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Research article

Formulation of complementary flours from pretreated pumpkin pulp, soybeans and spinach leaves: Nutritional, functional and sensory characterization

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A R T I C L E I N F O

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A B S T R A C T

One of the major causes of the high prevalence of young children suffering from malnutrition in developed countries is inadequate complementary feeding practices, and especially the low quality of homemade complementary foods. The present study aimed to use available local plant foods to formulate a complementary flour Which can be able to meet energy and nutrients requirements of children aged from 6 to 23 months. To achieve this goal, pumpkin was fermented, soybean soaked and roasted, and spinach steamed. The pre-treated ingredients were ground to obtain individual flours, which were blended in various proportions to obtain four complementary flours (PSS1, PSS2, PSS3, PSS4). The proximate and micronutrient composition, and the energy value of the blends were determined, and based on the results, two of them, that is; (PSS1 [Pumpkin 70 %/Soybean 25 %/Spinach 5 %], and PSS2 [Pumpkin 65 %/Soybean 25 %/Spinach 10 %]) were selected to pursue the Study. The functional properties (water absorption capacity, water solubility index, bulk density) and pasting properties of these two flours were then evaluated. Gruels were prepared from the flours and their energy densities, physical as well as sensory properties were evaluated. Moisture, ash, protein, fat, and sugar contents of PSS1 and PSS2 met the FAO/WHO standards. Fiber content in both flours was higher than the recommendation. Vitamin A and iron were sufficient in PSS2, while PSS1 had low iron content. Calcium, phosphorus, and magnesium content of PSS1 and PSS2 were significantly higher than the standards. PSS1 and PSS2 had good water absorption capacity and solubility index, with low viscosity values (213 and 173 cP respectively), interesting functional properties for complementary flours. The gruels prepared with PSS1 and PSS2 flours had good fluidity and energy densities. They were fairly appreciated based on their organoleptic characteristics, with scores of 5.96 and 5.75 for overall acceptability. PSS2 could be recommended as infant flour rich in iron, vitamin A, and protein, with good nutritional values and functional properties.

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1. Introduction

When an infant reaches around the age of 6 months, his energy and nutritional needs expand beyond what is provided from consumption of breast milk, hence the introduction of complementary feeding practices [1]. Complementary feeding practice refers to the introduction of solid, semi-solid and liquid foods other than breast milk [2]. In many developing countries, homemade complementary foods are based on cereal and tuber flours that are generally poor in protein and micronutrients, especially vitamin A and iron [3]. To solve this problem, mothers sometimes blend these flours with legumes such as soybeans or groundnuts to improve their nutritional quality [4]. However, protein-energy malnutrition and micronutrient deficiencies remain a public health concern [5].

In Cameroon, 29 % of children which are less than five years old suffer from protein-energy malnutrition, and the most affected are those aged from 6 to 23 months.57 % suffer from anemia due to iron deficiency, and 35 % are affected by vitamin A deficiency [6], coinciding with the initiation of complementary feeding practice. One of the main causes of the high incidence of malnutrition, child morbidity and mortality is the quality of the complementary foods used [1]. To overcome this, the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) recommend the optimal use of available local plant resources to produce enriched complementary foods [7]. Good quality complementary foods must have a high nutrient density (energy, protein and micronutrients), an appropriate texture with low viscosity, a semi-solid consistency that allows easy handling and swallowing by children [8].

Several studies reported the formulation of complementary foods based on starchy staple foods blended with legumes as sources of protein and fat, with fruits and vegetables as sources of vitamins and minerals [9–12]. However, the current growing prevalence of children's malnutrition justifies that the available solutions are not enough, and research should continue to propose better options using different local foods. Based on this, pumpkin, soybean, and spinach were investigated as sources of essential nutrients to improve the nutritional quality of complementary foods.

With its yellow-orange pulp, pumpkin (*Cucurbita pepo*) is a good source of β-carotene and carbohydrates, but these carbohydrates are mainly starch [13,14], which is not easily digested in the gastrointestinal tract of children, so needs to be hydrolyzed to break down these carbohydrates into simple sugars. Studies have reported that fermentation of pumpkin flesh in optimal conditions hydrolyzes complex carbohydrates into simple sugars while preserving its β-carotene content, making the flesh a good source of provitamin A and energy for young children [15,16].

