

Evaluating the Functional Properties of Wheat-Sorghum-Sunflower Seed Flour

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Abstract

The increasing demand for healthier and functional food products has spurred interest in composite flour formulations for baking, with wheat (*Triticum spp.*) being the predominant grain due to its gluten content, which imparts elasticity and structure to baked goods. This study aimed to investigate the functional properties of wheat, sorghum (*Sorghum bicolor*), and sunflower seed (*Helianthus annuus*) flours. The methodology involved cleaning the grains and seeds, removing foreign materials, washing, and drying them at 60 °C for six hours (wheat and sorghum) and eight hours (sunflower seeds) before milling them into flour using a hammer mill (F-23ZS England). The resulting fine flours were sieved (800 microns) and stored in airtight nylon bags for further analysis. The functional properties assessed were loose bulk density (0.37 to 0.4 g/cm³), packed bulk density (0.63 to 0.72 g/cm³), swelling index (1.20 to 1.57 g/ml), water absorption capacity (1.25 to 1.55 g/g), oil absorption capacity (0.99 to 1.30 g/g), gelation capacity (13.00–15.00%), emulsion capacity (53.75–100.00%), and foaming capacity (4.81–14.29%). The findings indicate that the incorporation of sorghum and sunflower seed flours alongside wheat flour can enhance the nutritional profile and functional properties of baked products, suggesting their potential use in developing nutritious food formulations. This study contributes to the understanding of alternative flour sources in the baking industry, highlighting their functional benefits.

Keywords: Functional Properties, Wheat, Sorghum, Sunflower Seed, Composite Flour.

Introduction

Wheat originated from the Fertile Crescent region of the Near East but is now cultivated worldwide. Wheat is well adapted to harsh environments and is mainly grown in windswept areas that are too dry and cold for the more tropically inclined rice and corn, which do best at intermediate temperature levels (Shiju, 2017). In February 2019, world wheat production was 757.4 million tons, making it the third most-produced cereal after maize and rice (Sakin and Yanardağ, 2023).

Globally, wheat is the leading source of vegetable protein in human food, having higher protein content than maize (corn), rice, and other significant cereals (DeFries *et al.*, 2018). Regarding total production tonnages used for food, wheat is currently second to rice as the main human food crop and ahead of maize (Ghude *et al.*, 2016). Wheat grain is a staple food used to make flour for leavened, flat and steamed bread. (Patil, 2019). From its early cultivation in the Balkans, wheat spread to other parts of Europe, and species of wheat appeared in India probably before the fourth millennium BC, yielding varieties of wheat that have been developed through research (Betts *et al.*, 2014).

Sorghum (*Sorghum bicolor* (L.) Moench) is an important food crop in Africa. It is the fifth most important cereal crop grown in the world and the most important cereal in the Northern states of Nigeria that cover the Sahelian, Sudanian and Guinea Savannah ecological zones. Sorghum is locally called guinea corn or dawa, the most widely cultivated cereal crop and the most important food crop in the Savanna areas of Nigeria. Nigeria is the second largest producer of sorghum, grown on about 5.9 million, with current annual production estimated to be about 6.7 million tonnes. Sorghum is grown by over 59% and 55% of farmers in the Adamawa and Borno States. It is mainly grown for domestic consumption, and the excess is sold to generate income. Among the constraints to sorghum production are subsistence farmers who invest little in fertilizer and improved varieties, rising labour costs, changing consumer food preferences, bird attacks and parasitic weeds such as Striga. Another major problem is the variable rainfall that leads to wild fluctuations in production. Prices fall abruptly in good years, leaving traders reluctant to enter the market. This increases the price risk that sorghum producers face, hence their reluctance to invest in commercial sorghum production (Ajeigbe *et al.*, 2020).

