Research Article

DOI: 10.22146/ifnp.87952 https://journal.ugm.ac.id/ifnp
ISSN 2597-9388

Complementary Potentials of the Flour Blends Formulated From Sprouted Soybean (*Glycine max*), Sprouted Sorghum (*Sorghum bicolor*), and Unripe Plantain (*Musa paradisiaca*) Flour Intended for Infant Feeding

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Submitted: August 13th, 2023; Revised: August 25th, 2024; March 15th, 2025; May 29th, 2025; July 12th, 2025; Accepted: July 31st, 2025; Published: November 21st, 2025

ABSTRACT: High cost, as well as scarcity of commercial complementary foods, have long prevented the rural nursing mothers, especially those from developing countries, from readily accessing them. Consequently, the malnourished children become weaker and sicker, which calls for an option. Complementary formulation using readily available home-grown staples becomes the preferred option. In line with this, various locally formulated complementary foods have emerged from flour blends of cereals, legumes, and plantain, among others. Hence, this study is on the sprouted legume and cereal flour blends. The blends were investigated for proximate, vitamin, mineral, and functional properties with already established methods, while sensory properties were subjectively conducted on the hot water reconstituted blends using 25 semi-trained panelists. The results of proximate composition revealed that moisture, dry matter, protein, fiber, fat, ash, carbohydrate, and energy ranged respectively from 5.27-5.84%, 94.16-94.73%, 14.12-39.23%, 13.75-23.41%, 3.94-5.22%, 2.85-4.72%, 22.18-54.60% and 292.62-335.34 Kcal. Vitamins A, B1, B2, B3, and C, respectively, ranged from 682-930 µg/100g, 0.24-0.76 mg/100g, 0.16-0.27 mg/100g, 3.51-7.81 mg/100g, and 28.83-49.61 mg/100g. Calcium, magnesium, potassium, phosphorus, and iron, respectively, ranged from 18.08-32.12, 129.55-189.96, 450.53-796, 304.15-520.72, and 1.82-2.42 mg/100. Water absorption capacity, oil absorption capacity, bulk density, foam capacity, foam stability, wettability, gelatinization temperature and emulsion capacity respectively ranged from 1.53-2.30 g/g, 1.84-2.31 g/g, 0.69-0.74 g/ml, 24.42-31.15%, 38.81-72.50%, 49.92-82.12 sec, 61-68 °C, and 58.15-70.17%. A sample blend of 40:30:30, respectively, for soybean, sorghum, and plantain flours was liked very much, while 30:40:30 were liked moderately. The complementary blends were nutrient-dense, highly acceptable, and therefore gold mine for complementary food production.

Keywords: complementary food; sprouted soybean; sprouted sorghum; unripe plantain flours

INTRODUCTION

Complementary foods (CFs) are nutritional companions of breast-or formula-fed infants and young children from six months to up to two years. They are non-breast milk, nutritive, additional, readily consumed, and digested foods given as part of their diets during transition to an adult diet. The CFs provide additional nutrition to meet the extra needs of growing children during their vulnerable time and reduce the high risk of malnutrition and illnesses (Okwunodulu *et al.*, 2020). The CF could be in the form of solid, semi-solid, or liquid foods prepared specially or modified family meals (Iwe, 2010a; Okwunodulu & Okwunodulu, 2016).

According to the World Health Organization (WHO) recommendation, CFs are introduced as the best start transitional food from immediately after exclusive breastfeeding till up to two years of age to adult food. This range of period is very vulnerable (Okwunodulu *et al.*, 2019a) as after exclusive breastfeeding, the contribution of human milk can no longer meet the nutritional and energy needs of the growing infants. It therefore becomes mandatory for introduction of the appropriate and adequate CF. Despite this, such factors as infants' age, existing taboos, and the vocation of the mother or caregiver have determined when to introduce complementary foods for some mothers.

In most developing countries, the use of cereal, legumes, vegetables, and animal products to prepare complementary food for infants and children has been recommended (Okwunodulu *et al.*, 2020). Cereal proteins lack lysine and tryptophan but have an adequate amount of amino acids. Cereals are relatively cheap, generally, with enough sulphur-containing amino acids like methionine and cysteine. On the other hand, legumes are richer in protein (19–26%) and fat (40–46%), but moderate in tryptophan and thiamine. It is, however, evident that cereal and legumes are low in trace minerals and vitamins (Okwunodulu *et al*., 2024). Proteins from animal sources, like meat, fish, eggs, milk, yoghurt, among others, have higher biological value than those from plants such as legumes, grains, nuts, seeds, and vegetables.

Soybean (*Glycine max*) is a protein-rich legume valued for its oil and is also relatively high in dietary fiber, vitamins, and minerals such as calcium and magnesium. The carbohydrate content is relatively low. The oil is predominantly polyunsaturated fatty acids, while the protein contains all the essential amino acids. Various CFs have been formulated using soybeans of different varieties (Okwunodulu *et al.,* 2019b). Sprouting of soybeans involves steeping and controlling germination to improve the nutritional values (Okwunodulu *et al*., 2019b) while reducing the fat, anti-nutrients, and carbohydrate content of the sprouts and any products enriched with it compared to the unsprouted counterpart.

Like other cereals, sorghum protein is limited in such amino acids as threonine, tryptophan, and methionine. It is particularly rich in niacin. Amylopectin content of normal and waxy varieties of sorghum starch varied to a large extent. The starch content of normal sorghum contains about 21% amylose and can gel and retrograde, while that of waxy sorghum starch contains 1-2% amylose with higher amylopectin and cannot gel or retrograde (Cornejo-Ramírez *et al*., 2018). Sorghum contains some anti-nutrients like phytate, lectins, tannins, protease inhibitors, and calcium oxalate, which can be eliminated by steeping overnight, sprouting, boiling, and fermentation. Sprouted sorghum flour contains higher nutrients, lower fat, carbohydrate, and anti-nutrients compared to unsprouted counterparts.

