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Quality Assessment of Composite Flours from Blends of Acha (*Digitaria exilis*), African Breadfruit (*Treculia africana*), and Soybean Protein Concentrate (Glycine max)

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Abstract: This research explored the quality characteristics of composite flour samples from two varieties of acha (brown and white) fortified with soybean concentrate and breadfruit flour. Acha and soybean concentrate flours were blended (%, w/w) at ratios 100:0, 90:10, 85:15, and 80:20. 5% breadfruit flour was added to each blend as a constant, and 100% of each of the two varieties of acha flour containing 5% breadfruit flour were used as the control samples. Proximate composition of the flours and their blends, and sensory evaluations of the swallow produced from the blends were determined. The replicated experimental data were analyzed using Analysis of Variance at a 0.05 level of significance and Pearson correlation coefficient at a 0.05 level of significance, employing one-way ANOVA. The results of the proximate compositions of the flours showed that protein concentrate recorded the highest values for moisture, ash, and protein. Breadfruit flour recorded the highest values for fibre, fat, and energy value. Brown acha flour had the least fat and protein, while white acha flour had the least ash and fibre. Significant ($p < 0.05$) increases in ash, fibre, fat, and protein contents, and decreases in carbohydrate content, were recorded in the flour blends with increasing concentrations of soybean protein concentrate and decreasing concentrations of acha flours. Overall, a blend of 80% white acha flour, 20% soybean concentrate, and 5% breadfruit flour showed a better proximate composition in terms of ash, fibre, fat, and protein than others. White acha variety recorded the highest values in aroma and texture. The sensory attributes were all above 5 for all the parameters studied, which indicates that they were acceptable to a reasonable degree to the panelists. The overall quality of the composite flour samples indicates that they are suitable for use in infant food formulations, baking, and the production of other food products.

Keywords: Nutritional enrichment; breadfruit; soybean concentrate; composite flour; sensory evaluation.

1. Introduction

Carbohydrates comprise more than 50% of daily energy intake; therefore, the quality and source of these carbohydrates are important, as ingesting refined grains is associated with increased risks of metabolic

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diseases, while whole grain intake is associated with a reduced risk of metabolic disease [1,2]. Also, consuming too many carbohydrate-dense foods could adversely affect glucose metabolism and blood sugar levels, thus increasing the risk of developing diabetes. Studies have shown that eating diets rich in carbohydrates leads to a higher risk of suffering type 2 diabetes, heart disease, stroke, and weight gain [3]. Over the last decade, the market for gluten-free (GF) products has grown considerably because of better diagnostic methods for identifying an increasing number of people suffering from celiac disease and other gluten-related disorders, as well as the increase in the number of people who have eliminated gluten from their diet because they perceive it as a healthy improvement [4,5]. There are many concerns about the nutritional inadequacy of the gluten-free diet, often characterized by an excess of calories and a reduced intake of fiber, minerals, and complex carbohydrates [6].

Acha (*Digitaria exilis*), a traditional cereal crop native to West Africa, is popular due to its well-adapted nature to local conditions and its good nutritional and culinary properties [7]. Scientists have reported that the crude protein content of the grain is similar to that of maize and complementary to legumes in terms of methionine and cysteine content [8]. The cereal is uniquely rich in methionine and cystine and has a low sugar content upon consumption [9]. The balancing of protein and amino acid profiles of acha requires supplementation with legume and oilseed proteins, which are of high benefit [10]. Acha has been linked to health benefits, including the prevention and treatment of constipation, cardiovascular diseases, and hypertension [11].

Soybeans (Glycine max) also contain up to 45% protein with a digestibility value of 91.41% and are a good source of vitamins and minerals, as well as an adequate amount of different amino acids required for repairing damaged body tissue. It could be an essential component of functional foods and can be used to enhance product quality [12]. One important soybean protein product is soy protein concentrate (SPC). SPC is defined as an edible protein product with a protein content of at least 65% on a dry weight basis. Protein concentrates from plant sources can be used to enrich cereal-based carbohydrate-dense flours [13].

African breadfruit seeds are a leguminous crop rich in fiber (especially unhulled seeds), healthy lipids, and minerals. Processing the whole breadfruit seeds into flour has been shown to result in a significant increase in protein and fiber content. Additionally, it results in a reduction of antinutritional nutrients in the flour [14]. Breadfruit undergoes physiological deterioration after harvesting. The fruit can be processed into flour as a way of reducing post-harvest losses and increasing the utilization of breadfruit, which is more shelf-stable [15].

The high health risk associated with the overconsumption of carbohydrate-dense diets, resulting from their effects on glucose metabolism and blood sugar levels, has led to the need to develop food products from plant crops with a low glycemic index that are still rich in carbohydrates. Additionally, the prevalence of protein-energy malnutrition and the high cost of animal proteins in developing countries, as well as health issues associated with consuming animal proteins, have led to increased interest in utilizing proteins from plant sources or using plant-source proteins in the fortification of carbohydrate-dense foods. Composite flours made from blends of acha, African breadfruit, and soybean concentrate will exhibit improved nutritional profiles compared to single-component flour. Therefore, this study was conducted to evaluate the nutritional quality of composite flours derived from blends of acha, African breadfruit, and soybean protein concentrate, as well as the sensory properties of swallows produced from these flours.