Sunflower (*Helianthus annuus*) is an oilseed crop native to North America. It is cultivated worldwide, and most of its products have been commercialized as culinary or livestock feed (Yegorov *et al.*, 2019). Adapting sunflowers to different climatic and soil conditions has enhanced their cultivation as an oilseed plant worldwide (Forleo *et al.*, 2018). The growth of sunflowers requires fertile soil, moderate rainfall, viable seeds, etc. Among the three leading oilseed crops, soybeans, rapeseed, and sunflower, in the world today, sunflower has been recognized as a significant source of high-quality edible oil that is most used for culinary purposes (Pal *et al.*, 2015).

Sunflower is one of the important oilseed crops grown worldwide as a source of premium oil and dietary fibre that significantly contributes to human health (Khan *et al.*, 2015). In some countries like India and South Africa, growing sunflowers might be more competitive with other crops like maize, soybeans, and sorghum (Adeleke and Babalola, 2020). Due to the continuous increase in the human population, the demand for edible sunflower seeds, oil, and by-products has also increased, and to meet the demand, there is a need to intensify efforts to expand sunflower output (Taher *et al.*, 2017). Today, the international oilseed market is dominated mainly by sunflowers and other crops such as soybean, rapeseed, peanut, and cottonseed.

Functional properties are the essential physiochemical properties of foods that reflect the complex interactions between the structures, molecular conformation, compositions, and physicochemical properties of food components with the nature of the environment and conditions in which these are measured and associated (Awuchi *et al.*, 2019). Functional characteristics are required to possibly help to predict and precisely evaluate how new proteins, fat, carbohydrates (starch and sugars), and fibre may behave in specific food systems, as well as demonstrate whether or not such can be used to stimulate or replace conventional protein, (Awuchi *et al.*, 2019) fat, carbohydrates (starch and sugars), and fibre. Functional properties also describe the behaviour of ingredients during preparation and cooking, and how they affect the finished food products in terms of how they look, feel and taste. Functional properties include Swelling capacity, water absorption capacity, oil absorption capacity, Emulsion activity, Emulsion stability, Foam capacity, Foam stability, Gelatinization, Bulk density, Dextrinization, Preserving, Denaturation, Coagulation, Gluten formation, Jelling, Shortening, Plasticity, Flakiness, Retention of moisture, Aeration, Sensory attributes, among others (Awuchi *et al.*, 2019). The functional property of food is characterized by the structure, quality, texture, nutritional value, acceptability, and (or) appearance of the food product. The organoleptic, physical, and chemical properties of the food often determine the functional properties of the food. Further examples of functional properties of foods and flour include solubility, water retention, frothing ability, elasticity, absorptive capacity for fat and foreign particles, emulsification, hydration (water binding), viscosity, cohesion, and adhesion (Awuchi *et al.*, 2019).

The inability of the country to meet the industrial demand for wheat has caused a constant rise in the prices of baked products like cake and biscuits, which, in turn, has resulted in a call for research into alternative local sources of flour for baking. Most of the typical local cereal grains, including sorghum and oil seed plants such as sunflower seeds, though having similar structure and composition were left in a state of underdevelopment and inadequate processing due to the ignorance of the industrialists. Wheat is becoming a rare commodity owing to the high rate of population growth and its high global consumption rate. They are low in protein content; hence, their products have low protein content. Wheat is considered nutritionally poor, as cereal proteins are deficient in essential amino acids such as lysine and threonine (Sibian *et al.*, 2017).

Despite the known nutritional benefits of sorghum and sunflower seeds, there is limited research on the functional properties of flours derived from these sources in comparison to wheat flour. This study seeks to fill this gap by systematically analyzing the functional characteristics of these flours, including their water absorption capacity, oil absorption capacity, and emulsifying properties.

The study's main objective is to assess the functional properties of flours from wheat, sorghum and sunflower seeds. The specific objectives are to produce flours from seeds of wheat, sorghum and sunflower and to determine the functional properties of wheat, sorghum and sunflower seeds. The research will help nutrition education by helping the

general public understand that flour from sunflower seeds could be used in food preparations.

Materials and Methods

Source of Raw Materials

Wheat and sorghum were bought from Eziukwu Aba market, Abia State, Nigeria while sunflower seeds were bought from Kano market in northern Nigeria. The white variety of sorghum grain and dwarf wheat were selected, and high sun 33 variety of sunflower seeds were chosen.