Plantain (*Musa paradisiaca*) is endowed with some desirable nutrients like starch, minerals (iron, potassium, magnesium, phosphate), dietary fibre, and vitamins (A, C, B_6, folate, niacin, riboflavin, and thiamine). It is desired due to its numerous health benefits resulting from low cholesterol and fat (Okwunodulu *et al*., 2019a). Besides, plantain contains very low sugar due to the storage of its carbohydrate as a complex starch, resulting in slow release during cooking. This, therefore, predisposed it as good food for the diabetic. Therefore, utilization of ripe and unripe plantain flours as home-grown staples in the formulation of various CFs (Okwunodulu *et al.,* 2019a; Okwunodulu *et al*., 2020) becomes appropriate to make readily available otherwise scarce and expensive CFs for the rural nursing mothers to meet the nutritional requirements of their infants.

A combination of sprouted soybean and sorghum will result in legume-cereal nutrient improvement, complementation, and supplementation. The addition of unripe plantain is another nutrient enrichment to meet the nutrient-complementary requirement. Furthermore, this combination will help alleviate protein-energy malnutrition, which is more prevalent in developing countries as a result of the consumption of mostly starchy foods with little or no nutrient content (Okwunodulu *et al*., 2024). This study evaluated the potential of CF formulated from sprouted soybean, sorghum plus and unripe plantain flour blends.

MATERIALS AND METHODS

Material sourcing

Soybeans, sorghum, and plantain fingers were procured from Ubani's main market in Umuahia, a North Local Government Area of Abia State, Nigeria.

Material preparation

Sprouted soybean flour

The modified protocol described by Okwunodulu *et al*. (2017) was employed. Soybean seeds were carefully sorted to remove immature seeds, stones, and other extraneous contaminants. The cleaned soybeans were washed with tap water and steeped (12 h) in a stainless steel basin. The water was drained after, and the steeped soybean seeds were evenly sprayed on a jute bag on the floor, covered with black polyethylene, and left to sprout. During sprouting, the seeds were constantly sprayed with water as soon as their surface dried until after 72 h. The sprouts were washed several times to remove fermented odour, boiled in 0.5% sodium bicarbonate solution for 20 min, drained, allowed to cool, and hand-dehulled. The hulls were removed by water flotation, and the cotyledons obtained were oven dried (65 °C) to constant weight, allowed to cool, milled, and sieved (355 µm) to obtain sprouted soybean flour that was stored in an air-tight container for use in formulation.

Sprouted sorghum flour

The same process was repeated here except that the sprouts were not dehulled or boiled but washed to reduce odour and some shoots before oven drying, milling, and sieving to obtain sprouted sorghum flour (355 µm). The remaining shoots were removed by hand-squeezing and winnowing after oven drying, before milling.

Table 1. Blending ratios of sprouted soybeans, sprouted sorghum, and unripe plantain flours

Samples	Soybean	Sorghum	Plantain
401	100	0	0
402	0	100	0
403	0	0	100
404	40	30	0
405	30	40	30
406	30	30	40

Where 401= 100% soybean, 402 = 100% sorghum, 403 = 100% plantain, 404= 40% soybean + 30% sorghum + 30% plantain, 405= 30% soybean + 40% sorghum + 30% plantain, and 406= 30% soybean + 30% sorghum +40% plantain.

Unripe plantain flour

Sorted unripe plantain fingers were peeled with a stainless steel knife individually and cut into small pieces. The slices were blanched at 100 °C for 5 min and oven-dried as above. The dried plantain slices were thereafter milled and sieved (355 µm) to obtain fine flour, which was stored in an air-tight container for use in formulation.

Blending of the flours

The elaborated and stored sprouted soybean and sorghum as well as unripe plantain flours were blended (Table 1), stored in airtight containers, marked, and kept for analysis.

Proximate composition

Moisture content (MC) was evaluated using the gravimetric protocol described by Onwuka (2018), and dry matter was determined by subtracting the respective MC from 100%. Ash was determined by the furnace incineration method of Pearson (1976). Fat was determined by the Soxhlet solvent extraction method of AOAC (2010), crude fibre was evaluated by the protocol of James (1995), protein was evaluated with the Kjeldahl protocol of Change (2003), and carbohydrate was determined by subtracting the total values of all the other proximate compositions from 100%.

Vitamin

The procedure described by Kirk and Sawyer (1998) was used to analyse vitamins A and C, riboflavin, niacin, and thiamine by the respective calorimetric, spectrophotometric, and dichromate colorimetric methods of Okwu and Ndu (2006).

Mineral

Calcium and magnesium were evaluated using the complexometric titrimetry protocol. The flame photometry procedure described by James (1995) was used to analyse sodium and potassium, while phosphorus was evaluated by dry ashing using James (1995) methods. Iron was analysed using the orthophenanthroline procedure of AOAC (2010).

Functional properties

The analytical procedures described by Onwuka (2018) were used to analyse the following functional properties of the flour blends: bulk density, water/oil absorption capacity, foam capacity, foam stability, wettability, emulsion capacity, and gelation temperature.

Sensory analysis

Each sample was reconstituted by mixing (1:2) the flour blend and hot water (100 °C) to obtain the desired consistency. The reconstituted blends were allowed to cool before the sensory analysis. Their sensory properties were subjectively evaluated with the procedures described by Iwe (2010b). Exactly 25 semi-trained panellists comprising both male and female students (17-25 y) drawn from the Department of Food Science and Technology, Michael Okpara University of Agriculture, aged between. They were presented each in a separate cabinet with the coded samples in similar plates along with a bottle of water, in a well-lighted room. They were instructed to rinse their mouths after tasting each sample and score their appearance, taste, flavour, and general acceptability according to a 9-point Hedonic scale. Where 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely.