Soybean (*Glycine max*) is one of the best sources of vegetable protein and unsaturated fatty acids usually used to improve complementary foods [10,12,17]. But, it also contains antinutrients like protease inhibitors, allergic compound such as β-conglycinin, glycinin, and beany flavour which may however be destroyed by soaking and roasting of soybeans in optimal conditions [18].

Spinach leaves (*Spinacia oleracea*) are a main source of iron [19], which makes them useful to enrich foods, notably complementary flours. The high ash content of this leafy vegetable indicates that it may contain other essential minerals, which are good for the development and immunity of young children [20]. Unfortunately, spinach leaves also contain antinutrients such as oxalates and phytates which reduce the bioavailability of minerals, and allergens such as lipid transfer protein (LTP) and chenopodin. A study reported that steam blanching of spinach leaves in optimal conditions significantly reduced these compounds, improving the bioavailability of divalent cations, making them a good source of bioavailable iron [21].

On the basis of these reports, the present study aimed to formulate complementary flour blends rich in iron, vitamin A, protein and energy using fermented pumpkin pulp, soaked and roasted soybeans, and steam-blanched spinach leaves, that meet the FAO/WHO standard for complementary foods.

2. Material and methods

2.1. Production of ingredients

Pumpkin, spinach, and soybeans were bought from the local main market of the town of Ngaoundere (Cameroon) and brought to the Laboratory of Food Biophysics, Biochemistry and Nutrition of the University of Ngaoundere for processing.

The pumpkin (*Cucurbita pepo*) was washed, sliced. The seeds were stripped from the flesh and and peeled. The pulp obtained was ground using a grinder (GEFU, model 10400, Ningbo, Zhejiang, China) and fermented with *Lactobacillus plantarum* at 45 °C/70 h as described by Tedom et al. [16]. The fermented pulp was dried in a ventilated oven (Rivière & Bar QD105A, Paris, France) at 45 °C for 48 h.

Spinach leaves (*Spinacia oleracea*) were washed, drained and steam blanched at 95 °C for 5 min as described by Tedom et al. [21]. The blanched leaves were then dried at 45 °C for 24 h in a ventilated oven (Rivière & Bar QD105A, Paris, France).

Soybean (*Glycine max*) was sorted, cleaned, and soaked at 30 °C for 16 h, after which it was drained and dried in a ventilated oven at 45°Cfor 24 h and roasted at 121°Cfor 15 min with a roaster (Model Panacea 2430, Torre Picenardi, Italy) as described by Codex Alimentarius [18] and Agume et al. [22].

Each ingredient was finally ground and sieved (500 μm) using a crusher (Culatti Micro Hammer Mill DCFH 48, Lutoslawskiego Witolda, Poland), and the flours obtained were stored in polyethylene bags at 4 °C.

2.2. Formulation of complementary flour

Based on the proximate composition of each ingredient obtained from previous studies [16,21,22], flours of pumpkin (60–70 %), soybeans (25–30 %), and spinach leaves (5–10 %) were mixed to produce complementary flours which meet the FAO/WHO standards in terms of their contents in proteins, carbohydrates, iron and vitamin A [8]. Four formulations were produced with different proportions of pumpkin/soybeans/spinach (PSS) as presented in Table 1.

2.3. Determination of macronutrient content and energy value

Dry matter, total and soluble sugar, crude protein, total fat, crude fiber and total ash contents were determined according to methods which were previously described [10,12]. Dry matter was determined by drying a sample at 105 °C in a ventilated oven until the weight became constant. Total sugar content was assayed using phenol in an acidic medium, while soluble sugars were measured using 3,5-dinitrosalicylic acid (DNS) reagent. Crude protein content was obtained through the mineralization of the samples by the Kjeldahl method and the determination of total nitrogen by colorimetric method. Fat content was determined by the difference after oil extraction in hexane using a Soxhlet apparatus. Crude fiber content was obtained after treatments of samples in acidic and basic media, followed by calcination. Total ash content was determined by weight difference after the complete incineration of samples at 550 °C.

