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CHEMICAL COMPOSITION AND FUNCTIONAL PROPERTIES OF WHOLE WHEAT (TRITICUM DURUM) AND DEFATTED SESAME SEEDS COMPOSITE FLOUR BLENDS

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ABSTRACT: This study assessed the chemical composition and functional properties of flour blends produced from whole wheat and defatted sesame seeds flour blends formulated in respective percentages ratio of 100:00 (WF), 95:5 (WDS1), 90:10 (WDS2), 85:15 (WDS3) and 80:20 (WDS4). The 100 % (WF) served as the control and standard analytical protocols were used. The results showed an increase in crude protein (12.93-22.07 g/100g), crude fat (2.82 – 6.92 g/100g), ash (1.90 – 3.06 g/100 g) and crude fibre (8.03 – 9.45 g/100 g) with increase in defatted sesame seed flour substitution. The micronutrients results were lowest in the control (WF) and highest at WDS4 with values ranging between 26.74 to 158.45 mg/100g, 3.11 to 17.87 mg/100g and 79.84 to 260.75 mg/100g for calcium, sodium and potassium respectively. While Vitamin B6 and Vitamin E ranged between 0.20 to 1.24 mg/100g and 2.30 to 13.84 mg/100g signifying an approximate increase of 520 % and 502 % respectively. The whole wheat flour exhibited higher peak viscosity and breakdown viscosity of 3265 cP and 1414 cP than the composite flours. Also, the pasting temperature and pasting time decreased with increase in substitution of defatted sesame seeds flours. These results showed that the defatted sesame seeds substitution of up to 20 % improved the nutritional value and the functional properties which could be advantageous and this justifies the use of defatted sesame seeds and whole wheat flour in bakery and food system in general.

Key words: Functional properties, Whole Wheat, Defatted, Sesame Seed, Flour blends

INTRODUCTION

In recent times, composite flour has become the subject of focus in innovative flour development to replace or reduce the traditional wheat used in pastries and other food product development (Emmanuel *et al*., 2019; Nyembwe *et al*., 2018). Composite flour are combination of crop flours from tubers, roots and /or protein-rich flours such as ground nut, sesame seeds, lentils and /or cereals (which may or may not include wheat flour) created to improve specific functional and nutritional characteristics. Composite flour has the advantage of providing an improved supply of proteins and other nutrients to better human nutrition and overall health; other advantages include saving of foreign exchange especially in areas where wheat is not produced, improvement of domestic agriculture and rural income generation (Banu et al., 2021).

Wheat is a widely cultivated and leading staple cereal crop of the *Poaceae* family (Igbal *et al*., 2022). It is an exceptional crop of importance in human diet with an estimate of 80 million peasants depending on it for sustenance especially in the developing nations (Giraldo *et al*., 2019). After rice, wheat is rated as the second most powerful food crop, in ensuring food security in the undeveloped nations (FAOSTAT, 2020). Whole wheat flour is the milled whole grains of wheat which consists of the intact (proportion as they exist in intact caryopsis), ground, cracked, or flaked kernel after the removal of inedible parts, such as the hull and husk (Gomez *et al*., 2020). Whole wheat flour has about 71.20 % carbohydrate, 10.60 % fibre, protein 15.60 % and lipids 2.73%. It has also been reported to decrease the risk some kind of chronic diseases such as type 2 diabetes, cancer, cardiovascular disease and these positive effects are

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ascribed to the fibre and the phytochemicals contents in the flours. Despite these nutritional and health benefits attributed to it, the consumption is reported to be extremely lower than the recommended levels (Li *et al*., 2019).