Analysis of data

All the mean data obtained from all the triplicate analyses were subjected to one-way analysis of variance (ANOVA) of a completely randomized design (CRD) with SPSS version 20. Treatment means were separated using Duncan Multiple Range Test (DMRT) at 95% confidence level (P<0.05).

Table 2. Proximate composition of the flours and their complementary blends (%)

Samples	Moisture	Dry Matter	Protein	Crude fibre	Fat	Ash	CHO %	Energy Value (Kcal/100g)
401	3.02±0.04^{e}	94.56±0.04^{b}	31.03±0.01^{d}	13.03±0.01^{d}	5.47±0.01^{a}	2.35± 0.01^{f}	43.56±0.05^{e}	347.87±0.21^{b}
402	5.44±0.04^{c}	96.98±0.04^{b}	9.09±0.01^{e}	2.82±0.02^{f}	2.12± 0.02^{e}	2.63±0.01^{e}	83.15±0.00^{a}	373.44±0.38^{a}
403	1.77±0.01^{f}	98.23±0.01^{a}	3.08±0.0^{ef}	9.33±0.01^{e}	0.29± 0.01^{f}	2.80±0.01^{d}	79.50±0.04^{b}	347.53±0.01^{c}
404	5.84±0.02^{a}	94.16±0.02^{f}	39.23±0.01^{a}	23.41±0.01^{a}	5.22± 0.02^{b}	2.85±0.01^{d}	22.18±0.02^{f}	292.62±0.22^{f}
405	6.62±0.02^{b}	94.38±0.02^{e}	20.37±0.01^{c}	13.75±0.01^{c}	3.94±0.01^{d}	3.72±0.02^{b}	54.60±0.05^{c}	335.34±0.07^{d}
406	5.27±0.04^{d}	94.37±0.04^{c}	14.12±0.02^{d}	20.11±0.05^{b}	4.42±0.01^{c}	4.72±0.02^{a}	53.60±0.05^{c}	309.20±0.09^{c}

The values represent triplicate analytical determinations with mean separations. Those values with different superscript in the column are significantly different (P<0.05) Samples 401= 100% sprouted soybean flour, 402 = 100% sprouted sorghum flour, 403 = 100% plantain flour, 404 = 40% sprouted soybean flour + 30% sprouted sorghum flour + 30% plantain flour, 405 = 30% sprouted soybean flour + 40% sprouted sorghum flour + 30% plantain flour and 406 = 30% sprouted soybean flour + 30% sprouted sorghum flour + 40% plantain flour. CHO-carbohydrate

RESULTS AND DISCUSSION

Proximate composition

Moisture content (MC)

Table 2 presents the proximate results, which captured the highest (P<0.05) MC (6.62%) of sample 405 (30% sprouted soybean + 40% sprouted sorghum + 30% plantain) than the rest, while sample 406 (30% sprouted soybean + 30% sprouted sorghum + 40% plantain) had the least value (5.27%). With this, it becomes apparent that sorghum had a positive linear relationship with MC, while plantain had a negative one in the formulation. The variation could be associated with higher sprouted sorghum MC, which is traceable to its higher carbohydrate content and water imbibition during steeping. The MC decrease with plantain inclusion could be traced to the low MC of the unripe plantain (1.77%), which MC increases with ripening. Values obtained in this study (5.27-5.84%) were within 4.50-6.43% reported by Okwunodulu *et al*. (2020) from their complementary blends of sprouted soybean, breadfruit, and plantain flour blends and Cerelac (5.12%) as a control. The slight variations could be due to the inclusion of breadfruit. Higher MC (11.5-16.51%) compared to those obtained in this study reported by Ojinnaka *et al*. (2013) for infant CF from soybean and cocoyam starch flour blends could be attributed to the inclusion of cocoyam, which contains predominantly water and starch (Arukwe & Onugha, 2020). Low MC is desired in this formulation as it will increase the water absorption, swell more when reconstituted, and liable to extend the shelf stability compared to samples with higher MC.

Dry matter (DM)

The DM is an indication of organic matter content (excluding MC), which is a measure of nutrient content of the blends. This study revealed that DM had a linear increase (P<0.05) with unripe plantain flour and an inverse correlation with sprouted soybean flour. The increased DM could be due to higher DM (98.23%) content from unripe plantain flour, while the least (94.56%) DM of sprouted soybean flour may be the major contributor to the DM decreasing trend. Unripped plantain flour may have contained more of insoluble fibre, unlike sprouted soybean flour, and may not be ideal for young infants. The increased DM in this study is highly appreciated as it connotes an increase in nutrients, mostly minerals from unripe plantain that are essential for the growing infants. The general high DM from this study could be traced to the ingredients used and their low MC, which has an inverse correlation with DM in any food formulation. High DM is a measure of the nutrient content of foods, including CFs.

Protein

Protein is needed for adequate growth, development, as well as human body tissue repair, including that of infants. It is also part of human blood, organs, skin, and glands (SFGATE, 2017). The significant (P<0.05) protein content improvement due to an increase in sprouted soybean flour inclusion is nutrient security and therefore encouraging, while the decrease due to an increase in unripe plantain flour inclusion is not in this regard. These discrepancies may be explained by the respective highest and lowest protein values from sprouted soybean (31.10%) and unripe plantain flour (3.08%). Similar results had been reported by Okwunodulu *et al*. (2020) on the legumes and cereal-based complementary blends of sprouted soybean, breadfruit, and plantain to improve the protein content. The results of their protein contents (10.05-15.13%) were within the range obtained in this study. The slight variations could be pinned to the inclusion of breadfruit. The entire protein values of the blends from this study actually met the >15% recommendation for infant CFs (FAO/WHO, 1991) except sample 406 with 40% plantain, which was marginally lower as a result of low unripe plantain flour protein value (3.08%). This notwithstanding, the entire blended samples were excellent protein sources with respect to the recommended daily intake (RDI) of 9.1g/d (Byid-Bredbenner *et al*., 2013).