Sample Preparation

Cleaning and preparation of wheat flour

The wheat was cleaned, stones and other foreign materials removed and the cleaned sample was washed and dried at 60°C for six hours in an oven and milled using a Hammer mill (F-23ZS England) into flour. Wheat fine flour was obtained using a sieve of 800 microns and packaged in an airtight nylon for further use (Figure 1).

Cleaning and preparation of sorghum flour

Pebbles and other extraneous particles were handpicked. A flat metal tray was used to winnow out sand and dust. The cleaned sample was washed and dried at 60°C for six hours in an oven. The dried sorghum was milled using a Hammer mill (F-23ZS England) sieved using a sieve of 800 microns to obtain fine flour powder and packaged in airtight nylon for further use (Figure 2).

Cleaning and preparation of Sunflower seed flour

Sunflower seeds were cleaned, and other foreign materials were sorted; the cleaned sample was washed and dried at 60°C for six hours in an oven. The sample was then milled using a Hammer mill (F-23ZS England) until the seeds were finely broken; ground sunflower seeds flour was arranged in trays and dried in an electric air-drying oven, using the temperature of 60°C for 8 hours to enable sunflower flour to pass through a tiny open sieve of 800 microns to obtain fine flour and packaged in an airtight nylon for further use (Figure 3).

Cleaning

(The wheat grains were thoroughly cleaned; Stones and other foreign materials were removed).

Washing and Drying

(The cleaned wheat was washed with clean water; and dried in a hot air oven at 60°C for 6 hours).

Milling

(Dried wheat was milled using a hammer mill (F-23ZS, England)).

Sieving

(The milled flour was sieved using an 800-micron mesh; this process yielded fine wheat powder).

Packaging

(The fine flour was packaged in airtight nylon bags; stored properly for further use.

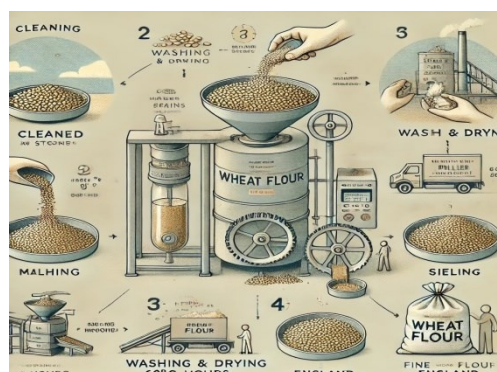


Figure 1: Flow chart for processing of wheat seed flour

Source: Dziki (2023).

Sorting

(Pebbles and extraneous particles were handpicked manually).

Winnowing

(A flat metal tray was used to winnow out sand and dust from the grains).

Washing and Drying

(The cleaned sorghum grains were washed thoroughly and dried in a hot air oven at 60°C for 6 hours).

Milling

(Dried sorghum was milled using a hammer mill (F-23ZS, England).

Sieving

(The flour was sieved using an 800-micron mesh sieve; this process produced fine sorghum powder).

Packaging

(The fine flour was packaged in airtight nylon bags and stored properly for further use.



Figure 2: Flow chart for processing of sorghum seed flour

Source: Palavecino *et al.* (2016)

Cleaning

(Sunflower seeds were cleaned and foreign materials were manually sorted).

Washing and Initial Drying

(The cleaned seeds were thoroughly washed; and dried in an oven at 60°C for 6 hours).

Milling

(The dried seeds were milled using a hammer mill (F-23ZS, England); and milled until finely broken into coarse flour).

Tray Drying

(The ground flour was arranged in trays; and further dried in an electric air-drying oven at 60°C for 8 hours).

Sieving

(The dried flour was sieved through an 800-micron mesh sieve; this produced a fine sunflower seed powder).

Packaging

(The final product was packaged in airtight nylon bags; and stored for further use).



Figure 3: Flow chart for processing of sunflower seed flour

Source: (Tamilselvan and Kushwaha, 2020)

Functional Properties

The functional properties of the flour samples were evaluated, including bulk density, swelling index, water and oil absorption capacities, gelation capacity, foam stability, and foam capacity was determined.