2. Materials and Methods

2.1. Source of Raw Materials

Two different varieties of *Acha* (brown and white) and soybean samples were purchased from Saborn Gari Central Market, Kano State, Nigeria. Whole African breadfruit seeds were purchased at Oyibo market, Old Aba Road, Port Harcourt, Rivers State, Nigeria. Plates 1, 2 and 3 show the raw material samples.

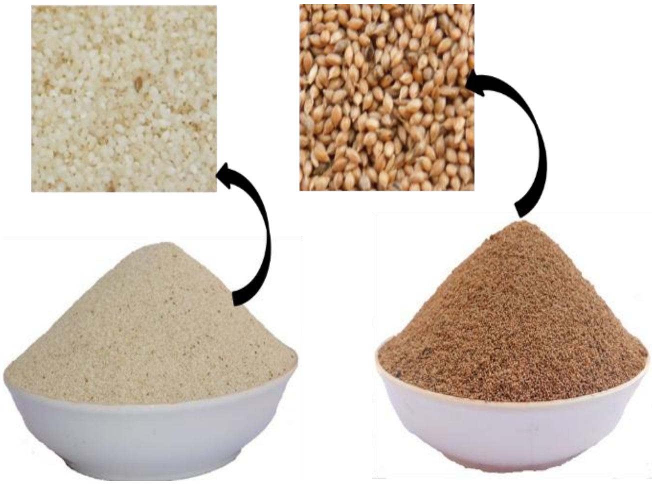


Plate 1. White and brown varieties of acha **Plate 2.** Soybean seeds

Plate 3. Raw whole breadfruit seeds

2.2. Sample Preparation and Processing

The preparation and processing of the samples were conducted at the Grifeon Projects Laboratory in Umuahia, Abia State. The samples were cleaned to remove unwanted materials and spoiled grains. After which, each of them was processed into flour.

2.2.1. Production of Acha Flour

Acha flour was produced from the brown and white varieties of *acha* according to the method described by Olapade and Aworh [16]. The grains were cleaned by manually removing extraneous materials, such as chaff, stones, and stalks. This was followed by washing in portable water, and stones were removed by sedimentation. The washed grains were dried in an oven at 55 °C, then milled using an attrition mill, sieved through a 425 µm mesh screen, and packaged in air-tight zip lock nylon bags that were labeled and stored at 4 °C for subsequent use. The flowchart for the process is shown in Figure 1.

2.2.2. Production of Breadfruit Flour

The roasted breadfruit seed flour was prepared as described by Akubor *et al.* [17]. The raw and sorted breadfruit seeds were roasted in acid-washed sand (140 °C, 20min), sieved to remove the sand, and milled in a laboratory mill. After Milling, it was sieved with a 200 nm mesh sieve to obtain the roasted breadfruit flour (RBF). The flowchart for the process is shown in Figure 2.

Acha Grains
↓
Cleaning
↓
Washing
↓
Drying (55 ºC)
↓
Milling
↓
Sieving (425µm Mesh Screen)
↓
Packaging
↓
Acha flour (stored at 4ºC)

Figure 1. Flow chart to produce acha flour

Whole African breadfruit seeds
↓
Sorting/cleaning
↓
Roasting (140 ºC, 20min with sand)
↓
Sieving
↓
Milling
↓
Sieving (200 Mesh Sieve)
↓
Packaging
↓
Roasted breadfruit seed (stored at 4ºC)

Figure 2. Flow chart to produce whole breadfruit seed flour

Defatted soybean flour
↓
Extraction
(10:1 water/flour ratio, pH 8.5)
↓
Mixing by stirring
(Addition of 40% Citric Acid, pH 4.5 40 ºC)
↓
Centrifugation
(1500rpm, 15mins)
↓
Protein/Fiber
↓
Neutralize
(Using 0.3N NaOH to pH 7)
↓
Drying
↓
Packaging
↓
Soybean concentrates

Figure 3. Flow chart to produce soybean concentrate

2.2.3. Production of Soybean Concentrate

Soybean concentrate was prepared from the defatted soybean flour using the standard method described by Lusas and Rhee [18]. The Soybean seeds were sorted to remove pebbles, stones, and other extraneous materials. They were washed and steeped for 10 hours. The steeped soybean seeds were drained and pre-cooked for 15 minutes at 1000 °C, after which they were manually dehulled (by rubbing in between the palms) and the hulls were removed by flushing with clean water. The dehulled soybean seeds were dried in the cabinet dryer at 70 °C for 4 hours and milled into soybean flour. The soybean flour was defatted using the Soxhlet apparatus and ethanol. The flour samples were wrapped and suspended in a Soxhlet apparatus, refluxed for 12 hours with ethanol, and subsequently dried at room temperature. The defatted soybean flour was mixed thoroughly with distilled water in a 10:1 ratio of soybean flour to water. Approximately 40% Citric acid was added to the mixture to adjust the pH to 4.5, and the temperature was increased to 40 °C for 30 minutes while the mixture was stirred to ensure proper mixing. The mixture was then centrifuged at 15,000 rpm for 15 minutes. The supernatant was separated, and the protein/fiber was neutralized to a pH of 7 using 0.3N NaOH, dried, and stored as the soybean protein concentrate. The flow chart for the production process is shown in Figure 3.