Crude fibre (CF)

This is an indigestible carbohydrate absent in breast milk and therefore not needed by exclusive breastfeeding infants except those aged 6 to 12 months who require 5 g per day (FAO/WHO, 1991). The CF was encouraged by the use of whole-grain cereal and legumes in this work. The linear CF increase ($P<0.05$) as sprouted soybean flour increases in the formulation is acceptable despite the reduction by the sprouted sorghum flour. The increase attested to the literature assertion that soybean is a rich source of fibre. Besides, sprouting may have contributed to the increase as well. The decrease due to sprouted sorghum flour may be due to the variety and proportions of amylase and amylopectin composition of the carbohydrate content. The results confirmed that legumes and whole grains are good sources of fibre. The CF values obtained in this study (13.75-23.41) were higher than 5.02-10.62% as advanced by Okwunodulu *et al*. (2020) from their complementary formulations of sprouted soybean, breadfruit, and unripe plantain. The higher CF levels in this study than (<5%) recommended by (FAO/WHO, 1991) are an attestation to the complementary potentials of this study, with sprouted soybean being the major contributor in this regard, which may have contained soluble fibre.

Fat

The fat content improved significantly ($P<0.05$) as the proportion of sprouted soybean increased in the blend, unlike with unripe plantain flour. This improvement can be attributed to the higher value of sprouted soybean oil (5.47%), which aligns with reports indicating that soybean is an oil-rich legume. Similarly, the decrease could be due to the lowest oil value of plantain (0.29%). A similar result trend for plantain was recorded by Okwunodulu *et al*. (2020) from their CF formulations using sprouted soybean, breadfruit, and plantain flour blends, probably due to the low fat content of unripe plantain (Okwunodulu *et al*., 2019a). This improvement notwithstanding, the fat values from the blends were lower than the recommendation (10-25%) for CFs by FAO/WHO (1991), probably due to soybean oil reduction by sprouting. However, consumption of these complementary blends along with other fatty foods may likely meet the recommendation. Lower fat content in turn may lower the calorific value, flavor, lipid nutrients, acceptability, and ease of swallowing, among others, in foods (Okwunodulu *et al*., 2020). The fat content range (3.94-5.22%) of this study was within the range (2.58-6.60%) reported by Okwunodulu *et al*. (2020). The fat improvement will contribute to meeting the energy needs of active infants.

Ash

Ash content depicts the mineral level of any food, which has some biochemical functions in the human body (Okwunodulu *et al*., 2022a). The ash content of this work increased ($P<0.05$) as the unripe plantain flour inclusion levels increased. However, the decrease observed may be pinned to the increase in sprouted soybean addition in the blending. The variations may be associated with a higher ($P<0.05$) plantain ash value (2.80%), while the lowest value stems from the sprouted soybean (2.35%). The ash values of this study (2.85-4.72%) were superior compared to 2.25-2.80% reported by Okwunodulu *et al*. (2020) from their complementary formulations, and Cerelac (2.68%) as a control. The variations could be due to unripe plantain levels included in the blends. However, only samples 405 (30% sprouted soybean + 40% sprouted sorghum + 30%plantain) and 406 (30% sprouted soybean + 30% sprouted sorghum + 40%plantain) met the ash value recommendation of (<3) by FAO/WHO (1991) while 404 (40% sprouted soybean + 30% sprouted sorghum + 30% plantain) was lower.

Carbohydrate

The carbohydrate values from the blends increased ($P<0.05$) as the sprouted sorghum flour increased in the formulations, but correlated negatively with the increase in sprouted soybean. Higher carbohydrate content of sprouted sorghum (83.15%) and the lowest value of sprouted soybean flours (43.56%) justified the variations. The carbohydrate levels obtained in this study (22.18-54.60%) were lower than 70.27-74.60% advanced by Okwunodulu *et al*. (2020), perhaps due to lower carbohydrate content from the blending materials (22.18-83.15%) resulting from low carbohydrate content of unripe plantain and sprouting of soybean and sorghum. As carbohydrate is a major energy component of foods, the blends could likely have lower energy content due to their low carbohydrate levels.

Energy

The calculated energy contents of the formulated CFs had a significant (P<0.05) positive linear correlation with the increasing sprouted sorghum flour levels, but decreased as the blending levels of soybean flour increased. Higher carbohydrate content of the sprouted sorghum flour than sprouted soybean may have made the energy variation as carbohydrate is a major energy substrate (Okwunodulu *et al*., 2018). This could be justified by the higher energy content of sprouted sorghum flour (373.44 Kcal/100g) compared to the lower value of sprouted soybean flour (347.87 Kcal/100g). The values obtained (292.62-335.34 Kcal/100g) were lower than 397 Kcal/100g for Cerelac and 313-387.20 Kcal/100g for CF (Okwunodulu *et al*., 2020). Compared to the RDA energy range (200 to 550 Kcal per day) recommended by WHO (2002) for infants aged 6 to 23 months, all the complementary blends were good energy sources, therefore, they will meet the energy demand of active infants. The high energy levels of the complementary blends analogised with the recommendation of feeding infants with energy-dense and adequate protein foods by the FAO/WHO (1985) to meet their energy needs and other essential nutrients, taking into consideration their stomach capacity of 200 ml (Okwunodulu *et al*., 2018).