Determination of bulk density

The bulk density of the flour samples was determined using the method described by Onwuka (2018). A 10ml graduated cylinder was filled with the sample. The bottom of the cylinder was gently tapped on a laboratory bench several times. The process was repeated until there was no further diminution of the sample level after filling the 10ml mark. Bulk density was calculated as the weight of samples per unit volume of sample (g/ml).

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of Sample (g)}}{\text{Volume of Sample (ml)}}$$

Determination of swelling index

Using the technique outlined by Mbanali *et al.* (2018), the swelling index was calculated. It was calculated as the proportion of the swollen volume of extra water. One gramme sample of flour was mixed with 10 ml of distilled water in a calibrated 10-millilitre measuring cylinder, and the volume was recorded. For one hour, the cylinder was allowed to remain undisturbed. After recording the volume that the sample subsequently occupied, the swelling capacity was computed as follows:

$$\text{Swelling Index} = \frac{\text{Volume occupied by sample after swelling}}{\text{Volume occupied by sample before swelling}}$$

Determination of water/oil absorption capacity

According to Peter-Ikechukwu *et al.* (2020), the water and oil absorption capacity was determined. Ten millilitres of distilled water or oil were added to a graduated centrifuge tube containing a sample weighing one gram. After that, the sample was well combined and left to stand at room temperature for half an hour. For thirty minutes, the mixture was centrifuged at 4000 rpm. To convert the volume of free water or oil (the supernatant) to grams, its density was multiplied. The result was expressed as grams of water or oil absorbed per gram of sample. It was assumed that oil had a density of 0.88 g/ml and water had a density of 1 g/ml.

$$\text{WAC/OAC} = \frac{V_1 - V_2}{W} D$$

Where:

WAC	=	Water absorption capacity
OAC	=	Oil absorption capacity
V ₁	=	Initial volume of water or oil
V ₂	=	Final volume after centrifuging
W	=	Weight of sample.
D	=	Density of water/ oil

Determination of gelation capacity

A modified Onwuka (2018) method was used to determine gelation capacity. Flour suspensions of 2-20% (W/V) were prepared in 5ml distilled water in test tubes. The suspensions were boiled in a water bath for 1 hour, followed by rapid cooling under cold tap water. The lowest concentration at which the gel formed did not collapse or slip from the inverted test tube and was regarded as the most negligible gelling concentration or gelation capacity.

Determination of Emulsion Capacity

The emulsion capacity was determined using the method described by Onwuka (2018). From each sample, 2 g was blended with 25 ml of distilled water at room temperature for 30 seconds in a warming blender at 1600 rpm. After complete dispersion, 25 ml of vegetable oil was gradually added, and the blending continued for another 30 seconds. Then the mixture was transferred into a centrifuge tube and centrifuged at 1600 rpm for 5 minutes. The volume of oil separated from the sample was read directly from the tube after centrifuging. The emulsion capacity was expressed as the amount of oil emulsified and held per gram of sample.

$$\text{Emulsion capacity} = \frac{\text{Height of emulsified layer}}{\text{Height of whole solution in the centrifuge tube}} \times 100$$

Determination of Foam Capacity

The Chukwu *et al.* (2018) method was utilized to ascertain the foam capacity. Each sample was weighed out at 2 g, and it was blended for 5 minutes at 1600 rpm using 100 ml of distilled water in a blender. A 150 ml graduated cylinder was filled with the whipped mixture. After being cleaned with 10 millilitres of distilled water, the blender jar was carefully placed into the graduated cylinder, and after 30 seconds, the volume was recorded. Volumes recorded both before and after whipping were computed as follows:

$$\text{Foam capacity} = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100$$

Statistical analysis

The data generated from the samples' functional analysis were subjected to Analysis of variance (ANOVA) using the statistical package for social science (SPSS) version 23. The means were separated, and statistical significance was considered at p-values ($P \leq 0.05$).

