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Assessment of Nutritional and Functional Properties of Complementary Food from Orange-Fleshed Sweet Potato, Soybean and Tropical Almond Seed Composite Flour

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LN and MOE did the Conceptualization. Authors LN and CNE Investigated the study and performed methodology. Authors LN and NBB wrote original draft. Author MOE supervised the study. All authors read and approved the final manuscript.

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ABSTRACT

The study evaluated the quality characteristics of complementary food produced from Orange-Fleshed Sweet Potato, soybean, and tropical almond seed composite. The sample formulation was in ratios of 100:0:0, 90:5:5, 80:15:5, and 70:25:5 for Orange-Fleshed Sweet Potato, soybean, and

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tropical almond seed composite, respectively. A commercial complementary food was used as a control sample. A commercially available complementary food served as the control sample. The samples underwent analysis for nutritional, functional, and pasting properties using established standard methods. The obtained data were subsequently analyzed utilizing SPSS version 25. Significance was approved at $p<0.05$. The proximate composition of the complementary food ranged as follows: moisture (4.58-6.55%), fats (1.39-3.61%), Protein (3.67-14.15%), ash (1.94-2.78%), crude fibre (1.67-3.48%), carbohydrates (69.53-87.09%), and energy values (364.89-375.55 kcal/100 g). The micronutrients ranged as follows: calcium (0.62-4.98 mg/100 g), magnesium (1.54-2.25 mg/100 g), potassium (11.23-23.28 mg/100 g), sodium (1.24-6.42 mg/100 g), iron (3.01-8.00 mg/100 g), zinc (1.24-2.75 mg/100 g), beta carotene (6.65-27.61 mg/100 g), vitamin C (0.30-1.54 mg/100 g), vitamin B_1 (0.65-1.39 mg/100 g), and vitamin E (0.72-4.29 mg /100 g). The functional properties ranged as follows; bulk density (0.50-0.85 g/mL), swelling capacity (1.52-3.19%), water absorption capacity (3.64-4.93 mL/g), oil absorption capacity (0.61-1.88 mL/g), and gelatinization temperature (57.5-66.0 °C). The pasting properties ranged as follows: peak viscosity (143.67-296.67 RVU), Trough viscosity (55.47-94.04 RVU), breakdown viscosity (87.11-202.63 RVU), setback viscosity (702.87-2642.29 RVU), final viscosity (758.33-2736.33 RVU), peak time (4.10-5.37 min), and pasting temperature (72.40-79.47 °C). The composite flour herein produced Substantially ($p<0.05$) enhanced the nutritional, functional, and pasting characteristics of the complementary food contrast to the control sample.

Keywords: Complementary food; orange-fleshed sweet potatoes; proximate; micronutrient; functional properties; pasting properties.

1. INTRODUCTION

In low-income countries, undernutrition is a significant public well-being issue that increases newborn mortality, children's physical and intellectual inactivity, stunted growth, lowers their immune systems, and stifles development [1] When children transition from consuming liquids to incorporating semi-solid or fully adult foods during the weaning process, a critical transitional phase may lead to the development of protein-energy malnutrition. Therefore, complementary food is essential for children's overall growth, development, and mental health. In addition to protein and calories, newborns in low countries need additional calcium, vitamins A and D, iron, and certain significant micronutrients in their complementary diets [1]. These can be made by combining the regional foods that are currently accessible in the country. Addressing undernutrition is a major global well-being preference that is important to multiple of the United Nations' Sustainable Development Goals (SDGs) notably emphasized in Goal 2 ('Zero hunger') [2].

Complementary feeding (CF) begins when an infant's nutritional requirements surpass the adequacy of breast milk alone, necessitating the introduction of complementary meals and liquids alongside breastfeeding [3]. The significance of complementary foods (CF) lies in facilitating the transition from milk feeding to family foods, addressing both nutritional and developmental needs. Newborns endure rapid growth and development throughout the CF period, which also sees noticeable dietary changes as a result of exposure to novel foods, tastes, and eating experiences. During this time, infants are particularly vulnerable to nutritional deficiency [4]. However, compared to the extensive research on breast and formula feeding, the CF period has received less study, particularly in terms of the kind of meals provided and whether or not this period of considerable dietary change has an impact on later health, development, or behavior [4].

Initiating the gradual introduction of soft, semisolid, and solid foods is implemented as a complementary feeding strategy for infants starting at the age of six months. Additionally, it is important to start supplemental feeding practices on schedule and to breastfeed infants [5]. According to Obasi1 et al. [6] complementary foods are combinations of various nutrient qualities that are high in protein, fats, carbohydrates, vitamins and minerals and are derived from grains, fruits, milk, and different food origins. An infant that is ready to start eating solid foods needs food that is high in energy, nutrient-dense, soft, and simple to chew and swallow [7].

The cost of commercially available complementary foods is high for low standard of living households in low-income countries. This households then look for other means of nourishing their kids by cooking complementary foods using local staple crops. In Africa, complementary foods are typically derived from cereal grains or root crops [8]. Traditional African complementary foods are sourced based on the region and the accessibility of cereal grains such as maize, cassava, sorghum, and guinea corn. Maize and millet are the most widely utilized primary ingredients in complementary foods in West Africa [9]. Sources of complementary meals in some parts of East Africa are Teff, sorghum, barley, maize, and wheat [10]. Much later, other essentials like cocoyam, cassava, yams and potato are added; they can be used to make marshes or served with sauce or soup [8]. To address the nutritional needs of developing infants, complementary meals must be balanced and include enough protein and carbohydrates, and vital trace elements (vitamins and minerals).