Vitamin content of the flours and their complementary blends

Vitamin A

Table 3, which presented the entire vitamin contents of the samples, established an enhancement (P<0.05) of vitamin A content as the sprouted sorghum flour increased in formulations. Conversely, the increase in sprouted soybean flour in the formulations decreased vitamin A. Probably, the highest (712 µg/100g) vitamin A content of sprouted sorghum flour must have aided the increase, while the lowest value of sprouted soybean flour may be responsible for the decrease. The entire vitamin A values obtained were higher than 22.15-62.90 µg/100g reported by Okwunodulu *et al*. (2019a) for complementary blends of cocoyam, sprouted soybean, and firm ripe plantain. The variations could be a result of the blending of materials and the ripening of plantain. Plantain is a good source of vitamin A and liable to easily meet the infants and young children (6 months to 2 years) RDI of 500 µg/d by Duyff (2006). Vitamin A is vital in infant diets since the deficiency is a serious global health concern. In infants, it helps to maintain soft tissues, white blood cells, the immune system, and boosts vision (Ndife *et al*., 2019).

Vitamin B1, B2, and B3

Vitamins B_1, B_2, and B_3 are part of the eight vitamins that comprise the B-complex family. They improved as the sprouted sorghum flour increased in the blends, except for vitamin B_2, which improved with the increase of unripe plantain. Vitamin B_2 decreased as sprouted sorghum flour increased in the formulation, while B3 decreased as unripe plantain flour increased. These implied that the blending samples contained different proportions of the B-complex vitamins. Their improvements were desired as B-complex vitamins boost the immune system, aid in brain, nerve, muscle, and heart function (Everyday Health, 2018), which are needed by infants. The blends are sources of the B-complex, liable to meet their respective RDI of 1.4 µg, 1.6 µg, and 18 µg (Lennetch, 2018).

Vitamin C

The increase of sprouted soybean flour proportion in the blends improved their vitamin C content significantly (P<0.05), unlike unripe plantain flour, which decreased

Table 3. Vitamin content of the flours and their complementary blends

Samples	A (µg/100g)	B1 (mg/100g)	B2 (mg/100g)	B3 (mg/100g)	C (mg/100g)
401	432 ± 0.02^{f}	0.14 ± 0.00^{e}	0.10 ± 0.01^{e}	2.41 ± 0.01^{e}	32.52 ±0.02^{c}
402	712 ± 0.01^{c}	0.26 ± 0.01^{d}	0.05 ± 0.00^{f}	5.17 ± 0.01^{b}	11.45 ± 0.02^{e}
403	511 ± 0.01^{e}	0.10 ± 0.00^{e}	0.17 ± 0.00^{c}	1.92 ± 0.00^{f}	7.29 ± 0.01^{f}
404	682 ± 0.00^{d}	0.24 ± 0.01^{a}	0.24 ± 0.00^{a}	4.12 ± 0.01^{c}	49.61± 0.01^{a}
405	930 ± 0.00^{a}	0.76 ± 0.02^{a}	0.16 ± 0.01^{c}	7.81 ± 0.01^{a}	37.52 ± 0.02^{b}
406	720 ± 0.00^{b}	0.31 ± 0.01^{c}	0.27 ± 0.00^{a}	3.31 ± 0.01^{d}	28.83 ± 0.02^{d}

The values represent triplicate analytical determinations with mean separations. Those values with different superscript in the column are significantly different (P<0.05) Samples 401= 100% sprouted soybean flour, 402 = 100% sprouted sorghum flour, 403 = 100% plantain flour, 404= 40% sprouted soybean flour + 30% sprouted sorghum flour + 30% plantain flour, 405= 30% sprouted soybean flour + 40% sprouted sorghum flour + 30%plantain flour and 406= 30% sprouted soybean flour + 30% sprouted sorghum flour + 40% plantain flour.

the vitamin C content. The improvement could be due to the higher vitamin C value of sprouted soybean flour (32.52 mg/100g), while the decrease may come from the lowest value of unripe plantain flour (7.29 mg/100g). The entire complementary blends were excellent vitamin C sources compared to either of the blending materials, since most of them met the RDI of 30-35 mg/serving for infants, considering infants' stomach capacity of 200 ml. Therefore, the blends proved their complementary potentials in this regard. It has been reported that vitamin C improves the nutritional quality, enhances nutrient absorption, and prevents nutritional disorders. It also stabilizes food products and improves the aesthetic appeal among others (Okwunodulu *et al*., 2019a).

Mineral composition of the flours and their complementary blends

Calcium

Calcium (Table 4) improved (P<0.05) as the sprouted sorghum flour inclusion levels increased. However, it decreased as the inclusion levels of unripe plantain flour increased in the formulation, probably due to the higher value of sprouted sorghum flour (20.50 mg/100g) and the lowest value of plantain flour (1.21 mg/100g). Furthermore, sprouting may have hydrolyzed some anti-nutrients that bound the minerals in the sprouted sorghum flour, thereby increasing the calcium content, while that of unripe plantain flour was still bound. None of the blends is a good source of calcium, considering the RDI of 270 – 600 mg/day for infants within the aged bracket of 7 to 12 months (WhereinCity, 2009). This notwithstanding, the calcium content of other diets could help to make up the RDI since this CF is not an exclusive diet for infants. Calcium is inevitable in CF formulations because of its healthy development in babies' bones, teeth, muscles, and heart growth. Also, calcium helps in nutrient flow across the cell wall (WhereinCity, 2009).