Results and Discussion

Functional Properties of Flours of Wheat, Sorghum and Sunflower Seeds

The functional properties of the wheat, sorghum and sunflower seed flours are presented in Table 1.

Bulk Density

The result revealed that the loose bulk density of the flour samples was significantly ($p \leq 0.05$) different, ranging from 0.37 g/cm^3 in wheat and sunflower flour to 0.40 g/cm^3 in sorghum flour. However, the loose bulk density of the sorghum flour was significantly the highest of the three flour samples. There was no significant difference in the packed bulk density of the flour samples as their content ranged from 0.63 g/cm^3 in the wheat flour to 0.72 g/cm^3 in the sorghum flour. The bulk density of flour is a favourable attribute and a function of the transport and storage of the flour. The loose bulk density of the flour samples was significant. This was in line with the findings of Mudau *et al.* (2021). The loose bulk density of the sorghum flour (0.40 g/cm^3) was significantly the highest of the three flour samples. The figures obtained in this study were slightly lower than but comparable with the $0.45\text{--}0.48 \text{ g/mL}$ reported for loosed bulk density of wheat and finger millet flour by Mudau *et al.* (2021). There was no significant difference in the packed bulk density of the flour samples as their content ranged from 0.63 g/cm^3 in the wheat flour to 0.72 g/cm^3 in the sorghum flour, Omah and Okafor (2015) and Mudau *et al.* (2021) reported similar findings on packed bulk density on wheat and millet pigeon pea flour which ranged from 0.64 to 0.81 g/mL . The variation in bulk density of foods could be attributed to the variation in the starch content of the foods. The higher the starch, the more likely the increase in bulk density; also, bulk density depends on factors such as geometry, method of measurement, particle size, surface properties, and solid density of the material (Awuchi *et al.*, 2019).

Swelling Index

The swelling index of the flour samples ranged from 1.20 mL in the sorghum to 1.57 mL in the wheat flour, with the wheat flour being significantly the highest of the three samples. In contrast, sorghum flour recorded the lowest value for the swelling index. The swelling index (SI), also known as swelling capacity (SC), is the volume in millilitre taken up by the swelling of one gram (1g) of food material under specific conditions. Its determination is based on the water addition or addition of a swelling agent as indicated in the test procedure for every food material (whole, pulverized, or cut) (Awuchi *et al.*, 2019). The swelling index of the flour samples was significantly different, ranging from 1.20 mL in the sorghum to 1.57 mL in the wheat flour, with the wheat flour being significantly the highest of the three samples. This was contrary to the results of Mabogo *et al.* (2021), who reported a swelling index of 1.03 mL for wheat. However, the values obtained in this present study were comparable with the 1.03 to 2.04 mL range reported by Mabogo *et al.* (2021) for the partial replacement of wheat flour with unripe banana flour. Swelling capacity (index) is considered a quality measure in some food products, such as bakery products. It indicates the non-covalent bonding between the molecules of starch granules and one of the factors of the α -amylose and amylopectin ratios (Iwe *et al.*, 2016). The swelling capacity (index) of flour is influenced by the particle size, species variety and method of processing or unit operations (Suresh and Samsher, 2013).

Water Absorption Capacity

The water absorption capacity of the flour samples showed that the wheat flour (1.57) recorded the highest significant score when compared with the other flour samples, and the sunflower flour (1.25g/g) recorded the lowest value. Water absorption capacity (WAC), also called water absorption, is the amount of water (moisture) taken up by food/flour to achieve the desirable consistency and create quality food products (Awuchi *et al.*, 2019). The water absorption capacity (WAC) of flour indicates the amount of water available for gelatinization (Eke-Ejiofor and Oparaodu, 2019; Mudau *et al.*, 2021). The water absorption capacity of the flour samples in the present study showed that the wheat flour (1.57g/g) recorded the highest significant value. The figure reported in the present study for wheat flour was slightly lower than the 1.85g/g reported by Joshi *et al.* (2015) for wheat flour. However, the water absorption capacity of the flour samples in this present study was higher than what was reported for other seed flours such as peanut (1.12g/g) and cashew (0.96g/g) (Joshi *et al.*, 2015). The sunflower flour (1.25g/g) recorded the lowest value. High WAC value can be attributed to many hydrophilic components contained in foods, such as carbohydrates (especially polysaccharides), proteins, especially polar amino acid residues, which have a high affinity for water molecules (Sreerama *et al.*, 2012), and other hydrophilic constituents (Awuchi *et al.*, 2019). The variation in the water absorption capacity of the flour samples could be attributed to the following factors: starch content of the flour samples, pentosans composition of the flour samples, the composition of proteins in the flour sample, vital wheat gluten, and the presence of other water binding ingredients such as fibre, bran hydrocolloids (gums), eggs etc.