Orange-Fleshed Sweet Potato (OFSP) is a significant dietary origin of Vitamin A carotenoids (VAC) and Non-Pro Vitamin A Carotenoids (NPVAC) [11]. Because of the importance of vitamin A (VA) in eradicating vitamin A deficiency (VAD) in w-income countries amongst children, OFSP is highly valued [12]. In contrast to white-fleshed sweet potatoes (WFSP), the orange fleshed sweet potato has an appealing yellow-to-orange color and a sweet taste that appeals to children [13]. As a result, the OFSP has been suggested as having the potential to address calorific and VAD undernourishment issues among children. OFSP serves as a rich provider of indigestible dietary fiber, specific minerals, diverse vitamins, and antioxidants [14]. However, the low protein content of OFSP may not be enough to balance the nutrient requirement of children (one to six months). In low-income countries, this is often complemented with a high-protein legume. Among these legumes, soybeans stand out because, in addition to the health advantages, they are a rich source of isoflavones, which reduces the possibility of cancer, cardiac disease, and osteoporosis [15]. The protein in soybeans is referred to as a complete protein because of its amino acid composition. It is also reported that infants who drink soybean milk instead of cow's milk may have low incidences of rickets [16]. The quest for making foods functional has also spurred the incorporation of plant bioactive compounds in foods, either wholly or as extracts. In addition to having great nutritional content, almonds have been particularly noted for their health benefits, including control of blood glucose swings, a decrease in postprandial plasma lipids, and free radical scavenger activity [16].

To formulate a cheap and affordable complementary food and also make this food functional, OFSP, soybean, and almond seed flour will be used. Hence, this research seeks to use OFSP, Soybean and Tropical Almond Seed Flour Composite to produce and analyze the nutritional, functional, and physical attributes of nutrient-dense complementary food.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Sourcing of material

Orange Fleshed Sweet Potato (*Impomoea batatas L.) and soybean* (*Glycine max L.* Merril) were purchased from Umudike Research Institute and Wurukum market, Makurdi Benue State, Nigeria while tropical Almond (*Terminalia catappa*) was collected from Benue State University Makurdi, College of Health Sciences and CEFTER hostel. All reagents used were of analytical grade.

2.2 Methodology

2.2.1 Production of orange fleshed sweet potato flour

Orange fleshed sweet potato flour was produced following the steps enumerated by Kudadam et al. [17]. The OFSP roots were manually sorted, and peeled with a stainless-steel knife into uniform slices three millimeters thick. Slices underwent a blanching process in hot water at 80 ^{o}C for three minutes to denature the action of the enymes. The chips were removed from the water, drained, and dehydrated in a dehydrator (model: ST-02) at 70 ^{o}C for 48 h. The chips were ground in a roller mill (model: DE-200g) and sieved through a 0.5 millimeters mesh size. The flour was wrapped in polypropylene plastic vessels for future utilization. The processes are summarized in Fig. 1.

2.2.2 Soybean flour production

The flour was produced with the aid of the modified approach of Shiriki et al. [18]. The soybean was destoned and winnowed, immersed in clean tap water for twelve hours and cleaned by rubbing between the palms to remove the testa and endosperm. The soybean was rinsed multiple times with additional water until a significant portion of the testa was removed. Subsequently, it underwent a 15-minute boiling process in water, followed by sun-drying for 48 hours and further drying in a hot air oven at 70 ˚C for 30 minutes. The dried grains were processed using a roller mill (model: DE-200g), ground, and sifted through a 0.5 mm mesh size. The resulting flour was then placed in polypropylene plastic containers for later utilization. The processes are summarized in Fig. 2.

2.2.3 Almond flour production

The procedures described by Akpakpan & Akpabio [19] was used to produce Almond flour. Almond fruits were air dried for a period of 7 days and cracked open to extract the seeds. The seeds underwent oven-drying at a temperature of 60 ºC for 24 hours and were subsequently ground into a powder using a roller mill (model: DE-200g). The flour was sieved with a 0.5 mm mesh sieve. The flour was packaged in polypropylene plastic containers for future use. The process is summarized in Fig. 3.