2.2.4. Formulation of the Composite Flour

Whole breadfruit seed flour (5%) was added to each blend as a constant. Each of the two varieties of acha flours (100%) containing 5% whole breadfruit seed flour was used as a control. The blends were thoroughly mixed using a blender, and the samples were packed in just bags. The formulation of the composite flour was summarized in Table 1.

Table 1. Formulation of acha flour/ soybean concentrate composite flour.

Variety	Blends	BSF	SBC
BAV	BAS1	100	0
	BAS2	90	10
	BAS3	85	15
	BAS4	80	20
WAV	WAS1	100	0
	WAS2	90	10
	WAS3	85	15
	WAS4	80	20

BAV= brown *acha* variety, WAV= white *acha* variety, BSF = breadfruit seed flour and SBC = soybean concentrate, BAS = brown *acha* flour and soybean concentrate blends, WAS = white *acha* flour and soybean concentrate blends, BAS1- BAS4 are brown *acha* flour-based blended samples, while WAS1-WAS4 are white *acha* flour based blended.

2.3. Determination of Proximate Composition

The moisture, crude protein, fat, ash, crude fiber, carbohydrate, and energy value contents of the ground rice varieties were all determined using the method described by AOAC [19].

$$\%\text{Moisture} = \frac{\text{W2} - \text{W3}}{W2 - W1} \times \frac{100}{1}$$

Where, W_1 = weight of empty dish; W_2 = weight of dish and sample before drying; W_3 = weight of dish and sample after drying

$$\%\text{Ash} = \frac{\text{W3} - \text{W1}}{W2 - W1} \times \frac{100}{1}$$

Where, W_1 = weight of empty crucible; W_2 = weight of crucible+sample before ashing; W_3 = weight of crucible + sample after ashing

$$\%\text{Fat} = \frac{\text{W2} - \text{W1}}{W} \times \frac{100}{1}$$

Where, W = weight of sample; W_1 = weight of flask; W_2 = weight of flask and oil extracted

$$\%\text{Crude fibre} = \frac{\text{W1} - \text{W2}}{W} \times \frac{100}{1}$$

Where, W = weight of sample; W_1 = weight of crucible + residue after drying; W_2 = weight of crucible + sample after ashing

% Total Nitrogen = Titre Value x Atomic mass of nitrogen x Normality of HCl used x 4. Therefore, the crude protein content was determined by multiplying the percentage Nitrogen by a conversion factor of 6.25, i.e., % crude protein = % N x 6.25.

The percentage of carbohydrate content was obtained by the differential method as follows:

Carbohydrate (%) = 100 - [%Moisture + % Ash + %Protein + %Crude fiber + %Fat]

The energy value was calculated by multiplying the proportion of protein, fat, and carbohydrate by their respective conversion factors of 4, 9, and 4 kcal/g, respectively, and taking the sum of their products.

The energy value was calculated as follows:

Energy value (Ev) = (% Crude protein x 4) + (% Crude fat x 9) + (% Carbohydrate x 4)

2.4. Sensory Test

The sensory test of the samples was conducted by 20 trained panelists using the method described by Pan *et al*. [20]. The panelists gave their consent before taking part in the exercise. Each panelist identified as a swallow consumer and had experience in evaluating swallow meals over the years. The panelists were further trained prior to the test. The samples were placed on white plates coded with random numbers. The panelists were allowed to taste the samples while they were still hot. The panelists were instructed to rinse their mouths with water before testing a fresh sample. The highest score on the hedonic scale expressed preference, and the lowest score indicated the panelist's dislike of the sample.

2.5. Data Analysis

The data were obtained in duplicate, and Analysis of Variance was used to determine significant differences ($p < 0.05$) among treatment means, with separation of means carried out using SPSS version 20.0. Separation of means was carried out using Duncan's Multiple Range Test, and values are reported as means and standard deviations.

3. Results and Discussion

The proximate compositions of the flour samples are shown in Table 2. The moisture content of the flour samples ranged from 1.86 – 8.16%. PC (protein concentrate) had the highest value (8.16%). The moisture content of the flour samples varies from the values reported by Tharise et al. [21] for cassava, rice, potato, and soybean flours, which range from 6.63 to 15.98%, and from the values reported by Mbaeyi-Nwaoha and Uchendu [22] for acha and fermented soybean flours, which are 4.71% and 9.88%, respectively. Moisture content is essential for life maintenance, and analysis of it is one of the most widely used instruments that determine how food is processed and its shelf life. It has also been used as a measure of stability and susceptibility to microbial contamination. The lower moisture content recorded in breadfruit flour shows that the flour would have good shelf stability. According to Akinsanmi *et al.* [23], flour with lower moisture content has greater shelf stability, as spoilage is often caused by microbial activities and related chemical reactions that require higher moisture levels.