The energy value (EV) (kcal/100 g) was obtained by multiplying carbohydrates, proteins, and fats content of flours by 4, 4, and 9 kcal respectively, which are the coefficients of Atwater and Benedict [23], as indicated by Equation (1).

$$EV(kcal) = \sum [(Carbohydrates \times 4) + (Proteins \times 4) + (Lipids \times 9)] \quad (1)$$

2.4. Determination of micronutrient content

To quantify total carotenoids, 1 g of dried sample was added to 30 mL of hexane-acetone mixture 30/70 (v/v), and the mixture heated under reflux for 1 h, after which it was cooled and filtered. The filtrate was washed with distilled water in a separator funnel, then the oil phase was decanted into a 25 mL graduated flask and the volume adjusted to the mark with hexane. The solution obtained was diluted 10 times with hexane and the maximum absorbance was read by scanning using a spectrophotometer (ZUZI, model 4211/50, Beriain [Navarra], Spain) between 430 and 450 nm. Total carotenoids content was then quantified using equation (2) [10].

$$C = \frac{(Amax \times f)}{(196 \times m)} \quad (2)$$

where, C is total carotenoid content, A_{max} is absorbance where max absorption was obtained; f is the dilution factor and m is the mass of the sample. The Conversion Factor of 1 μg of vitamin A equivalent to 12 μg of carotenoids was used to estimate the vitamin A content of the samples [10].

From the ash obtained, mineral content was deduced. The colorimetric method was used for the quantification of iron and phosphorus [24]. In a hot acidic medium, iron reacts with orthophenanthroline to give a red coloured complex with a maximum absorption at 510 nm. In the same conditions, phosphorus reacts with ammonium molybdate to give a blue-coloured product with a maximum absorption at 690 nm. The calcium and magnesium content were obtained by the titrimetric method [25]. Total hardness was firstly determined by titration with a solution of disodium salt of ethylene diamine tetra-acetic acid (EDTA) at pH 10. Calcium was quantified in a strongly basic medium at pH 13, and difference between total hardness and calcium content is used in calculating the magnesium content.

2.5. Determination of functional properties

To determine the water absorption capacity (WAC) and the water solubility index (WSI), the method previously reported by Ngaha et al. [10] was used. A mass of 2 g of flour (M1) was added to 20 mL of distilled water, the mixture was shaken (GRIFFIN flash shaker) for 30 min and centrifuged (Centrifuge DL-6000B) at 3500 rpm/10 min. The wet pellet was weighed (M2) before being dried at 105 °C/24 h and reweighed (M3). Apparent and real WAC (aWAC and rWAC), as well as WSI were calculated using equations (3)–(5).

$$rWAC(\%) = \frac{(M2 - M3)}{M3} \times 100 \quad (3)$$

$$aWAC(\%) = \frac{(M2 - M1)}{M1} \times 100 \quad (4)$$

$$WSI = \frac{(M1 - M3)}{M1} \times 100 \quad (5)$$

Table 1
Experimental matrix for the different formulations.

Flours code	Pumpkin flour (%)	Soybean flour (%)	Spinach flour (%)
PSS 1	70	25	5
PSS 2	65	25	10
PSS 3	65	30	5
PSS 4	60	30	10

Bulk density (BD) (g/mL) was obtained by adding 2 g (m) of flour in a measured cylinder flask of 10 mL, followed by vibration for 1 min (Vortex RS Lab_6Pro). The volume (v in mL) occupied by the mass of flour was noted and BD was calculated using equation (6) [26].

$$BD\ (g\,/\,mL) = \frac{m}{v} \tag{6}$$

2.6. Evaluation of pasting properties

The pasting properties were determined using the AACC method [27]. The viscosity of the flours was investigated using a Rapid Visco Analyzer (model Tec Master, Perten Instruments, Australia). Flour suspensions were prepared in distilled water at a concentration of 3 % (w/v). The speed of rotational of the blade was 960 rpm for the first 10 s and then 160 rpm. The software "Thermocline for Windows" was used to program the analyses and display the measurement parameters in real time. The parameters recorded were the peak of viscosity, retrogradation, final viscosity, time, and temperature of gelatinization.

2.7. Preparation and characterization of gruels

To prepare the gruels, 100 g of flour was mixed with 250 mL of water, and the resulting mixture was poured into 250 mL of boiling water and stirred regularly for about 5 min. The fluidity of the gruel was measured using a Bostwick Consistometer. Each gruel was cooled down to 45 °C respectively in the viscometer and allowed to run out for 30 s. The distance expressed in centimeter covered by each gruel during the 30 s represented its viscosity [10].