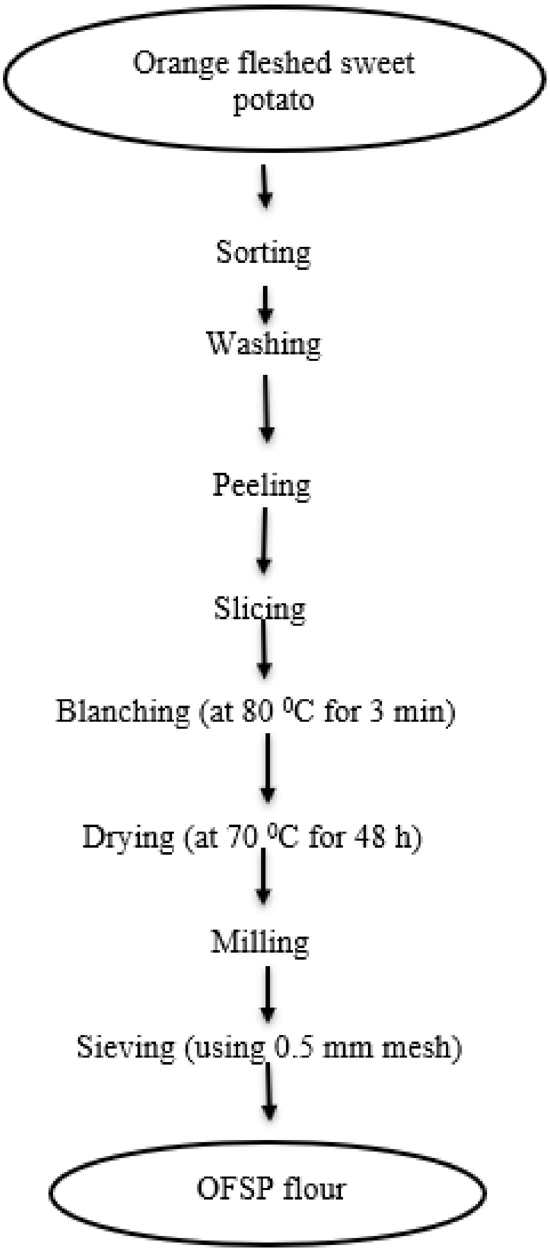

Fig. 1. The process of OFSP flour production

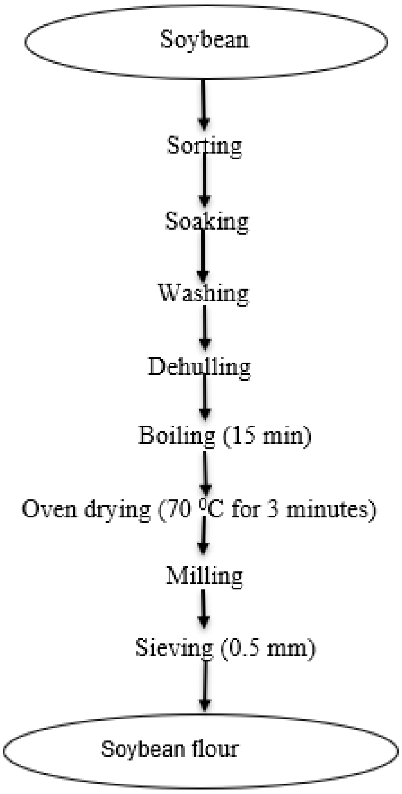

Fig. 2. The process of soybean flour production

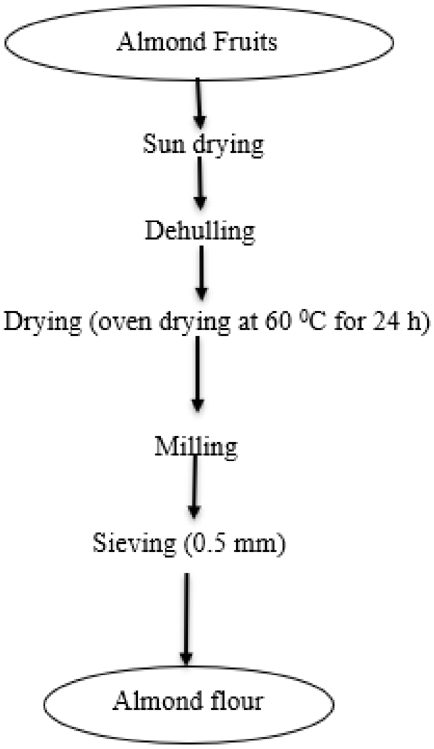

Fig. 3. The process of almond flour production

2.2.4 Sample formulation

The samples were formulated from the three raw materials as outlined in Chart 1.

2.3 Proximate Analysis of Samples

The official methods of AOAC were used to analyze the crude protein, moisture content, crude fat, crude fiber, and ash content [20]. The carbohydrate content was estrerblished by subtraction while the energy values were esterblished using the Atwater conversion factors for fats, proteins, and carbohydrates as indicated in Equations 1 and 2, respectively.

$$\% \text{ Carbohydrates} = 100 - (\text{moisture} + \text{proteins} + \text{fats} + \text{ash} + \text{fibre}) \quad (1)$$

$$\text{Energy (Kcal)} = 4 \times \text{proteins} + 4 \times \text{carbohydrates} + 9 \times \text{fats} \quad (2)$$

2.3.1 Analysis of the vitamin content in the complementary food

Thiamine (vitamin B1), Riboflavin (vitamin B2), Niacin (vitamin B3), Ascorbic acid (vitamin C), and Tocopherol (vitamin E) were analyzed using AOAC's officially recommended methods [20].

2.3.2 Analysis of minerals in the complementary food

Calcium, potassium, iron, sodium, magnesium and Zinc were analyzed using an Atomic Absorption Spectrophotometry (AAS) (Thermoelemental UNICAM 969) as described by AOAC [20]. The sample weighing one gram was digested with 30mL of aqua regia, consisting concentrated Nitric acid and Hydrochloric acid, in a ratio of 1:3. 50 mL of the filtered sample was made up with deionized water. The aliquots of the digested filtrate were used for AAS analysis and different wavelengths (calcium, potassium, iron, Sodium, magnesium, and zinc: 422.7, 766.5, 372.0 285.2, 258 nm, respectively). Readings were taken at corresponding absorbances for the different elements and extrapolated using the standard curves of these elements.