Oil Absorption Capacity

The oil absorption capacity of the flour samples ranged from (1.30g/g) in the wheat flour to 0.50g/g in the sunflower flour. Oil absorption capacity (OAC), also called water absorption, is the binding of fat by the non-polar side chain of proteins. The Oil absorption capacity is an essential functional property that contributes to enhancing mouth feel while retaining the food products' flavour (Iwe *et al.*, 2016). The oil absorption capacity of the flour samples in this present study were significantly different ranging from 0.50g/g in the sunflower flour to 1.30g/g in the wheat flour. The values obtained in this study were comparable with those reported for other seed flours such as millet (0.86g/g), wheat (1.05g/g), rice (0.75g/g), sesame (1.17g/g), soybean (1.23g/g), peanut (0.98g/g), chickpea (0.94g/g), walnut (1.19g/g), cashew (0.95g/g) (Joshi *et al.*, 2015). The oil absorption rate is very high in foods with high protein content. The protein's oil and water binding capacity in food depends on intrinsic factors such as protein conformation, amino acid composition, and surface polarity or hydrophobicity (Suresh and Samsher, 2013; Awuchi *et al.*, 2019). The ability of flours to bind with oil makes them useful in food applications where optimal oil absorption is desired, making flours have potential functional applications in foods such as pastries and sausage production. The oil absorption capacity also makes the flour suitable for facilitating

enhancement in flavour and mouth feel when used in food preparation (Suresh and Samsher, 2013; Awuchi *et al.*, 2019). The possible reason for the increase in the OAC of flours is the presence of non-polar side chains, which may bind the oil hydrocarbon side chains in foods and flours. The flours with high OAC are potentially beneficial in structural interactions in foods, especially for the improvement of palatability, an extension of shelf life, and flavour retention particularly, in meat or bakery products where fat absorption is desirable (Suresh *et al.*, 2015; Awuchi *et al.*, 2019).

Gelation Capacity

The gelation capacity of the samples was similar, ranging from 13% in the sorghum flour to 15% in the sunflower flour. Gelatinization is breaking down intermolecular bonds of starch molecules in the presence of heat and water, allowing the hydrogen bonding sites (hydroxyl and oxygen) to absorb more water. The gelation capacity of the samples was not significantly different, ranging from 13% in the sorghum flour to 15% in the sunflower flour. The figures observed in this present study for gelation capacity were comparable with those reported for other seed flours such as millet (18%), wheat (14%), rice (18%), sesame (16%), soybean (16%), peanut (16%), chickpea (12%), walnut (18%), and cashew (8%) (Joshi *et al.*, 2015). Starch gelatinization improves and increases the availability of starch for hydrolysis by amylase. Gelatinization of starch is constantly used in the cooking and food industries to make

starch is digestible and thickens/binds water in sauce, soup, and roux (Awuchi *et al.*, 2019). This implies that the flours were suitable thickeners in food production/preparation; also, the variations in the gelation capacity could be attributed to several factors such as types of starch, stirring, water, temperature, addition (presence) of other ingredients, such as protein, sugar, acids, fat, etc. The degree of gelation affects the dough's viscosity and elasticity. A well-gelatinized dough exhibits improved handling properties, making it easier to shape and mould. Additionally, the gel matrix contributes to the retention of carbon dioxide produced during fermentation, which is crucial for achieving the desired volume and texture in the final product. Insufficient gelation, on the other hand, can lead to a dense and heavy texture, as the dough fails to trap gas effectively (Zhang and Wang, 2023).