The ash content of the flour samples ranged from 1.15% to 5.50%. The brown and white acha flours vary significantly ($p < 0.05$) from other samples. The ash content of the flour samples varies from the values reported by Mateos-Aparicio et al. [24], which is 4%, and the result provided by Fei et al. [25], which was 3.9%. This could be due to the processing method used by Mateos-Aparicio et al. [24], who cooked the rehydrated soybeans before grinding and filtering, which differed from the method employed. The percentage of ash in the sample provides insight into the inorganic content of the samples, from which the mineral content could be obtained [26]. Protein concentrate (PC) exhibited a higher amount of ash, though it was lower compared to the 6.51% reported for jack bean flour by [27] and the 7.86% reported for *S.*

innocua seed's flour [26]. Samples with high percentages of ash content are expected to contain high concentrations of various mineral elements, which are anticipated to enhance metabolic processes and promote growth and development [26].

WAF (white acha flour) had the lowest value (0.20%) for fiber, while BFF (bread fruit flour) had the highest value (7.72%). The brown and white acha flours vary ($p<0.05$) significantly from the other samples. The higher fiber content of the bread fruit flour recorded in this study could be a result of the processing method adopted, as it was not dehulled before milling. This is in line with the findings of Nwabueze et al. [14], who reported that un-dehulled African bread fruit flour is rich in dietary fiber. The fiber content of the flour samples varies from the values 1.17 – 5.88% reported by Olorode et al. [28] for the fiber contents of benoil seed, watermelon seed, pear seed, pawpaw seed, and melon seed flours, and 0.47 – 2.62% reported by Tharise et al. [21] for fiber contents of cassava, rice, potato, and soybean flours. The inclusion of bread fruit flour will help improve glucose tolerance. According to Eromosele and Eromosele [29], the presence of high crude fiber improves glucose tolerance and is beneficial in treating maturity-onset diabetes. Fiber helps in the maintenance of human health and has been known to reduce cholesterol levels in the body. Fiber diets promote the wave-like contractions that move food through the intestine. High-fiber food expands the inner walls of the colon, easing the passage of waste, thus making it an effective anti-constipation [29].

The fat content of the flour samples ranged from 4.05% to 10.71%. BAF (brown acha flour) had the lowest value (4.05%), while BFF (breadfruit flour) had the highest value (10.71%). The WAF (white acha flour) and PC significantly differ ($p < 0.05$) from the other samples. The higher fat level in the breadfruit highlights the seed's importance for oil production. The fat content of the flour samples varies between 1.57% and 16.29%, as reported by Mbaeyi-Nwaoha and Uchendu [22] for the moisture content of acha and fermented soybean flours; however, it is lower than the 23.2% reported by Vishwanathan et al. [30]. Breadfruit flour, with its higher fat content compared to other samples, carries a greater risk of oxidative rancidity. Nevertheless, it is acknowledged that the higher the fat content of a given flour, the greater the flavor and improved texture of its products.

BAF (brown acha flour) had the lowest value (6.96%) for protein content, while protein concentrates (PC) had the highest value (60.16%). There were significant ($p<0.05$) differences among the samples. The protein content of the flour samples varies from the values of 5.93 – 31.04% reported by Olorode et al. [28] for fiber contents of benoil seed, watermelon seed, pear seed, pawpaw seed, and melon seed flours, 9.00 – 33.53% reported by Mbaeyi-Nwaoha and Uchendu [22] for moisture content of acha and fermented soybean flours, and 4.54 – 13.70% reported by Tharise et al. [21] for fiber contents of cassava, rice, potato, and soybean flours. The high protein content recorded in the soybean protein concentrate could result from the high protein content of soybeans. A similar observation was made in a research study by Olaoye et al. [31]. Proteins are essential components of the diet needed for the survival of animals and humans, and their basic function in nutrition is to supply adequate amounts of required amino acids [32].

Protein concentrates (PC) recorded the lowest carbohydrate content at 19.18%, while brown acha flour (BAF) had the highest at 81.02%. There were significant differences among the samples ($p<0.05$). The carbohydrate content of the flour samples varied from the 37.57% to 78.47% range reported by Olorode et al. [28] for fiber contents of benoil seed, watermelon seed, pear seed, pawpaw seed, and melon seed flours, and from 8.00% to 71.0% as noted by Mbaeyi-Nwaoha and Uchendu, [22] for moisture content of acha and fermented soybean flours. The higher carbohydrate contents of both acha varieties align with the findings of Chukwu and Abdul-kadir [33], as well as the results from the FAO [34], which stated that acha has a high carbohydrate content ranging from 70% to 89.5%. The elevated carbohydrate levels observed in both acha varieties and breadfruit flours suggest that they could serve as beneficial supplements to cereal grains as sources of energy. The high carbohydrate content of these flour samples indicates that products made from them would be good sources of energy. Carbohydrates are excellent sources of energy, and a high concentration of them is desirable in breakfast meals and weaning formulas. In this regard, the high carbohydrate content of these flours makes them suitable for providing the necessary energy in breakfast formulations [35].