2.4 Analysis of Bulk density

The method for determining the bulk density of the flour samples followed the procedure outlined by Abolaji et al. [3]. Fifty grams (50 g) of the sample were placed into a 100 mL graduated cylinder. The cylinder was gently tapped on a laboratory bench until there was no further reduction in the sample level. The final volume of the content in the cylinder was recorded, and the bulk density was calculated in grams per milliliter (g/mL) using Equation 3.

$$\text{Bulk density} = \text{Weight of sample (g)} / \text{Volume of sample in the cylinder after tapping (mL)} \quad (3)$$

2.4.1 Analysis of water absorption capacity

According to the method described by AOAC [20], 1 g of the sample was combined with 10 mL of distilled water in a weighed centrifuge tube . The tube underwent agitation on a vortex mixer for 2 minutes and was subsequently centrifuged at 4000 rpm for 20 minutes. The clear supernatant was decanted and discarded. The adhering drops of water were removed and weighed. WAC was denoted as the amount of water absorbed per 100 g of dried powder.

$$WAC\ (mL/g) = \frac{Water\ absorbed\ (mL)}{Weight\ of\ sample\ (g)} \quad (4)$$

Water absorbed (ml) = (volume of water added (10 mL)– Volume of water obtained after centrifugation).

2.4.2 Analysis of gelatinization temperature

According to Steve & Babatunde [21], various sample suspensions ranging from 0.2 to 1.6 g were measured and mixed with 10 mL of distilled water to create 20% (w/v) suspensions. These suspensions were placed in test tubes and subjected to one hour of heating in a boiling water bath, followed by rapid cooling under running tap water. After an additional hour of cooling, gelation was identified as the concentration at which the sample in the inverted test tubes exhibited no slipping or falling. The experiment was conducted in triplicate.

$$\text{Gelation (\%)} = \frac{Weight\ of\ Sample}{10ml\ of\ Water} X\ 100 \quad (5)$$

2.4.3 Determination of swelling index

The centrifuge tube was initially weighed on its own. Subsequently, five grams (5 g) of the sample were weighed into the tube and combined with 30 mL of distilled water. The mixture was heated at 120 °C for 15 minutes, followed by centrifugation at 3000 rpm for 10

Chart 1. Complementary food samples formulation

Sample	OFSP (%)	Soybean (%)	Almond (%)
ComF1	100	0	0
ComF2	90	5	5
ComF3	80	15	5
ComF4	70	25	5
ComF5	Reference sample		

minutes, and the resulting supernatant was poured off. After drying, the tube was reweighed, and the swelling capacity was computed using the following formula:

$$\text{Swelling capacity (g)} = \frac{W1-W2}{\text{Weight of the sample}} \qquad (6)$$

Where;

W1 = the weight of centrifuge tube; W2 = the weight of the centrifuge and the sample.

2.4.4 Pasting properties

According to AOAC [20] The pasting properties of each flour sample were determined using a Parten Rapid Visco Analyzer (RVA-4). The sample (3.5 g) of flour was added into a canister already containing twenty-five milliliters of distilled water, a paddle was placed into the canister the canister was inserted into the instrument and the pasting properties were recorded.

2.5 Statistical Analysis

The data was analyzed through one-way ANOVA using Statistical Package for Social Science (SPSS) software version 24. To separate means, the Duncan multiple range test (DMRT) was used, and statistical significance was acknowledged at a level of p<0.05.

3. RESULTS AND DISCUSSION

3.1 Functional Propeties of the Complementary Food

Table 1 represents the functional properties of the complementary food. shows the functional properties of the complementary food samples. The bulk density (BD) of the complementary food samples varied from 0.50g/ml (ComF1) to 0.73 g/ml (ComF5). The swelling capacity (SC) of the flours varied from 1.52% (ComF1) to 3.19% (ComF5). The WAC of ComF1 was significantly (*p*<0.05) lower than that of ComF2 to COMF5 (composite). The oil absorption capacity (OAC) of the flours varied from 0.61g/mL (sample A) to 1.88g/mL (sample E). Gelatinization temperature of the samples varied from 57.5 °C (ComF1) to 66.0 °C (ComF5).

Results reported by Ukom & Adiegwu, E. C., Ojimelukwe, P. C., Okwunodulu [22] for orange-fleshed sweet potato-based complementary food are similar to the functional properties of the complementary food. Proteins, fibres, and carbohydrates are the major components that contribute to the water absorption capacity of food products due to the hydrophilic polar or charged sides of their molecules. The increase in protein and fiber content of the flour influenced the increase in water absorption capacity of the complementary food as the quantity of the high-protein-dense rich SBF was added. Hydrophilic proteins attract and bind water molecules, contributing to the overall moisture content of food. Whereas the water absorption capacity of ComF1 was low due to its starch content and cellular structure. a similar trend was observed by Ojinnaka et al. [23] who used composite flours of soybean, ginger, and modified cocoyam starch and noted an increase in WAC with an increase in the substitution of the different flours to the modified cocoyam starch.

As observed, the complementary food samples bulk density increased with an increase in the incorporation of SBF. Flours from legumes have been reported to have high BD [24] and this could also be one of the reasons for the significant increase (p<0.05) in the BD from sample ComF1 to ComF5. A similar trend was observed by Ojinnaka et al. [23]. The bulk density of the composite flour increased with a decreased in the proportion of OFSP. The high bulk density of the flours indicates their appropriateness for utilization in food preparations. Bulk density serves as a measure for the weightiness of a flour sample. It is a parameter utilized in establishing packaging needs for flour, dependent on the particle size and moisture content of the product [25].