The energy density (ED in kcal/100 mL) was determined based on the dry matter level of the gruel (DM in %) (Equation (7)) [10].

$$ED = DM \times 4 \tag{7}$$

2.8. Sensory analysis of gruels

Sensory evaluation was performed in accordance with the rules of Ethics Committee of the Postdoctoral Training Unit in Food Science and Nutrition of the National School of Agro-Industrial Science (University of Ngaoundere, Cameroon), within the Food Sensory laboratory of the same school. A 9-point hedonic scale (1 = extremely dislike to 9 = extremely like) was used to assess the sensory properties of the gruels prepared from complementary flours. Samples were evaluated by untrained panelists made of 36 mothers aged from 18 to 30 years old, selected among women of Ngaoundere town who were familiar with complementary flours. Each study of the gruels was conducted for sensory attributes including appearance, taste, flavor, texture, and overall acceptability. The samples used for sensory analysis included gruels prepared from the flours formulations while a gruel prepared from a commercialized flour served as positive control. To prevent the influence of sample order presentation, samples were provided to participants at the same time. Panelists were instructed to cleanse 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 panelists, they were installed in individual cabin with a white light to prevent changes of the color of samples. Appearance was imposed to participant as the first parameter to be analyzed before any other parameters. Furthermore, to ensure that panelists were not allergic to ingredients used, they were all informed in advance on the composition of the gruels.

2.9. Statistical analysis

The results of triplicate analysis were expressed as means and standard deviations. They were calculated using Microsoft Excel 2016 software. XL Stat 2016 software was used to perform the student-test. Analysis of variance (ANOVA) was performed to test the effects of different experimental factors on measured responses and Duncan's Multiple Test to classify the various means using

Table 2
Macronutrient content and energy value of complementary flours produced.

Nutrients (g/100g DM)	PSS1	PSS2	PSS3	PSS4	FAO Standard*
Moisture	5.12 ± 0.19^b	5.31 ± 0.55^b	7.24 ± 0.07^a	7.01 ± 0.04^a	5
Ash	7.95 ± 0.36^b	8.85 ± 0.58^{ab}	5.55 ± 0.82^c	9.94 ± 0.64^a	>2
Total sugar	62.97 ± 1.43^a	$60.01 \pm 0{,}89^b$	56.88 ± 0.95^c	54.04 ± 1.01^d	65–68
Soluble sugar	57.42 ± 1.02^a	54.87 ± 1.15^a	44.87 ± 1.15^b	41.66 ± 0.95^c	55
Protein	13.44 ± 0.94^b	14.09 ± 0.85^b	18.24 ± 0.57^a	19.35 ± 0.67^a	13–17
Fat	8.79 ± 0.21^c	8.81 ± 0.34^b	9.82 ± 0.14^a	9.25 ± 0.23^c	7–10
Fiber	7.35 ± 0.51^c	8.53 ± 0.63^b	9.52 ± 0.33^a	7.12 ± 0.45^c	<5
Energy value (kcal/100g)	384.75 ± 11.39^{abc}	375.69 ± 3.90^c	388.86 ± 2.66^a	376.81 ± 2.01^c	400

*Source: [8]; Means in the same line with different superscript letters differ significantly ($P < 0.05$). PSS1: 70 % pumpkin flour; 25 % soybean flour; 5 % spinach leaves. PSS2: 65 % pumpkin flour; 25 % soybean flour; 10 % spinach leaves. PSS3: 65 % pumpkin flour; 30 % soybean flour; 5 % spinach leaves. PSS4: 60 % pumpkin flour; 30 % soybean flour; 10 % spinach leaves.

Statgraphics Centurion XVI.I software. The curves were plotted using the Sigmaplot 12.5 software.

3. Results and discussion

3.1. Proximate composition

Table 2 presents the proximate composition and energy value of complementary flours formulations. The moisture contents of PSS1 and PSS2 were close to 5 %, as recommended by FAO [8]. This is good for the storage of these flours. The storage of food products depends on their water content as it regulates the microorganism and enzyme activities [28]. A low moisture content generally indicates a possible long shelf-life of food flour [29]. A similar result was observed with weaning foods derived from locally obtained ingredients [9,10].