Protein concentrates (PC) had the lowest value (364.79 Kcal/g), while breadfruit flour (BFF) exhibited the highest value (405.83 Kcal/g) for energy content. The higher fat content found in breadfruit flour may have contributed to its elevated energy value. The differences in these energy values can be attributed to the variations in fat, protein, and carbohydrate contents of the flour samples. Overall, the high energy values recorded in all the samples suggest that their products would be rich in energy.

Table 2. Proximate composition of the flour samples

Samples	BAF	WAF	BFF	PC
Moisture (%)	$6.37^{ab}\pm0.13$	$2.36^{b}\pm3.34$	$1.86^{b}\pm0.05$	$8.16^{a}\pm0.42$
Ash (%)	$1.40^{c}\pm0.09$	$1.15^{c}\pm0.18$	$2.37^{b}\pm0.16$	$5.50^{a}\pm0.16$
Fiber (%)	$0.22^{c}\pm0.09$	$0.20^{c}\pm0.06$	$7.72^{a}\pm0.13$	$1.75^{b}\pm0.06$
Fat (%)	$4.05^{c}\pm0.05$	$5.51^{b}\pm0.35$	$10.71^{a}\pm0.04$	$5.27^{b}\pm0.36$
Protein (%)	$6.96^{d}\pm0.41$	$10.90^{c}\pm0.19$	$15.46^{b}\pm0.40$	$60.16^{a}\pm0.40$
Carbohydrate (%)	$81.02^{a}\pm0.23$	$77.37^{b}\pm0.26$	$61.90^{c}\pm0.33$	$19.18^{d}\pm0.57$
Energy value (Kcal/g)	$388.37^{b}\pm0.23$	$402.67^{a}\pm0.27$	$405.83^{a}\pm0.32$	$364.79^{c}\pm0.40$

Values show the mean of duplicate analysis and ± standard deviation. Figures with different superscript numbers down the column are significantly different ($p<0.05$). Group BAF = Brown acha flour, WAF = White acha flour, BFF = Bread fruit flour, PC = Protein concentrate

The proximate composition of the composite flour samples is shown in Table 3. Sample B1 (100WAF:5BFF) had the least value (5.44%) for moisture content, while sample A3 (85BAF:15SBC:5BFF) had the highest value (7.80%). The moisture content of the composite flour samples is lower than the values 8.89 – 9.11% reported by Esther *et al.* [36] for chemical and functional properties of composite flours made from yellow maize, soybeans, and jackfruit seed but like the values 5.33 – 6.39% reported by Ayo and Gidado [37] for physicochemical, phytochemical and sensory evaluation of acha-carrot flours blend. The moisture content values of the composite samples were within the recommended 15% acceptability value for long-term storage of grains and the acceptable limit for dry products [38]. The lower moisture content recorded in the composite flour indicates that it will have an extended shelf life. According to Okafor and Ugwu [39], the relatively low moisture content of flour samples is important because it helps extend the shelf life if adequately protected, by inhibiting the development of contaminating microorganisms whose growth and activities are favored by the presence of moisture. It is believed that materials such as flour and starch containing more than 12% moisture have less storage stability than those with lower moisture content; for this reason, a moisture content of 10% is generally specified for flour and related products [40].

The ash content of the composite flour samples ranged from 1.34% to 2.15%. Sample B4 (80WAF:20SBC:5BFF) varies significantly ($p < 0.05$) from other samples. The ash content of the composite flour samples is higher than the values 0.21 – 1.00% reported by Edet *et al.* [41] for composite flour (blends of rice (oryza sativa), acha (digitaria exilis), and soybeans (glycine max) but varies from the values 1.96 – 3.86 reported by Okechukwu-Ezike and Oly-Alawuba [42] for blends of acha, fluted pumpkin seed, and soybean flours. There were increases in the ash content of the samples with an increase in the soybean concentrate, indicating that soybeans are a good source of ash. This finding is similar to that of Edet *et al.* [41], who reported that samples with the highest portion of soybean were observed to have the highest ash content value. The increase in ash content could also be a result of an increase in the mineral contents of the samples with an increase in soybean concentrate. According to Omeire *et al.* [43], an increase in ash content could be attributed to the fact that soybeans are high in minerals. Ash is a non-organic compound that contains mineral content, and nutritionally, it aids in the metabolism of other compounds. The ash content recorded in the composite samples could be a source of minerals, which, apart from their nutritional value, are beneficial for the skin and promote strong bones [44]. The ash content represents the total mineral content in foods and serves as an available tool for nutritional evaluation [45].