Table 1. Functional properties of the complementary food

Sample	Bulk density (g/mL)	Swelling Capacity (%)	WAC (mL/g)	OAC (mL/g)	GT (°C)
ComF1	0.50^{e}±0.02	2.40^{b}±0.27	3.64^{d}±0.39	0.61^{d}±0.01	57.5^{c}±1.5
ComF2	0.61^{d}±0.02	1.81^{c}±0.05	4.23^{bc}±0.21	1.03^{c}±0.07	61.0^{b}±1.0
ComF3	0.78^{b}±0.01	1.65^{cd}±0.01	4.50^{b}±0.08	1.43^{b}±0.03	64.0^{a}±1.0
ComF4	0.85^{a}±0.06	1.52^{d}±0.01	4.93^{a}±0.05	1.88^{a}±0.01	66.0^{a}±1.0
ComF5	0.73^{c}±0.02	3.19^{a}±0.01	3.90^{cd}±0.10	1.45^{b}±0.01	65.5^{a}±1.5
LSD	0.04	0.18	0.30	0.04	1.71

Key: OFSP- Orange fleshed sweet potato, WAC- Water absorption capacity, OAC- Oil absorption capacity, GT- Gelatinization temperature, LSD- Least Significant Difference. Values represent mean ± SD of triplicate determinations. Means in the same column with different superscripts are significantly different at p<0.05

As observed in this study OAC increased with the increase in the incorporation of SBF. This could be due to the high protein content in soybeans and tropical almonds. Increased heat treatment of a protein leads to a greater hydrophobic nature, attributed to the high exposure of hydrophobic groups due to the unfolding of protein molecules [26]. This further explain the notable rise ($p<0.05$) in the Oil Absorption Capacity (OAC) of the flours as the substitution of ComF6 increases (ComF6 is generated through a sequence of heat treatment procedures, including roasting) [24]. Hasmadi, M., Noorfarahzilah, M., Noraidah et al. [26] reported results on the functional properties of composite flour similar to that of this study agree with those of. OAC refers to the capability of the fat within flour to attach to the non-polar side chains of proteins. This important functional attribute plays a key role in improving the mouthfeel of food products while preserving their original flavor. Iwe et al. [27]. Increased incorporation of SBF witnessed a significant increase ($p<0.05$) from COMF1 to COMF5. However, increased incorporation from ComF2 to ComF4 witnessed a significant change ($p>0.05$) in SC. The swelling capacity of flour is the volume in milliliters taken up by the swelling of one gram (1 g) of the flour under specific conditions. The swelling capacity (SC) of flour represents the volume in milliliters occupied by the swelling of one gram (1 g) of flour under defined conditions. SC is influenced by factors such as particle size, variety characteristics (such as the presence of starch), and the specific processing methods or unit operations used in flour production. The findings indicate a significant increase ($p<0.05$) in SC from ComF1 to ComF5. This could be attributed to an enhanced capability of the flour to absorb water and expand, indicating the extent of associative forces within the starch granules [28].

3.2 Proximate Composition of the Complementary Food

Table 2 presents the proximate composition of the complementary food. As the level of soybean substitution increased, the moisture, fat, protein, and fibre contents increased significantly ($p<0.05$) while there was a decrease in the carbs content. The increase in hydrophilic attribute of fiber in the SBF and TASF as the level of incorporation increased influenced the increase in moisture content. The low moisture contents (4.58-6.55%) were an indication of the shelf life of the product since at lower moisture contents, food tends to be more shelf-stable [29]. Adesanmi et al. [30] reported (3.32–6.7%) for yellow maize and almond seed-based complementary diets which are similar to those reported by this study. The trend in results also agreed with the results reported by Akindele, O., Gbadamosi, O., Taiwo, K., Oyedele, D., & Adeboye [31].

The high protein content of soybean influenced the increase in protein content of the food samples. The results obtained were in agreement with those reported (1.56 to 23.81%) by Bukuni [7] for a breakfast food processed with OFSP and African yam bean and lower than the range of values (14.78-16.96%) reported by Laryea [32] in a complementary food produced from sweet potato. Concerning fat content, ComF4 samples with 25% SBF exhibited the highest fat content, whereas the control sample (ComF1) displayed the lowest. The rise in fat content may be attributed to the substitution effect as a result of residual fat content present in the SBF. The results were in agreement with the study of Ojinnaka et al. [23] in soybean, ginger, and modified cocoyam starch-based complementary food even though these authors reported lower values (1.22-1.93%). This study reported results lower than those reported by other authors [30,7].

