation rate of the baobab pulp in the mixture. Based on the taste mainly the acidity of the gruel obtained from the blended flours, the highest proportion of the baobab pulp flour that can be incorporated in the mixture was limited to 2.5 %, because of its strong acid taste which reduces the acceptability of the final product. From these criteria and based on the proximate composition of the ingredients, the formulation was done from individual maize, soya bean, and baobab pulp flours following the domains of the different nutrients presented in Table 1. Design Expert software was used to develop a ternary mixture design, and eleven complementary flour mixtures presented in Table 2 were formulated.

**Table *2*.** Different mixtures used to formulate the instant complementary flour

|  |  |  |  |
| --- | --- | --- | --- |
| **Run** | **Component (%)** | | |
| **Maize flour** | **Soya bean flour** | **Baobab pulp flour** |
| **F1** | 79.31 | 18.39 | 2.30 |
| **F2** | 80.46 | 17.24 | 2.30 |
| **F3** | 80.46 | 18.39 | 1.15 |
| **F4** | 79.31 | 19.54 | 1.15 |
| **F5** | 80.07 | 18.01 | 1.92 |
| **F6** | 79.69 | 18.77 | 1.53 |
| **F7** | 78.16 | 19.54 | 2.30 |
| **F8** | 80.46 | 18.01 | 1.53 |
| **F9** | 80.46 | 19.54 | 0.00 |
| **F10** | 80.46 | 18.77 | 0.77 |
| **F11** | 78.93 | 19.16 | 1.92 |

* 1. **Proximate composition of the instant complementary flours formulated**

The macro and micronutrient composition of formulated complementary flours was determined by calculation using the physicochemical composition of individual flours (Formula 1)

**(1)**

Where X is a nutrient content in the formulation, M, S, and B are the proportion of maize, soya bean, and baobab pulp flours respectively, and Xm, Xs, and Xb are the nutrient content in individual maize, soya bean, and baobab pulp flours respectively.

* 1. **Preparation of gruels**

Gruels were prepared from formulated complementary flours following the modified method of Ngaha et al. [14]. Each of the selected flour (100 g) was mixed with 250 mL of boiled potable water, and transferred into a plate containing 250 mL of boiling water, to avoid the formation of clots, and the mixture was stirred for about 2 to 3 min. At the end of the preparation, 6% table sugar was added to improve the taste, and the gruel was cooled to about 45°C.

* 1. **Sensory assessment**

A sensory assessment was performed at the sensory analysis laboratory of the National School of Agro-Industrial Science, Ngaoundere-Cameroon. The study was carried out following the rules of the Ethical Committee of the Postgraduate Training Unit in Food Science and Nutrition of the same school. A 9-point hedonic scale (1 = extremely dislike to 9 = extremely like) was used to assess the sensory attributes of the gruels prepared from the samples of flour produced. The gruels were evaluated by 30 untrained mothers aged from 20 to 33 years old, selected among women of Ngaoundere town who were familiar with complementary flours, and having children from 6 to 24 months. Each evaluation of the gruels was conducted for sensory properties including color, flavor, taste, appearance (homogeneity), mouthfeel, viscosity, and overall acceptability. To prevent the influence of sample order presentation, samples were provided to mothers at the same time. The mothers were instructed to rinse their palate by drinking water between samples and to assess the next sample after an interval of 4 min. The sensory session was conducted at room temperature under controlled environmental conditions. To avoid any communication between panellists, they were installed in individual cabins with a white light to prevent changes in the color of samples. Color and appearance were imposed on mothers as the first parameters to be analyzed before any other parameters. To avoid the risk of allergy, the list of the ingredients used in the formulation was given to the panellists before the analysis.

* 1. **Functional analysis of the flour and porridge selected**

At the end of the hedonic test, the complementary flour giving the most accepted gruel was selected, and its functional properties were analyzed. Viscosity and energy density were determined for the gruel, while water absorption capacity (WAC), solubility index (SI), particle size, and energy value were assessed for the complementary flour.

The granulometry of the flour was determined using an electric digital sieve column (Retsch AS 200). The flour (100g) was introduced in the column of a series of four sieves with decreasing mesh sizes of 200, 150, 100, and 50 µm, and vibrated for 20 min with a frequency of 2 min per vibration. The different fractions retained by each sieve were weighed using a precision electronic scale. The proportion of flour retained per sieve (Q) was calculated (Formula 2) and used to express the granulometric distribution.