The fiber content of the composite samples increased with the addition of soybean concentrate, indicating that soybeans are a good source of dietary fiber. Gidamis et al. [46] and Sivakumar [47] reported that soybeans are an excellent source of fiber. However, the fiber content of the composite flour samples was lower than the values of 2.18 – 6.16% reported by Okechukwu-Ezike and Oly-Alawuba [42] for blends of acha, fluted pumpkin seed, and soybean flours, as well as the 2.05 - 3.00% reported by Tivde et al. [48] for the proximate, chemical, and functional properties of wheat, soy, and moringa leaf composite flours. In contrast, the values of 0.47–1.04% reported by Ayo et al. [44] for malted soybean-acha composite flour were like those observed. Crude fiber is known to add bulk to food volume, providing satiety without increasing caloric content, and it also aids the human digestive system. Whole grains are recognized as a good source of dietary fiber and are utilized in the prevention and treatment of constipation, cardiovascular diseases, and hypertension [11]. The health benefits of products made from whole grain acha are now widely acknowledged and attributed to the presence of bioactive components, including dietary fiber and phytochemicals [49].

The fat content of the composite flour samples was higher than the values of 1.20 – 4.56% reported by Ivo et al. [50] for rice flour blended with bambara groundnut flour and 2.04 – 3.50% reported by Obasi and Askepnde [51] for flour blends produced from wheat, unripe plantain, and pigeon pea. However, it was similar to the values of 5.59 – 10.11% reported by Oluwafunmilayo et al. [52] for the nutritional, phytochemical, functional, and antioxidant properties of acha, chia, and soycake flour blends. The fat content of the composite samples increased with the addition of soybean concentrate, indicating that soybean is a good source of fat. Adebowale et al. [53] reported higher fat content in legumes, and Iwe [54] also noted an increase in the fat content of whole meal acha flour due to the addition of soybean, which is a good source of oil. The high fat content recorded in sample B4 (80WAF:20SBC:5BFF) suggests that the composite flour will produce high-energy products because of the fat content. Fats and oils provide more than twice the energy of carbohydrates on a weight-weight basis [54]. One gram of fat or oil yields about 368 k/cal of energy when oxidized in the body. The high fat content of the product may inhibit microbial growth and activities, thereby improving the product's shelf life [38].

Sample A1 (100BAF:5BFF) recorded the lowest value (8.15%) for protein content, while sample B4 (80WAF:20SBC:5BFF) exhibited the highest value (19.37%). Samples A4 (80BAF:20SBC:5BFF) and B4 (80WAF:20SBC:5BFF) differed significantly ($p < 0.05$) from the other samples. The inclusion of soybean concentrate led to a significant increase in the protein content of the composite samples, indicating that soybeans are a rich source of protein. The protein content of the composite flour samples ranges from the values of 5.26% to 18.86%, as reported by Edet et al. [41] for composite flour (blends of rice (oryza sativa), acha (digitaria exilis), and soybeans (glycine max)), 7.30% to 9.79% as reported by Esther et al. [36] for the chemical and functional properties of composite flours made from yellow maize, soybeans, and jackfruit seed, and 9.00% to 16.24% reported by Ivo et al. [50] for rice flour blended with Bambara groundnut flour. The higher protein values of these composite flours will be nutritionally important in many developing countries, such as Nigeria, where many people struggle to afford high-protein foods due to cost [55]. With these results, high protein content in ready-to-eat swallows will be achieved. The presence of soybean concentrates in the formulation also contributed to the high crude protein recorded in this study. The high protein content of the flours has significant implications for a society with high protein deficiency. It will undoubtedly complement protein from cereals and other plant foods in the diets of Nigerians.

The differences in the carbohydrate contents of the composite samples can be attributed to the variations in their protein and fat content values. The carbohydrate contents of the composite samples decreased with a reduction in the quantity of the acha varieties, indicating that acha had a significant effect on the carbohydrate content of the composite samples and possesses a high carbohydrate content. The carbohydrate content of the composite flour samples is similar to the values of 64.47 – 79.26% reported by Obasi and Askepnde [51] for phytochemical, physical, and functional properties of flour blends produced from wheat, unripe plantain, and pigeon pea, and 40.06 – 78.47% reported by Olorode et al. [28] for chemical, phytochemical, and functional properties of selected seeds' flours, but higher than the values of

49.71 – 62.13% reported by Oluwafunmilayo et al. [52] for nutritional, phytochemical, functional, and antioxidant properties of acha, chia, and soycake flour blends. The substantial carbohydrate content present in acha has made it a valuable complement to the diet for diabetic individuals. It has been found that the consumption of whole acha grains by diabetic patients helps them recover due to its low glycemic index [56]. The high carbohydrate content of these samples suggests that the flours would be an excellent source of energy for the body [57]. This high carbohydrate content is attributed to the significant levels in acha, which is the principal ingredient in the samples. The overall carbohydrate content indicates that these types of flour are classified as food energy suppliers with nutritive and economical value, making them good sources for industrial flour and starch.

Sample B2 (90WAF10SBC:5BFF) varies ($p<0.05$) significantly from other samples in terms of energy values. This result could be attributed to the levels of protein, carbohydrate, and fat content in the samples. This is particularly desirable in famine and war zones where securing the next meal is challenging. High-energy foods have been shown to provide a protective effect in the optimal utilization of other nutrients [58]. Energy was noted to be high in all samples, so energy content serves as a key parameter for assessing food quality, especially for formulations designed for adults with high energy needs.