Emulsion Capacity

The emulsion capacity of the flour samples was significantly different, ranging from 53.75% in the sorghum flour to 100% in the sunflower flour. The emulsifying capacity, also called emulsion capacity (EC), of foods is associated with the amount of oil, and non-polar amino acid residues on the surface of protein, water, and other components in the food. The emulsion capacity of the flour samples was significantly different ranging from 53.75% in the sorghum flour to 100% in the sunflower flour. These figures were significantly higher than the range of values (1.52-3.17%) reported by Peter-Ikechukwu (2020) for composite flours produced from date fruit pulp, toasted watermelon seed and wheat. The high

emulsion capacity observed in this present study indicates that the flour samples could be an excellent emulsifier in various foods (Peter-Ikechukwu, 2020). This significant increase in EC could be attributed to protein being the surface-active agents and can form and stabilize the emulsion by creating electrostatic interaction on the oil droplet surface (Peter-Ikechukwu, 2020).

Foaming Capacity

Also, the study observed a significant difference in the foaming capacity of the flour samples as the sunflower flour (14.29%) was the highest while sorghum flour (4.81%) recorded the lowest value. The foaming capacity of a food or flour is measured as the amount of interfacial area created by whipping the food or flour. Foam stability is a measure of the time required to lose either 50 percent of the liquid or 50 percent of the volume from the foam (Awuchi *et al.*, 2019). The study observed a significant difference in the foaming capacity of the flour samples as the sunflower flour (14.29%) was the highest while sorghum flour (4.81%) recorded the lowest value. The figures presented in this study were comparable with the 9.48% to 11.95% reported by Peter-Ikechukwu *et al.* (2020) for composite flour produced with date fruit pulp, toasted watermelon seed and wheat. Generally, heating globular protein to accomplish partial denaturation will increase the foaming properties. As the structure gradually unfolds and exposes hydrophobic sites and tails, it may adsorb more rapidly to air-water interfaces and reduce the interfacial tension, thereby entrapping more air bubbles and increasing the foaming capacity of the food (Awuchi *et al.*, 2019). Extensive heat denaturation of proteins decreases their foaming capability. Well-aerated dough results in a light and airy texture, which is particularly desirable in cakes and soufflés. The stability of the foam is crucial; if the foam collapses before or during baking, the final product may be dense and unappealing. The ability of the dough to maintain its structure while allowing for gas expansion is vital to achieving the desired volume and crumb structure (Zhang and Wang, 2023).

Table 1 Functional properties of the flour samples

Parameter	Sample A	Sample B	Sample C	LSD _{0.05}
Loose Bulk Density (g/cm ³)	0.37 ^b ±0.00	0.40 ^a ±0.00	0.37 ^b ±0.00	0.021
Packed Bulk Density (g/cm ³)	0.63 ^a ±0.03	0.72 ^a ±0.07	0.64 ^a ±0.00	0.033
Swelling Index (mL)	1.57 ^a ±0.02	1.20 ^c ±0.03	1.35 ^b ±0.01	0.102
Water Absorption Capacity (g/g)	1.55 ^a ±0.07	1.45 ^{ab} ±0.07	1.25 ^b ±0.07	0.221
Oil Absorption Capacity (g/g)	1.30 ^a ±0.02	0.99 ^b ±0.04	0.50 ^c ±0.02	0.323
Gelation Capacity (%)	14.00 ^a ±0.00	13.00 ^a ±1.41	15.00 ^a ±1.41	2.22
Emulsion Capacity (%)	94.74 ^b ±0.15	53.75 ^c ±0.19	100.00 ^a ±0.00	4.748
Foaming Capacity (%)	7.49 ^b ±0.23	4.81 ^c ±0.22	14.29 ^a ±0.24	2.031

Values are means ± standard deviations of duplicate samples. ^{A-c} Means with the same superscripts across the rows are not significantly different (P>0.05). ^{A-c} Means with different superscripts across the rows are significantly different (P<0.05).