Magnesium

Sprouted sorghum flour also proved to be the major magnesium source in the blend as its increase improved significantly (P<0.05) the magnesium content, while unripe plantain flour increased and decreased it. Higher magnesium value of sprouted sorghum flour (168.42 mg/100g) and the lowest value of unripe plantain flour (60.16 mg/100g) may be responsible. All the complementary blends were good magnesium sources, as each consumption of 200 g per day will meet the RDI of 310 to 420 mg/day (Wyn, 2004) for infants. Magnesium improvement is encouraged for infants as it is vital for antioxidant and enzyme functions. Magnesium is endowed with some health benefits for infants, like supporting healthy bone, nerves, and immune system development, and in the formation and utilization of ATP for energy production (Wyn, 2004; Axe, 2018).

Potassium

The highest value of sprouted sorghum flour (510.05 mg/100g) proved to be the major source of potassium improvement (P<0.05) in the entire complementary blends because of its positive linear relationship with potassium content in the entire blends. Conversely, sprouted soybean flour with the least potassium content of 280.12 mg/100g decreased the potassium content of the blends. The entire blend was not a good potassium source compared to the potassium RDI of 3500 mg/d (LENNTECH, 2018) per serving. Higher levels of potassium in the entire samples proved the most abundant element compared to other minerals, which is

Table 4. Mineral profiles of the individual flours and their blends (mg/100g)

Samples	Calcium	Magnesium	Potassium	Phosphorus	Iron
401	10.12±0.02^{e}	121.59±0.01^{e}	280.12±0.01^{f}	242.09±0.01^{e}	1.06±0.02^{f}
402	20.05±0.01^{c}	168.42±0.01^{b}	510.04±0.02^{c}	402.14±0.03^{c}	2.06±0.04^{d}
403	1.21±0.0^{f}	60.16±0.02^{f}	430.19±0.01^{e}	104.08±0.02^{f}	4.92±0.01^{a}
404	24.64±0.02^{b}	147.61±0.01^{c}	450.53±0.01^{d}	411.11±0.01^{b}	1.82±0.01^{e}
405	32.12±0.02^{a}	189.96±0.02^{a}	796.90±0.00^{a}	520.72±0.02^{a}	2.42±0.02^{c}
406	18.08±0.02^{d}	129.55±0.02^{d}	606.78±0.01^{b}	304.15±0.02^{d}	3.86±0.01^{b}

The values represent triplicate analytical determinations with mean separations. Values with different superscript in the same column are significantly different (P<0.05) Samples 401= 100% sprouted soybean flour, 402 = 100% sprouted sorghum flour, 403 = 100% plantain flour, 404 = 40% sprouted soybean flour + 30% sprouted sorghum flour + 30% plantain flour, 405 = 30% sprouted soybean flour + 40% sprouted sorghum flour + 30% plantain flour and 406 = 30% sprouted soybean flour + 30% sprouted sorghum flour + 40% plantain flour.

encouraging due to its associated health benefits like enhancement of muscle strength and metabolism, regulation of body fluid balance, transmission of nerve impulses, muscle contraction, and proper metabolism (OrganicFact, 2018). Therefore, the improvement is good for infants' development.

Phosphorous

Sprouted sorghum flour with the highest phosphorous value (402.14 mg/100g) proved to be responsible for the significant (P<0.05) phosphorous major increase in the blends. Conversely, plantain flour with the least phosphorous content (104.08 mg/100g) decreased the same in the blends. All the blends are good phosphorous sources considering the RDI of 700 mg/d (Healthline, 2018), as they can easily meet the above infant RDI. Phosphorous works together with calcium in certain ratios for the hardness of the bones and teeth. With high calcium: phosphorous ratios of 1:16-1:17, the blends will improve infant bone structure, normal physiological functions, and may likely prevent rickets in children. Phosphorous is needed for energy transformation, cell division, essential for brain and nerve metabolism, body fluids buffer components, and ATP component (Okwunodulu *et al*., 2022b).

Iron

The iron values of the entire complementary blends were significantly (P<0.05) improved as the levels of unripe plantain flour in the formulation increased. A similar increase had been acknowledged in the complementary blends of sprouted soybean, breadfruit, and plantain flour (Okwunodulu *et al*., 2020). Plantain flour is rich in iron, as justified by its highest value (4.92 mg/100g) in this study. Conversely, iron content decreased as the sprouted soybean flour increased, with the lowest value (1.06 mg/100g). Only samples 405 and 406 were better iron sources as they could easily meet the infants' RDI of 11 mg/d (ODS, 2007) between the age range of 6 months to 2 years. Iron produces red blood cells through synergy with protein and copper, which is responsible for transporting oxygen from the lungs to all the tissues. In the tissues, the oxygen is used to maintain all the body's life functions, such as cell division and body growth and development (Okwunodulu *et al*., 2019a).

Functional properties of sprouted soybean and sorghum, and unripe plantain flours with their blends

Water absorption capacity (WAC)

The WAC is the ease with which flour particles could absorb moisture in the presence of a limited water supply. This, therefore, translates to the actual quantity of water per gram of the flour sample that it can absorb (Boye *et al*., 2011). The results (Table 5) revealed the positive linear relationship of WAC with an increase in unripe plantain flour levels in the blends, as opposed to the decrease due to the increase in sprouted sorghum flour. This may translate to higher water absorption per gram of sample 406 (30% sprouted soybean flour + 30% sprouted sorghum flour + 40% plantain flour) than 405 (30% sprouted soybean flour + 40% sprouted sorghum flour +