The same trend was observed for ash content with values higher than the recommended 2 % for all the flours produced. High ash content in foods is usually associated with high mineral content [30], thus the ash content of PSS2 (8.85 %) and PSS4 (9.94 %) indicates that are were potentially good sources of minerals, and this could be linked to the high proportion of spinach leaves incorporated in these samples, as many authors reported high minerals content in spinach leaves [19,21].

For macronutrients, PSS1 (70 % pumpkin flour; 25 % soybeans flour; 5 % spinach leaves) and PSS2 (65 % pumpkin flour; 25 % soybeans flour; 10 % spinach leaves) were better than PSS3 (65 % pumpkin flour; 30 % soybeans flour; 5 % spinach leaves) and PSS4 (60 % pumpkin flour; 30 % soybeans flour; 10 % spinach leaves). Soluble sugar content was highest in PSS1 (57.42 ± 1.02 g/100 g DM) and lowest in PSS4 (41.66 ± 0.95 g/100 g DM), and a similar trend was observed with total sugars where PSS1 had the highest value while PSS4 had the lowest content. This result may be linked to the proportion of fermented pumpkin flesh which is an important source of sugar as reported by Tedom et al. [15]. Pumpkin was used in this study as the main source of carbohydrates, and it level was higher in PSS1 (70 %) than in PSS4 blend (60 %). Based on the FAO recommendations for total and soluble sugar, PSS1 and PSS2 had levels that met the recommended values but were lower than those found in other complementary foods [9,10], probably due to the proportion of source of carbohydrates added in the blend, and also to the nature of foodstuffs used. Indeed, maize, sorghum and plantain used in previous studies are richer than pumpkin in carbohydrates (starch).

Protein content was between the standard range recommended by FAO (13–17 g/100 g DM) in PSS1 (13.44 ± 0.94) and PSS2 (14.09 ± 0.85), which was close to protein content reported for a similar study on complementary foods formulation based on soybeans as protein source [9,10,12]. The protein content was higher than the FAO recommended values in PSS3 (18.24 ± 0.57) and PSS4 (19.35 ± 0.67), and this may be justified by the proportion of pretreated soybeans added to each formulation. In PSS3 and PSS4, a proportion of 30 % of soybeans was used in the blended flours, and because it is the main protein source, higher content was observed in these blends. A high protein intake in the diet may be harmful to children because it may eventually lead to chronic kidney failure at later stages in life [31].

For all the complementary flours produced, fat content was within the standard range of 7–10 g/100 g DM, with the highest value for PSS3 (9.82 ± 0.14), which is particularly beneficial for young children with higher energy needs to support growth and development, especially for the brain cells. This energy is obtained mainly from sugars and fat [32]. In addition, fat favours the absorption of fat-soluble vitamins such as vitamin A [33], which is a major nutrient concerned with the micronutrient deficiency in developing countries.

Fiber content was higher than the FAO recommendations in all the flours produced, with values close to 10 g/100 g DM for PSS3. Fiber intake is beneficial for the body, but a high level in the diet could reduce the absorption of provitamin A, either by forming complexes with the latter or by interacting with bile salts to cause an increase in the fecal excretion of fat-soluble vitamins [34].

All the flours produced had energy values that were close to the recommended 400 kcal/100 g with energy values varying from 375.69 ± 3.90 to 388.86 ± 2.66 kcal/100 g.

Based on the requirements in complementary flour formulation, PSS3 and PSS4 were not considered good for complementary foods as they do not meet the requirements for total and soluble sugars. Thus, PSS1 and PSS2 were retained for further studies.

3.2. Micronutrient composition

The carotenoid and some mineral contents of the two flours retained are presented in Table 3. Carotenoid content in PSS1 and PSS2 was about 250 and 232 μg/g respectively, corresponding on average to 20 μg/g of vitamin A for 100 g DM. According to the recommended nutritional intake, from birth to 12 months, an average of 350–400 μg of vitamin A per day is recommended [35]. Thus,

Table 3
Carotenoids (μg/g DM) and minerals content (mg/100 g DM) of produced flours.