Table 2. Proximate composition of the complementary food

Sample	**%**						**(kcal/100g)**
	Moisture	**Fat**	**Proteins**	**Ash**	**Fibre**	**Carbohydrates**	**Total calories**
ComF1	$4.58^{d}\pm0.39$	$1.39^{c}\pm0.03$	$3.67^{e}\pm0.46$	$1.94^{e}\pm0.07$	$1.67^{c}\pm0.15$	$87.09^{a}\pm0.87$	$375..55^{a}\pm1.97$
ComF2	$4.98^{c}\pm0.80$	$1.61^{c}\pm0.02$	$7.37^{d}\pm0.49$	$2.33^{d}\pm0.02$	$2.72^{b}\pm0.09$	$80.99^{b}\pm0.30$	$367.96^{b}\pm3.07$
ComF3	$5.91^{b}\pm0.00$	$2.35^{b}\pm0.05$	$9.22^{c}\pm0.29$	$2.48^{c}\pm0.08$	$3.23^{a}\pm0.33$	$76.80^{c}\pm0.32$	$365.26^{b}\pm1.25$
ComF4	$6.55^{a}\pm0.06$	$3.61^{a}\pm0.29$	$14.15^{a}\pm0.04$	$2.63^{b}\pm0.05$	$3.48^{a}\pm0.02$	$69.53^{d}\pm0.32$	$367.20^{b}\pm1.33$
ComF5	$4.86^{cd}\pm0.05$	$1.39^{c}\pm0.03$	$11.56^{b}\pm0.41$	$2.78^{a}\pm0.02$	$2.88^{b}\pm0.13$	$76.53^{c}\pm0.54$	$364.89^{b}\pm0.92$
LSD	0.56	0.19	0.54	0.08	0.25	0.73	2.64

ComF1- 100% Orange Fleshed sweet potatoes flour: ComF2- 90% Orange Fleshed sweet potatoes flour, 5% Soybean flour, 5% Almond seed flour: ComF3- 80% Orange Fleshed sweet potatoes flour, 15% Soybean flour, 5% Almond seed flour, ComF4- 70% Orange Fleshed sweet potatoes flour, 25% Soybean flour, 5% Almond seed flour, ComF5- Reference sample, LSD- Least Significant Difference. Values represent mean ± SD of triplicate determinations. Means in the same column with different superscripts are significantly different at $p<0.05$

The high ash content of SBF of 5.03% reported by Tenagashaw [33] could be attributed to an increase in the ash content of the samples as substitution with SBF increased. The trend was also in agreement with the trend reported by Ojinnaka et al. [23], who observed an increase in the ash content in complementary food produced from soybean and also in millet-based complementary food reported by “Olatunde, S.J., Oyewole, O.D., Abioye, V.F., Babarinde, G.O and Adetola, R.O,” [34]. The high ash content in samples signified the presence of minerals since ash content in food indicates the presence of minerals in that food product [35]. The significant ($p<0.05$) increase in the fibre content could be due to the high fibre proportion (3.02%) in SBF. Shiriki [18] reported higher crude fibre values (4.42-2.25) in OFSP, soybean, and mushroom-based complementary food while [22] reported lower fibre (3.68-0.35%) values in complementary food produced from vitamin A maize ogi porridge fortified with OFSP and African yam bean seed composite flour.

The carbohydrate content of the flour blend samples increased with an increase incorporation of SBF. Findings from Bukuni et al. [7]; Shiriki et al. [18] who reported a decrease in carbohydrate content (53.91-50.25%) and (68.00-21.30%), respectively, for Bambara groundnuts and soybean flour-based complementary foods agreed with the results of this study. The carbohydrate content in this study is higher than those in the study by Ugwuanyi et al., (2020) reported carbohydrate content lower than those reported by this study but higher than those of Akindele, O., Gbadamosi, O., Taiwo, K., Oyedele, D., & Adeboye [31]; Dong et al. [29]. For the energy content, this study reported results higher than those (344.68 - 273.33 Kcal) reported by Siyame et al. [36] for soybean-based complementary food.

3.3 Vitamin Content of the Complementary Food

The vitamin content of the complementary food is presented in Table 3. With each level of the samples' substitution with soybean flour, the complementary food samples' vitamin composition decreased significantly ($p<0.05$) (as the incorporation of OFSP decreased). ComF1 (100% OFSP) had the lowest concentration of vitamin E at 0.72 mg/100g, whereas ComF5 had the highest concentration at 4.29 mg/100g (reference sample). The amount of vitamin E in the samples increased significantly ($p<0.05$) with increasing levels of OFSP substitution. The complementary food samples' vitamin B_1 concentrations ranged from 1.39 mg/100g in ComF1 to 1.95 mg/100g in ComF4. The control sample contained 0.65 mg/100g, which was different significantly ($p<0.05$) from the value found in ComF1. From 27.61 mg/100g in ComF1, pro-vitamin A (beta carotene) values significantly decreased, with ComF5 recording the greatest value at 6.65 mg/100g.

The high content of vitamin C in OFSP influenced the increase in vitamin C content of the samples. The reference sample was observed to have the least vitamin C content which was significantly different ($p<0.05$) from the other samples. High vitamin C in this sample indicated its potential for use as an antioxidant in the body through electron donation as reported by Fanta et al. [37]. For vitamin E, the significant ($p<0.05$) increase with increased substitution with soybean could be due to the high levels in soybean flour. The reference sample recorded the highest value of vitamin E (4.29 mg/100g), indicating that soybean is a rich source of vitamin E. The results reported were similar to the values (1.05 mg/100g) reported by Okoronkwo et al. [38]. As observed, the vitamin B1 content increased significantly ($p<0.05$) as the level of incorporation of the soybean flour increased. The observed trend was because soybean contains a great amount of vitamin B1 than OFSP so an increment in the soybean flour increased significantly in the vitamin B_1 content [39]. The pro-vitamin A (beta carotene) values reduced significantly ($p<0.05$) from 27.61 mg/100g in ComF1 to 6.65 mg/100g in ComF5. The orange colour of OFSP is an indication of the presence of carotene whose content increased overall in the samples. The orange colour of OFSP significantly added to the composition oof carotene in the soybean, and tropical almond flour blend. This study reported results similar to the findings of Mohammad et al. [11] who also reported a similar assertion.