The sensory properties of the swallow from the composite flour samples are shown in Table 4. The appearance had a score ranging from 6.53 to 7.53, with sample A4 (80BAF:20SBC:5BFF) recording the highest score. The appearance of the swallow samples varies from the scores of 5.23 to 7.20 reported by Okechukwu-Ezike and Oly-Alawuba [42] for the quality evaluation of swallow meal produced from blends of acha, fluted pumpkin seed, and soybean flours, and 6.28 to 8.50 reported by Ivo et al. [50] for the quality evaluation of swallow meal produced from blends of broken rice and bambara groundnut flour. Appearance is a crucial sensory attribute that elicits the initial response from consumers regarding the product. It plays a significant role in food choice and acceptance [59].

Aroma had scores ranging from 5.67 to 6.50. The inclusion of soybean concentrate showed no significant difference ($p>0.05$) in the samples. The aroma of the swallow samples varied from the scores of 4.20 to 6.83 reported by Okechukwu-Ezike and Oly-Alawuba [42] for the quality evaluation of swallow meal produced from blends of acha, fluted pumpkin seed, and soybean flours and 4.54 to 8.28 reported by Ivo et al. [50] for the quality evaluation of swallow meal produced from blends of broken rice and bambara groundnut flour. Smell is an integral part of the overall experience of taste and the general acceptance of food before it is put in the mouth. Therefore, it is an important parameter when testing the acceptability of formulated food [59].

Sample A1 (100BAF:5BFF) received the lowest score (6.23), while sample B1 (100WAF:5BFF) achieved the highest score (6.97) for texture. The inclusion of soybean concentrates had a significant effect on the samples, except for sample B3 (85WAF:15SBC:5BFF). The texture of the swallow samples ranges from scores of 2.50 to 7.90, as reported by Okechukwu-Ezike and Oly-Alawuba [42], for quality evaluation of swallow meal produced from blends of acha, fluted pumpkin seed, and soybean flours, and from 6.17 to 8.20 as reported by Ivo et al. [50], for quality evaluation of swallow meal made from blends of broken rice and bambara groundnut flour. Texture refers to the dominant textural characteristics of a product at the point of consumption, which typically determines whether the food is swallowable or chewable [60].

The inclusion of soybean concentrate had no significant ($p>0.05$) difference in sogginess, except for sample A3 (85BAF:15SBC:5BFF) and sample A4 (80BAF:20SBC:5BFF). Flowability scores ranged from 5.57 to 6.57, with sample B3 (85WAF:15SBC:5BFF) receiving the lowest score (5.57), while samples A3 (85BAF:15SBC:5BFF) and B1 (100WAF:5BFF) had the highest scores (6.57).

Table 3. Proximate composition of the composite flour samples

Samples (%)	Moisture (%)	Ash (%)	Fiber (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Energy value (kcal/g)
Sample A1 100BAF:5BFF	7.13^{a}±0.25	1.40^{ef}±0.06	0.23^{g}±0.01	4.88^{d}±0.14	8.15^{g}±0.00	78.23^{a}±0.05	389.44^{d}±0.07
Sample A2 90BAF:10SBC:5BFF	6.03^{b}±0.17	1.61^{cd}±0.08	0.35^{f}±0.01	5.49^{cd}±0.49	14.29^{e}±0.19	72.24^{c}±0.05	395.53^{b}±0.24
Sample A3 85BAF:15SBC:5BFF	7.80^{a}±0.01	1.79^{b}±0.09	0.49^{d}±0.02	6.04^{c}±0.42	17.58^{b}±0.21	66.32^{f}±0.15	389.96^{d}±0.26
Sample A4 80BAF:20SBC:5BFF	7.60^{a}±0.51	1.54^{de}±0.04	0.65^{c}±0.01	8.27^{a}±0.21	19.05^{a}±0.06	62.39^{g}±0.44	400.19^{a}±0.24
Sample B1 100WAF:5BFF	5.44^{b}±0.09	1.34^{f}±0.03	0.22g±0.01	5.93^{c}±0.29	13.01^{f}±0.21	74.07^{b}±0.11	401.69^{a}±0.20
Sample B2 90WAF:10SBC:5BFF	7.03^{a}±0.47	1.64^{bcd}±0.01	0.43^{e}±0.02	5.93^{c}±0.06	15.41^{d}±0.00	69.58^{d}±0.39	393.33^{c}±0.15
Sample B3 85WAF:15SBC:5BFF	7.29^{a}±0.37	1.71^{bc}±0.05	0.69^{b}±0.02	7.01^{b}±0.28	16.25^{c}±0.39	67.09^{e}±0.19	396.45^{b}±0.29
Sample B4 80WAF:20SBC:5BFF	7.11^{a}±0.23	2.15^{a}±0.11	0.79^{a}±0.01	8.34^{a}±0.06	19.37^{a}±0.19	62.27^{g}±0.02	401.62^{a}±0.09

Values show the mean of duplicate analysis and ± standard deviation. Figures with different superscript numbers down the column are significantly different (p<0.05). Group BAF = Brown acha flour, WAF = White acha flour, BFF = Bread fruit flour, SBC = Soybean concentrate