**(2)**

Where Ms (g) is the mass of flour retained per sieve and Mi(g) is the initial quantity weighed.

The water adsorption capacity (WAC) and solubility index (WSI) of the selected complementary flour were determined using the method described by Tedom et al [16]. Flour (1g) (M0) was mixed with 10 ml of distilled water, the whole shaken for 15 min and centrifuged at 2500 rpm for 30 min. The supernatant was discarded, and the bottom was weighed (M2) and dried in an oven at 105 ± 2°C for 24 h. The mass of the dry pellet (M1) was determined and the water absorbed was then calculated as water absorption capacity (WAC).

The viscosity of the porridge was determined using a graduated Bostwich concistometer, in which the gruel, cooled to 45°C, could flow for 30 s, the distance covered in cm representing the viscosity (fluidity). A table of conversion was used to convert cm in mPa/s.

* 1. **Evaluation of energy value and energy density**

The energy value (EV) of the selected complementary flour (kcal/100g) was calculated using the coefficients of Atwater and Benedictas expressed in Formula 3 [31].

**(3)**

Knowing the EV of the flour and the quantity of flour (Q) used to prepare 100 mL of porridge, the energy density (ED) (kcal/100 ml) of the porridge was calculated (Formula 4).

**(4)**

* 1. **Statistical analysis**

The analyses were carried out in triplicate, results were expressed as means ± standard deviation of three determinations. Data obtained were subjected to analysis of variance (ANOVA) for significance difference (p < 0.05) using Statgraphics Centurion software. Duncan’s multiple range test was used to separate the means.

1. **Results and discussion**
   1. **Proximate composition of ingredients**

The proximate composition of the different individual flours was evaluated, and the results were compiled in Table 3. Yellow maize flour has the highest total sugar content, while soya bean has the highest lipid and protein content. On the other hand, baobab has the highest ash and iron contents. Globally, the different treatments affect the composition of the maize and soya bean flours.

The high sugar content of maize justifies its choice as the main energy source of the complementary food formulation. The soluble sugar content of the maize increases with the pre-treatment, probably due to the biochemical process that occurs during malting( cite??) Germination facilitates the conversion of complex carbohydrate components into simple sugars through the activation of endo-enzymes such as α-amylase, which improves the digestibility of sugars, and the release of energy for growth activities in the seed [32]. However, this soluble sugar content remains low for complementary flour, meaning that the malting process needs improvement, maybe by a precooking of maize after germination, at the optimal temperature of α-amylase, to permit efficient hydrolysis of starch. The total sugar significantly (p<0.05) drops in soya beans from 20.32 g/100 g DM before treatment to 18.06 g/100 g DM after treatment. This could be explained by the effect of various biochemical reactions, such as the Maillard reaction, which involves sugars and amino acids giving the color after roasting. Under the effect of heat, the reducing sugars react with the proteins to form volatile products. This result is like those reported by Agume et al [29] who, after soaking and roasting soybeans, obtained a significant reduction of carbohydrate content.

Soya bean has the highest protein content and serves as the main source of protein in this study. The protein content of soya beans increases with pre-treatment, probably due to the re-dehulling and the decrease in carbohydrate content, resulting in an apparent increase in protein content, and this result is close to that obtained by Agume et al. [29]. The protein content of yellow maize drops significantly from 9.06 g/100 g DM to 6.53 g/100 g DM. This could be due to leaching during soaking and the breakdown of complex sugars into soluble sugars during cooking. This result is similar to results reported by Obasi and Wogu [33] who observed a reduction in the protein content of yellow maize during soaking.

The lipid content of soya beans increased significantly from 20.94 g/100 g DM before treatment to 31.33 g/100 g DM after treatment. This result is similar to the results reported in a previous study, indicating an increase in lipid content in soybeans after soaking [29]. This could be due to the leaching of soluble compounds like sugars, with the subsequent increase in lipid content, resulting in a relative concentration of lipid content.

The ash content of a food product gives information on its richness in minerals, the high ash content in baobab pulp indicates it is a source of minerals in this work, which is confirmed by the iron content of 12.35 mg found for 100 g DM of powder (Table 3).