Samples	Carotenoids	Iron	Calcium	Phosphorus	Magnesium
PSS1	250.05 ± 2.57^{a}	5.05 ± 0.45^{b}	393.94 ± 1.18^{b}	234.01 ± 0.89^{b}	109.26 ± 2.63^{a}
PSS2	232.01 ± 1.05^{b}	7.25 ± 0.24^{a}	399.76 ± 1.55^{a}	254.63 ± 0.76^{a}	105.18 ± 1.65^{a}
P-value	0.002	0.003	0.001	0.0001	0.149
Standard*	42	≥7	400	250	100

*Source: [8,37]; Values in the same column with different superscript letters differ significantly ($P < 0.05$). PSS1: 70 % pumpkin flour; 25 % soybean flour; 5 % spinach leaves. PSS2: 65 % pumpkin flour; 25 % soybean flour; 10 % spinach leaves.

100 g of complementary flour produced can cover at least five times the vitamin A needs in young children, which is a great benefit, given that vitamin A has a preventive effect on the different causes of diseases involved in the mortality of young children as it impacts the growth and development of cells and boosts the immune system [36]. The high content of carotenoids in the two complementary flours produced may be attributed to the presence of pumpkin. According to several studies, pumpkin flesh is a good source of pro-vitamin A carotenoid, especially β-carotene [13,14] which is not destroyed by fermentation [16].

The mineral content was significantly higher in PSS2 than in PSS1. For all the minerals studied (Table 3), the two flours met the FAO recommendations, except for iron with a content significantly lower than that of the standard for PSS1 (5.05 ± 0.45 mg/100 g DM). The consumption of this PSS1 flour in the long term, if not enriched, could lead to iron deficiency, with consequences such as anemia and weakness of the immune system in young children [38,39]. This result suggests that PSS2 is more suitable for a young child diet than PSS1 for the provision of minerals. The content of all the minerals was in the ranges found by Adepeju et al. [9] on a complementary flour made of fermented maize, sorghum, roasted soybeans, crayfish and date palm fruit.

3.3. Functional properties

Table 4 presents some functional properties of PSS1 and PSS2. There is no significant difference between the WAC, WIS, and BD of the two flours. In food matrices, WSI is complementary to WAC. WSI gives indications on the proportion of material that can be solubilized in a volume of water, while the WAC indicates the capacity of the material to absorb water [40]. Flours PSS1 and PSS2 are good at absorbing water, about 3.5 times more than their weights, which is very much appreciated since the solid-liquid interactions constitute a limiting factor in the use of food powders [41]. This ability to absorb water by these flours is attributed to their richness in the main absorbent components in foods, that is carbohydrates and proteins, [42].

The BD indicates the arrangement of particles, packaging, and settling profile of a material [43]. A BD of 0.6 % obtained for PSS1 and PSS2 indicates good packing, thus high nutrient-dense flours, due to their ability to be concentrated into a small volume [44].

3.4. Pasting properties

The viscosity of PSS1 and PSS2 is presented in Fig. 1. In the first phase (0–300 s), the viscosity of flour increased with temperature, due to the swelling of the starch granules and protein molecules [45]. Like starch, proteins can also form gels. The protein macromolecules soluble in the aqueous dispersant phase can contribute in increasing the viscosity of this phase [46]. This increase in viscosity would be due to the concentration, as well as the presence of hydrophilic amino acids in the protein [47].

During the temperature stabilization phase (300–450 s), cooking continues, cohesive forces inside the granules break and the viscosity of the mass tends to decrease: this is the resistance of cooking and shearing [48]. In the present study, an increase in viscosity during this phase was observed. This would be because the fatty acids (saturated) contained in the flours have formed an amylose-lipid complex responsible for this increase [49]. Similar viscosity profile appearances were obtained on roasted and fermented corn by Agume et al. [22].

The last phase (drop in temperature) shows the behavior during cooling, this is retrogradation [37]. It is linked to the reassociation of amylose molecules, by the formation of hydrogen bonds between hydroxyl groups [50]. During this phase, the final viscosity is obtained and indicates the ability of the flours to form a gel after cooking and cooling.