3.4 Mineral Composition of the Complementary Food Samples

The mineral composition is presented in Table 4. The calcium content ranged from 0.62-4.45 mg/100g and significantly differed ($p<0.05$), and increased as SBF incorporation increased. The magnesium content ranged from 1.54 mg/100g (ComF1) to 2.14 mg/100g, and there differed significantly ($p<0.05$) between the samples. For the potassium content, the results ranged from

11.23 mg/100g to 23.28 mg/100g and were significantly greater than that of the reference sample (20.28 mg/100g). As the quantity of SBF incorporation increased, the potassium concentration also increased. There was a decrease in the values of sodium as the quantity of OFSP decreased, with results ranging from 1.24 mg/100g to 6.42 mg/100g. The iron composition of the food increased significantly increased ($p<0.05$) from 3.01 mg/100g to 8.00 mg/100g, with ComF1 containing the least iron and ComF4 containing the highest value. The control sample on the other hand had 6.120 mg/100g. For zinc, the results ranged from 1.24 mg/100g to 2.39 mg/100g, and as the level of SBF incorporation increased, the zinc composition significantly increased ($p<0.05$).

The concentration of calcium in the formulation indicated the potential of the food in the development of infants since calcium has been reported to be relevant in the building and development of strong bones and teeth development in infants [40]. Potassium increased with increased incorporation of soybean flour could be attributed to the high values in soybeans. Legumes have been particularly noted to be high in potassium content [41]. The values reported for the potassium content were lower than those(1214-391mg/100) reported by Siyame et al. [36] for Effectiveness and Suitability of Oyster Mushroom in Improving the Nutritional Value of Maize Flour Used in Complementary Foods. The results were however higher than those (1.87-2.03mg/100g) reported by Obinna-Echem. et al. [42] for OFSP and soybean-based complementary food. The higher values for Mg compared to the reference sample (ComF5) proved that composing OFSP, soybean and tropical almond flour enriched the Mg composition of the gruels. The study obtained values lower than the varied of values (32-51.47mg/100g) reported for pea and anchote-based complementary food reported by Gemede [43]. Enhancement of Mg using the component formulation indicated the potential of the food to better boost the immune systems of the infant since a major function of magnesium support the immune system and maintain strong bones. An increase in the sodium content in the food compared to the control sample could be attributed to the high values in tropical almonds and soybeans [19].

For the iron and zinc contents, the results significantly increased with increased incorporation of soybean flour. Higher results were obtained for iron than those (0.7mg/100g-1.3mg/100g) reported by Mbah et al. [44]. Higher results were obtained For zinc compared to those reported by Gemede [43] for maize, pea and anchote-based complementary food. An increase in iron and zinc contents was due to the high values reported by USDA [45] to be high in legumes, including soybeans. The high zinc values were relevant since reports stipulates that zinc play a significant role in cell division, protein synthesis and growth [7].

Table 3. Vitamin composition (mg/100g) of the complementary food samples

Sample	Vitamin C	Vitamin B1	Vitamin E	Beta carotene
ComF1	1.54^{a}±0.01	1.39^{c}±0.18	0.72^{c}±0.15	27.61^{a}±0.82
ComF2	1.26^{b}±0.05	1.78^{b}±0.01	1.19^{bc}±0.08	24.13^{b}±0.29
ComF3	1.19^{b}±0.06	1.88^{ab}±0.02	1.24^{bc}±0.03	21.38^{c}±0.36
ComF4	0.77^{c}±0.04	1.95^{a}±0.05	1.34^{b}±0.06	18.37^{d}±0.30
ComF5	0.30^{d}±0.01	0.65d±0.02	4.29^{a}±0.61	6.65^{e}±0.36
LSD	0.07	0.12	0.40	0.67

Values represent mean ± SD of triplicate determinations. Means in the same column with different superscripts are significantly different at $p<0.05$

Table 4. Mineral composition (mg/100g) of the complementary food samples

Sample	Ca	Mg	K	Na	Fe	Zn
ComF1	0.62^{e}±0.01	1.54^{c}±0.01	11.23^{d}±0.00	1.24^{d}±0.01	3.01^{d}±0.00	1.24^{d}±0.00
ComF2	1.82^{d}±0.01	1.87^{b}±0.01	22.93^{b}±0.02	2.36^{c}±0.02	4.74^{c}±0.01	1.85^{c}±0.04
ComF3	3.88^{c}±0.02	2.12^{a}±0.02	22.98^{b}±0.11	2.38^{c}±0.10	6.12^{b}±0.01	1.88^{c}±0.01
ComF4	4.93^{a}±0.01	2.14^{a}±0.17	23.28^{a}±0.01	3.47^{b}±0.00	8.00^{a}±0.00	2.75^{a}±0.01
ComF5	4.45^{b}±0.00	2.25^{a}±0.04	20.88^{c}±0.00	6.42^{a}±0.01	6.12^{b}±0.01	2.39^{b}±0.01
LSD	0.00	0.11	0.08	0.06	0.00	0.00

Values represent mean ± SD of triplicate determinations. Means on the same column with different superscripts are significantly different at $p<0.05$