**Table 3.** Proximate composition of individual flours (g/100g DM)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameters** | **Yellow maize** | | **Soya bean** | | **Baobab** |
| Raw | Treated | Raw | Treated |  |
| **Dry matter** | 95.69 ± 2.98b | 91.76 ± 0.02a | 94.53 ± 0.21b | 92.60 ± 0.07a | 92.51 ± 0.31a |
| **Ash** | 1.71 ± 0.07b | 0.66 ± 0.04a | 5.07 ± 0.56d | 2.39 ± 0.06c | 8.29 ± 0.15e |
| **Total sugar** | 83.33 ± 0.56c | 82.94 ± 2.10c | 20.32 ± 1.90a | 18.06 ± 1.01a | 63.9 ± 0.02b |
| **Soluble sugar** | 2.67 ± 0.15a | 10.23 ± 0.60d | 4.53 ± 0.27c | 3.37 ± 0.12b | 14.92 ± 0.31e |
| **Protein** | 9.06 ± 0.50b | 6.53 ± 0.11a | 36.78±0.81c | 42.57 ± 1.02d | 6.78 ± 0.02a |
| **Lipid** | 3.40 ± 0.37a | 2.90 ± 0.50a | 20.94 ±0.22b | 31.33 ± 0.17c | 4.03 ± 0.41 a |
| **Fibers** | 5.47 ± 0.35b | 4.97 ± 0.05b | 14.43 ± 0.78c | 4.00 ± 0.52a | 17.25 ± 0.61d |
| **Iron\*** | 7.65 ± 0.45d | 6.67 ± 0.02c | 4.38 ± 0.01b | 3.56 ± 0.01a | 12.35 ± 0.65e |

\*Iron content: mg/100g DM; Values in the same line with different superscript letters differ significantly (P<0.05)

* 1. **Proximate composition of the instant complementary flour**

Table 4 presents the proximate composition of the 11 samples of complementary flour formulated. For all the 11 flours, macronutrient contents respect the recommendations which stipulate that an complementary flour should provide 60 to 70% carbohydrates, 8 to 16% protein, 7 to 13% fat, and less than 5% fiber [7]. These complementary flours could then be recommended to avoid protein energy malnutrition in young children. However, the ash content in all the formulated flours is lower than the minimum of 2% indicated for complementary foods [7]. This low ash content could be attributed to the small proportion of baobab pulp powder used in the formulations. A preliminary hedonic test has shown that formulations with more than 2.5% of baobab pulp were disliked by the tasters, probably due to the high acidity of baobab pulp. This low ash content explains why the iron content is also low in all the formulations. With iron content ranging from 6.06 mg for F9 to 6.26 mg for F2, the complementary flours produced are not good sources of iron if one refers to WFP which recommends that an complementary flour should provide 11.6 to 23 mg of iron for 100 g of flour [7]. However, this iron content is close to 7 mg/100 g recommended by FAO/WHO and found in most commercial complementary flours sold on the market.