Table 5 presents the viscosity profiles obtained from complementary flours PSS1 and PSS2. Apart from the peak viscosity (PV), time (Pt), and temperature (PT) of gelatinization, the other parameters are significantly different ($p < 0.005$). The low viscosity values observed could be due to the pretreatments (fermentation, steeping, roasting, and blanching) applied to the foods, which would have caused the hydrolysis of the starch, limiting the increase in viscosity. This can be confirmed through the low gelatinization time and temperature which show that the starch molecules were digested during the pretreatments, especially during fermentation, where *Lactobacillus plantarum* would have produced amylases responsible for the degradation of starch [51]. The final viscosity values of PSS1 and PSS2 were low (173–213 cP), as reported by Agume et al. [22] on roasted and fermented maize flour, indicating that these two flours are suitable for cooking gruels for young children.

3.5. Fluidity and energy density of gruels

Table 6 presents the consistency and energy density of gruels made from PSS1 and PSS2. There was no significant difference (p >

Table 4
Water absorption capacity, solubility index, and bulk density of formulated flours.

Samples	CAE (g H_2O/100 g MS)		WSI (%)	BD (g/mL)
	aWAC (%)	rWAC (%)		
PSS1	341.95 ± 9.54^a	392.9 ± 8.43^a	8.73 ± 0.52^a	0.63 ± 0.08^a
PSS2	322.53 ± 5.86^a	355.06 ± 6.88^a	8.04 ± 0.77^a	0.61 ± 0.04^a
P- value	0.161	0.62	0.444	0.8

Values in the same column with different superscript letters differ significantly ($P < 0.05$); WAC: Water Absorption Capacity; a: apparent; r: real; WSI: Water Solubility Index; BD: Bulk Density. PSS1: 70 % pumpkin flour; 25 % soybean flour; 5 % spinach leaves. PSS2: 65 % pumpkin flour; 25 % soybean flour; 10 % spinach leaves.

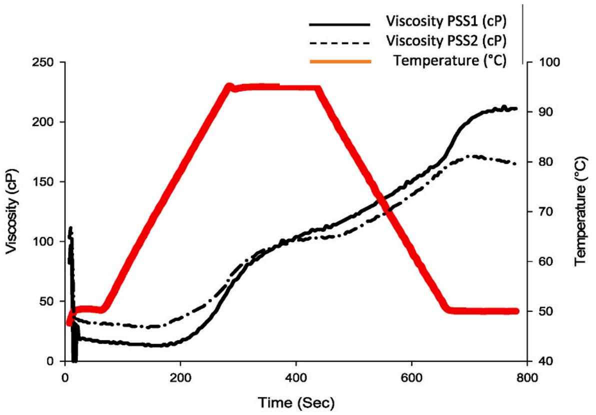

Fig. 1. Pasting properties of formulated complementary flours produced.

Table 5
Parameters of the PSS1 and PSS2 viscosity profiles.

Samples	PV (cP)	BD (cP)	SB (cP)	FV (cP)	PT (°C)	Pt (sec)
PSS1	113.33 ± 5.03^a	1.01 ± 0.09^a	100.33 ± 3.88^a	213.33 ± 4.13^a	75.0 ± 3.0^a	180 ± 2.0^a
PSS2	103.33 ± 4.06^b	0.29 ± 0.05^b	73.33 ± 2.02^b	173.33 ± 2.83^b	72.5 ± 2.5^a	167 ± 2.1^b
P-value	0.023	0.001	0.002	0.000	0.093	0.030

Values in the same column with different superscript letters differ significantly ($P < 0.05$); PV: Peak of viscosity; BD: Breakdown; SB: Setback; FV: Final viscosity; PT: Pasting temperature; Pt: Pasting time; sec: second; cP: Centipois. PSS1: 70 % pumpkin flour; 25 % soybean flour; 5 % spinach leaves. PSS2: 65 % pumpkin flour; 25 % soybean flour; 10 % spinach leaves.

0.05) between the fluidity, dry matter and energy density of the two gruels. With a dry matter varying from 30.1 to 31.1 %, a fluidity ranging from 120 to 121.5 mm/30 s, and an energy density between 120.2 and 124.5 kcal/100 mL, gruels prepared from PSS1 and PSS2 are therefore suitable for young children based on the recommended standards. The energy density obtained for PSS1 and PSS2 was close to the one found by Ngaha et al. [10] in complementary gruels, but lower than the energy density found in complementary puree by the same author [12], and this could be attributed to the high dry matter content in puree compared to gruel.