Table 5. Pasting properties of the complementary food

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (Min)	Pasting temperature (°C)
ComF1	296.67^{a}±1.53	94.04^{a}±0.01	202.63^{a}±1.52	2736.33^{a}±1.53	2642.29^{a}±1.52	5.37^{a}±0.10	79.47^{a}±0.06
ComF2	282.67^{b}±0.58	87.35^{b}±0.01	195.32^{b}±0,58	2593.67^{b}±0.58	2506.32^{b}±0,57	5.20^{b}±0.10	78.83^{b}±0.06
ComF3	181.00^{c}±1.00	78.73c^{c}±0.15	102.27^{c}±0.85	1135.00^{c}±1.00	1056.27^{c}±0.96	4.40^{c}±0.10	76.70^{c}±0.10
ComF4	145.67^{d}±0.58	58.56^{d}±0.99	87.11^{d}±0.57	999.00^{d}±1.00	940.44^{d}±1.00	4.27^{c}±0.10	74.53^{d}±0.25
ComF5	143.67^{e}±0.58	55.47^{e}±0.12	88.20^{d}±0.69	758.33^{e}±5.13	702.87^{e}±5.02	4.10^{d}±0.10	72.40^{e}±0.10
LSD	1.31	0.63	1.29	3.50	3.44	0.12	0.60

Values represent mean ± SD of triplicate determinations. Means in the same column with different superscripts are significantly different at $p<0.05$

3.5 Pasting properties of the Complementary Food

The results of the pasting attributes including the peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time, and pasting temperature are presented in Table 5. The pasting properties significantly (p<0.05) decrease in the pasting properties with increase incorporation of soybean flour. The pasting properties of food refer to the modifications (texture, digestion, and intended purpose) that occur in the food in water when heat is applied [46]. For gelatinization and pasting, food containing more are heated with water. The pasting properties can then be used to determine whether the food can be turned into a paste or not after heat application. As the percentage of soybean flour was increased, the pasting properties decreased significantly (p<0.05) as presented in Table 5. From 296.67 RVU in COMF1 to 143.67 RVU in COMF5, the peak viscosity steadily fell. Viscosity at the trough ranged from 55.47 RVU to 94.04 RVU.

The decrease in peak viscosity is in agreement with the reports by Laryea et al. [32]; Obinna-Echem. et al. [42] who found similar trends in their composite blends. Lower peak viscosity could be attributed to differences in protein content [47]. Peak viscosity is the highest viscosity developed during a heat process right before the starch granules result in a paste and physical breakdown [48]. It is therefore a good indicator of the water-holding capacity of the starch or mixture. The same decreasing trend was observed in trough velocity with ComF1 registering the highest value of 94.04 RVU and ComF5 registering the lowest value 55.47 RVU.

The lowest value for breakdown viscosity was registered in ComF5, 88.20RVU and the highest value was registered in ComF1, 202.63 RVU. A similar trend was registered for final viscosity with ComF5 containing the smallest value of 758.33 RVU and ComF1 having the highest value of 2736.33RVU. Setback viscosity also reduced from 262.29 RVU in ComF1 to 702.87 RVU in ComF5, with trough viscosity also decreasing steadily. Trough viscosity is influenced by temperature, the extent of mixing, or applied shear stress, and the inherent characteristics of the material. The capacity of a sample to endure both heating and shear stress is necessary for various processes. Breakdown viscosity serves as an indicator of starch stability and measures how easily swollen granules can be broken down. The breakdown viscosity of the flour blends diminishes as the substitution of soybean flour increases. This is in agreement with reports by Obinna-Echem. et al. [42] who reported that the higher the breakdown viscosity, the lower the ability of the flour to withstand heating and stress during cooking. Therefore, ComF1 (internal control) exhibited the least resistance to heating and stress during cooking, while ComF5 demonstrated the highest resilience. The ultimate viscosity of the flour blends provides an indication of the paste's ability to withstand shear force during stirring [49]. The trend observed indicated a decline from the control sample, implying that the control sample exhibited the highest resistance to stirring. Final viscosities are a widely utilized parameters for characterizing the quality of a specific sample, reflecting its capability to form a viscous paste or gel post-cooking and cooling. The re-formation of bonds between starch molecules during the cooling process is commonly known as setback viscosity. Among the samples, ComF4 (70:25:5) OFSP: Soybean flour: tropical almond displayed the greatest setback viscosity.

4. CONCLUSION

This study demonstrates the great potential of Orange Fleshed Sweet Potato (OFSP), soybean, and tropical almond flour in creating nutritionally rich complementary foods. The incorporation of soybean and tropical almond flour as substitutes for OFSP flour in complementary food production markedly enhanced nutritional composition, particularly in terms of protein, ash, fat, and crude fiber contents, with a corresponding decrease in carbohydrate content. Additionally, there was a reduction in the energy content of the flour blends with an increase in the substitution of soybean flour. The functional and pasting properties provided insights into the texture, stability, and processing characteristics of the formulations and also provided an understanding of how the formulations behaved under heating and mechanical agitation. These insights are pivotal in optimizing processing methods and ensuring the desired sensory attributes and nutritional benefits of the foods are retained. ComF3 was most acceptable because it contained all essential nutrients in their correct proportions, and had a minimum antinutrient content, it was generally accepted based on sensory evaluation and compared favorably with the reference sample.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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