Key:

Sample A: Wheat flour

Sample B: Sorghum flour

Sample C: Sunflower flour

LSD_{0.05} = Least Significant Difference at $p \leq 0.05$

Conclusion

The functional properties of flour blends play a crucial role in determining the quality of baked products. This study evaluates the effects of incorporating wheat, sorghum and sunflower seed flour on dough rheology, texture, and overall product characteristics. Understanding these functional interactions is essential for optimizing flour formulations in the baking industry.

The evaluation of the functional properties of wheat-sorghum-sunflower seed flour has yielded significant insights into its potential applications in food science and technology. The findings indicate that the loose bulk density of the flour ranged from 0.37 to 0.60 g/cm³, while the packed bulk density varied between 0.63 and 0.72 g/cm³. These density measurements are crucial as they influence the texture and mouthfeel of food products, indicating that this flour blend may be suitable for various formulations, particularly in baked goods where density plays a vital role in product quality.

The swelling index, which ranged from 1.20 to 1.57 ml, suggests that the flour has a moderate capacity to absorb water and swell, a property that is essential for products requiring hydration, such as doughs and batters. The water absorption capacity of 1.25 to 1.55 g/g further supports this, indicating that the flour can effectively retain moisture, which is beneficial for the shelf life and texture of food products.

Moreover, the oil absorption capacity, measured between 0.99 and 1.30 g/g, highlights the flour's potential in formulations where fat content is critical, such as in the production of snacks and fried foods. The gelation capacity, ranging from 13.00% to 15.00%, suggests that the flour can form gels, which may be advantageous in creating stable emulsions and improving the texture of various food products.

The emulsion capacity, which varied from 53.75% to 100.00%, indicates that the flour can effectively stabilize emulsions, making it a valuable ingredient in dressings, sauces, and other emulsified products. Additionally, the foaming capacity, ranging from 4.81% to 14.29%, suggests that the flour can incorporate air, which is beneficial in products like cakes and mousses where aeration is desired.

The practical implications of these findings are significant for the food industry, as they suggest that wheat-sorghum-sunflower seed flour can be utilized in applications, enhancing both the nutritional profile and functional characteristics of food products. Future research should focus on exploring the interactions between these flours and other ingredients in different formulations, as well as conducting sensory evaluations to assess consumer acceptance. Additionally, investigating the nutritional benefits of this flour

blend, particularly its potential as a gluten-free alternative, could provide valuable insights for health-conscious consumers.

Recommendations

1. **Adopt Ratio Optimization:** Food manufacturers should experiment with different ratios of wheat, sorghum, and sunflower seed flour to identify the optimal blend that maximizes functional properties while maintaining product quality. This optimization can lead to improved texture, taste, and nutritional benefits.
2. **Conduct Sensory Evaluations:** It is recommended that companies perform sensory evaluations to assess consumer acceptance of products made with this flour blend. Understanding consumer preferences will guide product development and marketing strategies.
3. **Explore Gluten-Free Applications:** Given the potential of this flour blend as a gluten-free alternative, further research should be conducted to explore its use in gluten-free formulations. This could cater to the growing market of health-conscious consumers seeking gluten-free options.
4. **Investigate Ingredient Interactions:** Future studies should focus on the interactions between wheat-sorghum-sunflower seed flour and other ingredients in various formulations. This research will provide insights into how to enhance the functional properties of flour in different food applications.
5. **Evaluate Nutritional Benefits:** It is essential to investigate the nutritional profile of the flour blend, particularly its health benefits. This information can be valuable for marketing and positioning the product as a nutritious alternative in the food industry.
6. **Develop Targeted Product Lines:** Food companies should consider developing targeted product lines that leverage the unique properties of wheat-sorghum-sunflower seed flour. This could include products aimed at specific dietary needs, such as high-protein snacks or low-fat baked goods.

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Conflict of Interests

The author declared no conflict of interest, as this work has not been published elsewhere, and is not under consideration for publication in any other journal.

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