Table 4. Sensory properties of the swallow meal

Sample	Appearance	Aroma	Texture	Sogginess	Flowability	Overall acceptability
Sample A1; 100BAF:5BFF	6.67^{ab}± 0.42	5.67^{b}± 0.79	6.23^{b}± 0.43	6.57^{a}± 0.74	6.23^{ab}± 0.76	6.80^{a}± 0.19
Sample A2; 90BAF:10SBC:5BFF	7.03^{ab}± 0.75	5.90^{b}± 0.83	6.53^{a}± 0.80	6.60^{a}± 0.61	6.33^{ab}± 0.67	6.93^{a}± 0.51
Sample A3; 85BAF:15SBC:5BFF	6.53^{b}± 0.31	5.83^{b}± 0.62	6.53^{a}± 0.53	6.40^{b}± 0.61	6.57^{a}± 0.38	6.80^{a}± 0.27
Sample A4; 80BAF:20SBC:5BFF	7.53^{a}± 0.43	6.30^{ab}± 0.42	6.77^{a}± 0.57	6.27^{b}± 0.26	6.43^{ab}± 0.38	6.60^{ab}± 0.30
Sample B1; 100WAF:5BFF	6.83^{ab}± 0.12	6.07^{ab}± 0.48	6.97^{a}± 0.25	5.73^{b}± 0.28	6.57^{a}± 0.72	6.30^{b}± 0.21
Sample B2; 90WAF:10SBC:5BFF	6.63^{ab}± 0.73	6.50^{a}± 0.59	6.40^{b}± 0.71	6.20^{b}± 0.47	5.73^{ab}± 0.53	6.50^{ab}± 0.28
Sample B3; 85WAF:15SBC:5BFF	6.77^{ab}± 0.77	6.37^{ab}± 0.88	6.67^{a}± 0.79	6.13^{b}± 0.61	5.57^{b}± 0.59	6.63^{ab}± 0.45
Sample B4; 80WAF:20SBC:5BFF	6.83^{ab}± 0.72	6.37^{ab}± 0.01	6.33^{b}± 0.71	6.20^{b}± 0.63	6.27^{ab}± 0.76	6.73^{ab}± 0.44

Values show the mean of duplicate analysis and ± standard deviation. Figures with different superscript numbers down the column are significantly different (p<0.05).
Group BAF = Brown acha flour, WAF = White acha flour, BFF = Bread fruit flour, SBC = Soybean concentrate

The inclusion of soybean concentrate showed no significant difference ($p > 0.05$) in the samples, except for sample B3 (85WAF:15SBC:5BFF). The flowability of the swallow samples varies from scores of 5.27 to 7.20, as reported by Ivo et al. [50], for the quality evaluation of swallow meal produced from blends of broken rice and bambara groundnut flour.

The overall acceptability score obtained from the swallow meals ranged from 6.30 to 6.93. Sample B1 (100WAF:5BFF) had the lowest score (6.30), while sample A2 (90BAF:10SBC:5BFF) achieved the highest score (6.93). The inclusion of soybean concentrate showed no significant difference ($p>0.05$) among the samples. The overall acceptability of the swallow samples varied from scores of 3.63 to 7.90, as reported by Okechukwu-Ezike and Oly-Alawuba [42] in their quality evaluation of swallow meals produced from blends of acha, fluted pumpkin seed, and soybean flours, and 5.06 to 8.03 reported by Ivo et al. [50] for swallow meals produced from blends of broken rice and bambara groundnut flour. It is evident from the mean score values for overall acceptability that the most acceptable swallow was prepared from a blend of 90% brown acha flour, 10% soybean concentrate, and 5% breadfruit flour. The variations in sensory scores among the samples could result from differing inclusion levels and the genetic variety of acha. Compared with findings from other studies, these variations may stem from differences in the plants used, species, variety, maturity, growing conditions (weather, growing season, intensity of sunlight, and soil quality), and the time and manner of harvesting. This study also indicates that all the flour samples can be used for swallow, and that the products will exhibit good organoleptic acceptability.

4. Conclusions

This study demonstrates that composite flour samples formulated from acha, fortified with soybean concentrate and whole breadfruit seed flour, exhibit superior quality characteristics compared to most flours made from a single cereal or leguminous plant material. The protein contents of the composite flour samples studied—specifically, those containing a proportion of soybean concentrate—were generally high enough to meet the recommended daily allowance (RDA) for such food materials used in diets. This addresses one of the problems identified that this research aims to solve: creating a composite flour that is rich in protein. The high protein content recorded in the composite flour samples further supports the inclusion of soybean concentrate and whole breadfruit flour in the flour formulation. The flour samples made from white acha contain more protein and fiber. Overall, the quality of the composite flour samples indicates that they are suitable for infant food formulations, baking, and the production of other food products, such as snacks and bolus meals (swallow), which is an important part of the diet in Nigeria and other developing countries and is currently gaining global recognition. Future research is recommended to investigate the shelf life of the composite flours and the food products derived from them, including the effects of storage conditions and packaging requirements. Additionally, the potential of composite flours to address nutritional deficiencies or health conditions should be explored.

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