Table 5. Functional properties of the individual flours and their blends

Sample	WAC (g/g)	OAC (g/g)	BD (g/ml)	FC (%)	FS (%)	Wettability (sec)	GT (°C)	EC (%)
401	1.60±0.00^{d}	1.70±0.00^{e}	0.63±0.01^{d}	23.18±0.01^{d}	78.22±0.02^{a}	44.60±0.00^{d}	60.00±.00^{e}	42.53±0.01^{f}
402	1.41±0.01^{f}	1.98±0.00^{c}	0.66±0.01^{d}	22.11±0.01^{e}	40.12±0.02^{e}	37.13±0.01^{f}	54.00±.00^{f}	60.12±0.01^{c}
403	2.42±0.00^{a}	1.31±0.01^{f}	0.57±0.01^{f}	18.05±0.01^{f}	53.25±0.02^{c}	41.12±0.02^{c}	65.00±.00^{c}	53.18±0.01^{d}
404	1.80±0.00^{c}	2.01±0.01^{b}	0.73±0.00^{a}	31.15±0.01^{a}	72.50±0.01^{b}	82.12±0.02^{a}	68.00±.00^{b}	58.15±0.01^{e}
405	1.53±0.00^{e}	2.31±0.01^{a}	0.74±0.00^{a}	24.42±0.01^{c}	38.81±0.01^{f}	49.92±0.01^{c}	61.00±.00^{d}	70.17±0.00^{a}
406	2.30±0.00^{b}	1.84±0.00^{d}	0.69±0.00^{b}	26.61±0.01^{b}	50.22±0.01^{d}	61.42±0.02^{b}	72.00±.00^{a}	61.43±0.01^{b}

The values represent triplicate analytical determinations with mean separations. Those values with different superscript in the same column are significantly different (P<0.05). Samples 401= 100% Sprouted soybean flour, 402= 100% Sprouted sorghum flour, 403 = 100% plantain flour, 404 = 40% sprouted soybean flour + 30% sprouted sorghum flour + 30% plantain flour, 405=30% sprouted soybean flour + 40% sprouted sorghum flour + 30% plantain flour and 406= 30% sprouted soybean flour + 30% sprouted sorghum flour + 40% plantain flour. WAC is water absorption capacity; OAC is oil absorption capacity, BD is bulk density, FC is foam capacity, FS is foam stability, GT is gelatinization temperature, and EC is emulsion capacity.

30% plantain flour) and may likely hold more water. The increase could be traced to a higher value of unripe plantain flour WAC (2.42 g/g), while the decrease may result from the lowest WAC value from the sprouted sorghum flour (1.41 g/g). Depending on the rate, high WAC may be encouraged as it may result in better texture, smooth mouth feel, and easier swallowing for the babies. Besides, variations in their polar amino acids could be responsible for their WAC variation. Sample 406 may have contained more hydrophilic substances than 405. Carbohydrate levels and types also decide the water absorption capacity levels of foods (Okwunodulu *et al*., 2022a). Besides, unripe plantain flour may have contained more amylose, which is more soluble than amylopectin. The values compared favourably with those of Okwunodulu *et al*. (2020).

Oil absorption capacity (OAC)

The OAC is the ease with which the flour protein content of the flour blends physically absorbs fat through capillary attraction (Okwunodulu *et al*., 2023), with which mouth feel and flavor are improved. Increasing the levels of sprouted sorghum flour in the formulations significantly improved ($P<0.05$) the oil absorption capacity (OAC) of the flour blends, while the OAC of unripe plantain flour decreased. With this, sample 405 with the highest OAC (2.31 g/g) may likely have better flavor, mouth feel, and soft texture than 406 with 1.84 g/g when reconstituted with hot water. Sprouted soybean flour with the highest protein content (Table 2) may have contributed by synergizing with that of the sorghum to give superior OAC over other samples, as fat interacts with protein. Sample 405 may have had more lipophilic starch granules with superior binding of lipids (Babu & Parimalavalli, 2012), probably from sprouted sorghum flour. This also implied that sprouted sorghum flour may have more lipophilic starch granules than sprouted soybean flour despite its higher protein content. Type and higher carbohydrate content of sprouted sorghum flour (83.15% in Table 2), particle sizes, and the degree of denaturation (Okwunodulu *et al*., 2023) may have also contributed. The OAC values of the entire formulated samples were superior to 1.48-1.64 g/ml, as advanced by Okwunodulu *et al*. (2020) in their study, which may be due to breadfruit inclusion.

Bulk density (BD)

The BD is the compactness (mass per unit area) index of the flour blends which invariably reveals their porosity, weight of a food, and criteria for choice of packaging material (Okwunodulu *et al*., 2020). It correlates inversely with flour blend porosity. An increase in BD due to increased inclusion of sprouted sorghum flour may signify a higher density or heaviness of sprouted sorghum flour than other flour samples in the blends. Sprouted sorghum flour with the highest BD (0.66 g/ml) may have contained more amylose (more soluble) than amylopectin. Conversely, an increase in unripe plantain flour level decreased the BD of the blends. Higher BD is desirable in CFs since it is an indication of bulkiness with increased nutrient density liable to dilution for easier swallowing and more food intake, considering the 200 ml of infants' stomach capacity. Sample 405 is therefore a better blend in this regard. The BD values of this study were more than 0.33 g/ml for sorghum flour, 0.38 g/ml for Cerelac, and 0.35-0.37 g/ml for sorghum reported by Okwunodulu *et al*. (2020) in their complementary study.

Foam capacity (FC)

This is the interfacial area created by the blended flour proteins. The FC is responsible for improving its textural consistency due to the incorporation of a high percentage of porosity. This is substantiated by an FC increase in sprouted soybean flour (higher protein content) and a decrease in sprouted sorghum flour. Table 1 revealed the proof of higher protein content (31.10%) of sprouted soybean flour, followed by sprouted sorghum flour (9.09%), which justifies a higher ($P<0.05$) FC of sample 404 with 40% sprouted soybean flour than 405 with 40% sprouted sorghum flour. Therefore, sample 404 may likely have better textural consistency than the rest of the blends, which is desired in CFs.