**Table 4.** Proximate composition (g/100g DM) of formulated complementary flour

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Run** | **Dry matter** | **Total sugar** | **Soluble sugar** | **Protein** | **Lipid** | **Fibers** | **Ash** | **Iron\*** |
| **F1** | 91.93 ± 0.04a | 70.57 ± 1.85a | 9.08 ± 0.51a | 13.16 ± 0.28a | 8.15 ± 0.44a | 5.07 ± 0.15a | 1.15 ± 0.05a | 6.23 ± 0.03a |
| **F2** | 91.92 ± 0.04a | 71.32 ± 1.86a | 9.16 ± 0.51a | 12.75 ± 0.26a | 7.83 ± 0.44a | 5.09 ±0.14a | 1.13 ± 0.05a | 6.26 ± 0.03a |
| **F3** | 91.92 ± 0.03a | 70.79 ± 1.88a | 9.02 ± 0.51a | 13.16 ± 0.28a | 8.14 ± 0.44a | 4.93 ±0.14a | 1.07 ± 0.04a | 6.16 ± 0.03b |
| **F4** | 91.93 ± 0.03a | 70.04 ± 1.86a | 8.94 ± 0.50a | 13.58 ± 0.29a | 8.47 ± 0.43a | 4.92 ±0.15a | 1.09 ± 0.05a | 6.13 ± 0.03b |
| **F5** | 91.93 ± 0.03a | 70.90 ± 1.86a | 9.09 ± 0.51a | 13.03 ± 0.27a | 8.04 ± 0.44a | 5.03 ±0.15a | 1.12 ± 0.05a | 6.22 ± 0.03a |
| **F6** | 91.92 ± 0.03a | 70.46 ± 1.86a | 9.01 ± 0.51a | 13.30 ± 0.28a | 8.25 ± 0.44a | 4.98 ±0.15a | 1.10 ± 0.05a | 6.17 ± 0.03ab |
| **F7** | 91.94 ± 0.04a | 69.82 ± 1.84a | 9.00 ± 0.50a | 13.58 ± 0.29a | 8.48 ± 0.43a | 5.06 ±0.15a | 1.17 ± 0.05a | 6.19 ± 0.03a |
| **F8** | 91.92 ± 0.03a | 70.96 ± 1.87a | 9.07 ± 0.51a | 13.02 ± 0.27a | 8.04 ± 0.44a | 4.98 ±0.14a | 1.09 ± 0.05a | 6.20 ± 0.03a |
| **F9** | 91.92 ± 0.03a | 70.26 ± 1.89a | 8.89 ± 0.51a | 13.57 ± 0.29a | 8.46 ± 0.44a | 4.78 ±0.14a | 1.00 ± 0.04a | 6.06 ± 0.02c |
| **F10** | 91.92 ± 0.03a | 70.62 ± 1.88a | 8.98 ± 0.51a | 13.30 ± 0.28a | 8.25 ± 0.44a | 4.88 ±0.14a | 1.04 ± 0.04a | 6.13 ± 0.02b |
| **F11** | 91.94 ± 0.03a | 70.15 ± 1.85a | 9.01 ± 0.50a | 13.44 ± 0.28a | 8.37 ± 0.44a | 5.02 ±0.15a | 1.14 ± 0.05a | 6.18 ± 0.03a |

\*Iron content in mg/100g; Values in the same column with different superscript letters differ significantly (P<0.05), DM: dry mass

* 1. **Sensory properties of the different complementary flours**

The 11 different samples were tested for their sensory properties and the results obtained are presented in Table 5. Amongst the different mixtures, the formulation F2 with 80.46% yellow maize flour, 17.24% soya bean flour, and 2.30% baobab pulp flour recorded the highest overall acceptability, though the difference with the other formulations is not significant (p > 0.05). This is due to the proportion of the different ingredients used in the formulation of this sample. FormulationF2 has the lowest content of soya bean known with a negative beany flavor and has the highest contents of pre-cooked maize flour and baobab pulp flour. Baobab pulp flour is also known for its appealing flavor and is consumed as a snack and used to produce baobab juice in many localities in northern Cameroon. Thus, formulation F2 has been retained for the next steps of the study.

**Table 5:** Sensory properties of the formulated instant flour

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Color | Odor | Viscosity | Taste | Mouthfeel | Acceptance |
| **F1** | 6.00 ± 0.96 ab | 6.22 ± 1.18a | 5.89 ± 1.23a | 6.67 ± 1.07ab | 5.78 ± 1.19ab | 6.00 ± 1.11ab |
| **F2** | 7.11 ± 1.23 a | 6.67 ± 1.25a | 6.33 ± 1.11a | 7.44 ± 1.11 ab | 5.44 ± 1.83a | 7.11 ± 0.62a |
| **F3** | 6.67 ± 0.98ab | 6.56 ± 0.94a | 5.22 ± 2.19a | 5.67 ± 1.51 ab | 6.11 ± 1.46ab | 6.67 ± 1.33ab |
| **F4** | 6.44 ± 1.48ab | 6.44 ± 1.16a | 5.56 ± 1.95a | 6.56 ± 1.163ab | 6.33 ± 1.70ab | 6.44 ± 1.51ab |
| **F5** | 5.50 ± 1.06a | 5.56 ± 0.94a | 6.11 ± 1.01a | 6.00 ± 1.46abc | 5.33 ± 1.48a | 5.56 ± 1.06a |
| **F6** | 5.89 ± 1.03ab | 5.67 ± 1.41a | 5.67 ± 1.40a | 6.33 ± 1.11ab | 5.89 ± 0.79ab | 5.89 ± 1.45ab |
| **F7** | 6.78 ± 1.03ab | 5.89 ± 0.81a | 6.33 ± 1.18a | 6.44 ± 1.33ab | 6.78 ± 0.96ab | 6.78 ± 1.18ab |
| **F8** | 6.89 ± 1.25ab | 6.33 ± 1.04a | 6.22 ± 1.35a | 4.89 ± 1.41a | 6.78 ± 1.35ab | 6.89 ± 1.48ab |
| **F9** | 6.44 ± 1.47ab | 6.11 ± 1.19a | 5.89 ± 1.45a | 6.78 ± 0.81ab | 6.33 ± 0.81ab | 6.44 ± 1.16ab |
| **F10** | 7.00 ± 1.13a | 6.33 ± 1.26a | 6.00± 1.33a | 7.11 ± 1.23b | 7.11 ± 0.81b | 7.00 ± 1.11a |
| **F11** | 6.56 ± 1.33ab | 6.67 ± 1.04a | 5.67 ± 1.33a | 7.00 ± 1.06ab | 6.33 ± 1.11ab | 6.50 ± 1.036ab |