3.6. Sensory properties of gruels

Although the mothers who constituted the panel had the tendency to choose nutritive complementary food for their children, they highlighted sensory properties, particularly appearance, flavor, texture and aroma of food products as the most important factors that they consider during purchase. It arises from Table 7 that aroma and texture of gruels prepared with both PSS1 (70 % pumpkin flour; 25 % soybean flour; 5 % spinach leaves) and PSS2 (65 % pumpkin flour; 25 % soybean flour; 10 % spinach leaves) were appreciated by the 36 mothers involved in the sensory test, contrary to appearance and flavor which were less appreciated with scores recorded lower than 6 over 9. For all the sensory attributes, there was no significant difference ($p > 0.05$) between the samples PSS1 and PSS2, and they were significantly lower than those of the control gruel prepared from a commercial complementary flour. In addition, the overall acceptability of PSS1 and PSS2 was lower by the one previously recorded for formulated complementary foods made from pumpkin [12] and plantain [10], and this indicates the necessity to improve the organoleptic properties of the formulated flours.

4. Conclusion

Two complementary flours PSS1 (70 % pumpkin flour; 25 % soybean flour; 5 % spinach leaves) and PSS2 (65 % pumpkin flour; 25 % soybean flour; 10 % spinach leaves) suitable to prepare gruels for young children were formulated from pretreated pumpkin pulp,

Table 6
Fluidity, dry matter, and energy density of gruels prepared from flours produced.

Samples	Fluidity (mm/30 s)	Dry matter (g/100gDM)	Energy density (Kcal/100 mL)
PSS1	120.0 ± 0.5^a	31.13 ± 1.57^a	124.52 ± 6.28^a
PSS2	121.5 ± 1.0^a	30.05 ± 1.09^a	120.20 ± 4.36^a
P-value	0.065	0.060	0.060

Values in the same column with different superscript letters differ significantly ($P < 0.05$). PSS1: 70 % pumpkin flour; 25 % soybean flour; 5 % spinach leaves. PSS2: 65 % pumpkin flour; 25 % soybean flour; 10 % spinach leaves.

Table 7
Sensory characteristics of the formulated gruels.

Samples	Appearance	Color	Flavor	Texture	Aroma	Overall Acceptability
PSS1	4.94 ± 0.23^b	5.71 ± 0.29^b	5.03 ± 0.16^b	7.19 ± 0.37^b	6.51 ± 0.13^b	5.96 ± 0.28^b
PSS2	4.96 ± 0.12^b	5.58 ± 0.21^b	5.01 ± 0.28^b	7.03 ± 0.28^b	6.38 ± 0.27^b	5.75 ± 0.19^b
Control*	7.89 ± 0.37^a	8.31 ± 0.23^a	8.74 ± 0.34^a	8.83 ± 0.22^a	8.89 ± 0.35^a	8.53 ± 0.31^a

Values in the same column with different superscript letters differ significantly ($P < 0.05$); PSS1: 70 % pumpkin flour; 25 % soybean flour; 5 % spinach leaves. PSS2: 65 % pumpkin flour; 25 % soybean flour; 10 % spinach leaves. *Commercialized complementary flour.

spinach leaves, and soybeans, with good nutritional and functional properties. This finding represents a contribution to alleviate nutritional problems in developing countries as the food material used is locally available, and the technology used may be transferred to the population. However, the low score recorded in the sensory evaluation of the gruels prepared from these flours, especially appearance, taste, and color attributes, indicates the need for improvement of its organoleptic properties. In addition, PSS1 needs to be fortified with iron to meet the WHO/FAO recommendations.

Ethics and consent

Many of our previous studies have focused on food materials already known and consumed by the participants. These studies have always been conducted without any concerns after the verbal informed consent was obtained from the panelists, and the results have been published. The authors did not find the need to go for written consent for this present study which was conducted according to the guidelines laid down in the Declaration of Helsinki. As the food materials used in the study were already known and consumed by the participants, a verbal informed consent was obtained from them for the sensory evaluation. Verbal consent was 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 formulation.

Data availability

Data associated with this study have not been deposited into a publicly available repository. included in the article.

CRediT authorship contribution statement

William Tedom Dzusuo: Writing – original draft, Methodology, Formal analysis. **Aurelie Solange Agume Ntso:** Writing – original draft, Data curation. **Wilfred Ngaha Damndja:** Writing – review & editing. **Richard Ejoh Aba:** Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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