Foam stability

This is the measure of the ability of the flour blend proteins to stabilize and withstand gravitational and mechanical stresses. It is also the time it takes the foam to collapse without disturbance, which invariably points to protein quality. Protein quality determines the tensile strength of the parent material, which in this case is the reconstituted complementary blends. Higher ($P<0.05$) FS value of sample 404 with 40% sprouted soybean flour than the entire samples validated its higher FS value, and probably the protein quality effect on FS. Therefore, sample 404 may likely stabilize the consistency of the reconstituted blend than the rest. Also, a higher FS of sprouted soybean flour (78.12%) could also be responsible for the increase.

Wettability

This reveals the propensity with which the flour blend particle surfaces associate and remain in contact with

Table 6. Sensory analysis of hot water reconstituted complementary flour blends

Samples	Appearance	Taste	Flavor	G. Acceptability
404	7.40±0.03^{a}	7.20±0.03^{a}	7.20±0.03^{a}	7.80±0.04^{a}
405	7.00±0.00^{b}	6.70±0.03^{b}	7.10±0.07^{a}	7.69±0.01^{b}
406	6.05±0.03^{c}	6.65±0.03^{b}	6.75±0.04^{b}	7.30±0.03^{c}

The values represent triplicate analytical determinations with mean separations. Values in the column with different superscripts are significantly different (P<0.05). Samples 404= 40% sprouted soybean flour + 30% sprouted sorghum flour + 30% plantain flour, 405=30% sprouted soybean flour + 40% sprouted sorghum flour + 30% plantain flour, and 406 = 30% sprouted soybean flour + 30% sprouted sorghum flour + 40% plantain flour. G. Acceptability = General acceptability

water due to intermolecular interactions. Therefore, it is an index of flour particles' swelling, reconstitutability, and dispersibility in hot water. Significantly (P<0.05) higher wettability of sample 404 with 40% sprouted soybean flour inclusion, higher sprouted soybean flour wettability (44.60), and protein content (Table 1) validated the influence of protein on wettability. Therefore, sample 404 will wet, disperse faster, and give a better consistency than the rest as protein binds and holds water (Okwunodulu *et al*., 2023) due to its higher hydrophilic than hydrophobic properties.

Gelatinization temperature (GT)

There were reasonable GT variations among all the entire blends more than the control, which signified noticeable GT contributions by the individual flours in the blends. Sample 405 with the least GT of 61 °C may likely gelatinize and gel faster, which could be pinned to sprouted sorghum flour (40%), while 406 with GT of 72 °C will take a longer time, which may be due to plantain flour (40%). Sprouted sorghum flour could therefore be responsible for the faster gelation and gelling, while unripe plantain flour delays the same. The variations may be due to carbohydrate type. Also, particle sizes of the starch granules and amylose and amylopectin ratios (Wikipedia, 2019) of flour blends may have contributed to this. Sprouting may have pre-digested the starch granules of the sprouted sorghum flour into smaller sizes and the anti-nutrients, thereby reducing them compared to sprouted soybean flour, unlike unripe plantain flour, thereby lowering the GT. Lower GT is preferred over higher in CFs to preserve the heat-sensitive nutrients.

Emulsion capacity (EC)

This is the rate at which the protein content of the flour blends will mix and stabilize two or more unstable immiscible liquids (emulsion) to maintain a good consistency. An emulsion, therefore, needs an emulsifier to prevent its natural separation tendency which will reduce the interfacial energy. Depending on their protein quality, sample 405 with 40% sprouted sorghum flour inclusion which had the highest EC content (70.17%), may likely have a better consistency with little tendency to separate. The higher EC value could be because sprouted sorghum flour had the highest EC than sprouted soybean flour and unripe plantain flours. Perhaps sprouted sorghum flour protein may have a better emulsion formation and stabilization capacity than other flours, including sprouted soybean flour. It may also mean that the protein content of other flours was denatured more by heat than that of sprouted sorghum flour, as protein denaturation and heat (Arukwe & Onugha, 2020) are associated with loss of emulsion power. Higher EC is highly advocated for CFs for better consistency and infant acceptability, which demands more inclusion of sorghum in the blend.

Sensory analysis of hot water reconstituted complementary blends

General acceptability results of Table 6 showed that sample 404 with 40% sprouted soybean flour was the most preferred (7.80), while 406 with 40% unripe plantain flour was the least (7.30). Their acceptability levels respectively translated to like very much and liked moderately, implying that all the blends were acceptable. Maximum acceptability could be attributed to the maximum scores of all the attributes evaluated by sample 404 and the least by 406. This is analogous to the assertion that any sample with the maximum score in the majority of the evaluated attributes will have the best acceptable score and will be preferred most (Okwunodulu *et al*., 2020). The results revealed that overall preference levels of the blends increased with sprouted sorghum flour and decreased with the inclusion of plantain flour inclusion levels. The variations (P<0.05) in all the attributes evaluated are proof of the different contributions from different flour blends to general acceptability.

CONCLUSION

This study proved that sprouted soybean, sprouted sorghum, and unripe plantain flour blends have good complementary potentials and therefore are good candidates for complementary food formulations. Their complementary blends had high nutritional value, good functionality, and were highly acceptable (liked moderately to liked very much). The blend of 30% sprouted soybean flour + 40% sprouted sorghum flour + 30% unripe plantain flour had the best nutritional and functional values, while that of 40% sprouted soybean flour + 30% sprouted sorghum flour + 30% unripe plantain flour had the least. Therefore, the blends can be used to combat common weaning deficiency (protein, energy, and trace elements), protein energy malnutrition (PEM) prevalence in infants from developing countries, and in meeting the recommended complementary RDI of most nutrients. Also, the high calcium-phosphorus ratio will help to build and maintain strong bones and teeth in infants.

ACKNOWLEDGE

The authors happily appreciated the Department of Food Science and Technology of Michael Okpara University Agriculture for the provision of the research space and the reagents used.

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