Values in the same column with different superscript letters differ significantly (P<0.05)

**3.4. Functional properties of the selected complementary formula and the different raw materials**

Water Absorption Capacity (WAC) indicates the ability of the material to absorb water [34]. Water absorption capacity and solubility index (WSI) of formulation F2 were respectively 382.00 ± 7.12 % and 47.00± 3.29 %. Flour F2 absorbs more than three times its weight in water. This is due to its high carbohydrate and protein contents, the main absorbent components in foodstuffs [35].

The particle size distribution of the flour indicates its fineness and this plays an important role in the hydration rate and the amount of water absorbed [36]. For the particle size of the flour F2, the mixture is made of 75% particles with a diameter ≤ 100 μm, which is the ideal flour for feeding young children. The remaining 25 % is made up of flour with particle size between 150 μm and 200 μm.

**3.5. Energy value and the viscosity of the instant complementary flour**

The energy value of flour F2 was 406.75 kcal/100g, which is close to the value of 400 kcal recommended by the WFP [30]. This result indicates that this flour meets the energy needs of young children and could thus contribute effectively to the fight against malnutrition. For 25 g of flour to be used to prepare 100 mL of porridge, the energy density obtained after calculation was 101.69 kcal/100 mL of porridge. According to the Codex Alimentarius Commission, the energy density of processed cereal-based foods intended for complementary and young children must not be less than 80 kcal/100 mL. This result therefore indicates that the gruel prepared from flour F2 is suitable for covering the caloric needs of young children. In addition, the gruel prepared from sample F2 has a viscosity of 3200 mPa/s which is within the range of 2500 - 3500 mPa/s recommended for children aged 6 to 12 months [9], indicating that children can easily swallow this gruel. Good viscosity combined with high energy density can be considered an important parameter for the ingestion of enough quantities of calories by the child. When the gruel is too viscous, either the child consumes very small quantities, or the mother adds water to dilute the porridge. In both cases, the child's calorie intake is reduced.

**Conclusion**

In conclusion, flour F2 made of 80.5 % yellow maize, 17.2% soya bean, and 2.3% baobab pulp complies with WFP recommendations in terms of nutrient composition and energy value and has good WAC and WSI. With a predominance of particles ≤ 100 μm, the gruel prepared from this flour has a smooth texture with an energy density and viscosity that makes it suitable for young child feeding. However, as the level of soluble sugar is low in F2, it would be suitable to improve the germination process of yellow maize to generate more soluble sugar by the action of amylases, and also to determine the digestibility of protein and quantify vitamin A.

**Data availability**

All the data used for this study are presented in this published article.

**Ethical approval**

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by an ethical clearance certificate (Certificate reference number 24 - / 2024) delivered by the ethics committee of the postdoctoral training unit in food science and nutrition of the University of Ngaoundere.

**Consent**

Appropriate protocols for protecting the rights and privacy of all the participants were applied during the hedonic test. Informed consent was obtained from the participants, witnessed and formally recorded. The anonymity of the participants was guaranteed, as well as the confidentiality of the information collected. In addition, measures were taken to ensure that all participants were neither ill nor allergic to foodstuffs used for the formulations.

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