Sesame (*Sesamum indicum L*.) is a widely grown plant of the *Pedaliaceae* family and it is reported to be one of the first oil crops with high versatility (Wei *et al*., 2022). Though underutilized, sesame seeds have been described as an 'all-purpose nutrient bank' because of its rich nutritional content (Ayo-Omogie, 2023; Wei *et al*., 2022; Haxia and Lu, 2015). In addition to having a richer nutritional profile than other seed proteins due to significant amounts of both essential and nonessential amino acids, the seeds have an enticing flavor that makes them more desirable in the diet (Idowu *et al*., 2021).Though the protein contents varies in the varieties and increase as the colour deepens (Vangaveti *et al*., 2016), generally, it has more protein (17 to 40%) compared to meat (18–25%) and cereals (7 to 13%), high amount of fat (61.7%) and mineral such as iron and calcium has been reported in appreciable amount in sesame seeds (Bassogog *et al*., 2020; Rout *et al.,* 2018). Sesame oil is the primary product produced from sesame seeds and defatted sesame seed/sesame meal is the by-product after the oil extraction (Agrahar-Murugkar *et al*., 2018). The defatted sesame seed possesses exceptional nutritional value because of its high dietary fibre, certain micronutrients, high-quality protein with a balanced amino acid composition. It has been found to contain significant bioactive compounds with high antioxidant activity such as sesamintriglucoside lignans and sesamindiglucoside compounds which exerts health-promoting effects (Melo *et al.*, 2021). The defatted sesame seeds cake is mostly used in animal feed as protein supplement and supplementation in variety of food products as a way to increase the protein quality and content (Chitra, 2021).

Composite flour utilization/application has been mandated by law in Nigeria in an effort to decrease the country's reliance on imported wheat, increase the utilization of domestic crops, and lower the price of baked goods (Okpala and Chinyelu, 2011; Agu and Okoli, 2014) prompting several researches in composite and alternative flour use in bakery and other food products. Several researchers have reported majorly on the substitution of wheat flour especially the refined flour with some oil seeds (Ocheme *et al*., 2018) and/or combination with root crops (Ariyo *et al.*, 2022; Chandra *et al*., 2015) to produce wheat-based product. It is however disturbing that Nigeria still stands as the fourth importer of wheat in the world and as at the year 2022, wheat is the second most imported product amounting to $3.03 billion according to Nigerian Bureau of Statistics 2023 foreign trade report (NBS, 2023).

Chemical properties and functional characteristics amongst others are factors determining the end use of a flour as they can be used to evaluate and predict the behaviour of new proteins, fat, carbohydrates (starch and sugars), and fibre during processing. Functional properties also describe the behaviour of ingredients as well as how they affect the finished food products with respect to some attributes such as the appearance, flavour and texture during preparation/processing. This study therefore is aimed at assessing the chemical and functional properties of whole wheat flour and defatted sesame seeds flour blends. The blends of whole wheat and defatted sesame seeds could increase the utilization of sesame seeds.

MATERIALS AND METHODS

Source of Materials and Preparation of Whole Wheat Flours and Defatted Sesame Seeds Flour

Whole wheat (*Triticum durum*) and white variety of sesame seeds (*Sesanum indicum*) were obtained from the local Kure Central Market, Minna, Niger State and Jos main market Plateau state, Nigeria respectively. Processing and other analyses were carried out in the Food Science and Technology Processing Laboratory, Federal University of Technology Minna Nigeria. Analytical grade chemicals (Sigma- Aldrich) were used for the analyses.

The whole wheat grains were sorted and washed to further remove extraneous particles. This was followed by drying (solar drying) for 48 h, milling and sieving (250 µm sieve) to fine flour and packaged in a Ziplock bag. The defatted sesame seeds flour was produced by adopting the method described by Chinma *et al.* (2012). Sesame seeds were sorted and all foreign materials were removed and soaked (12 h) in clean tap water at room temperature and dehulled by hand rubbing and the use floatation technique, drained to remove the outer coatings and water blanched (100 ºC, 5 minutes), drained and solar dried for 72 h and milled into flour using an attrition mill (R175A Model) to obtain a full fat sesame seeds flour. The full fat sesame seed oil was extracted by weighing 500 g into a white muslin cloth and one liter (1 l) of n-hexane was added and allowed to stand for 12 h and the oil was extracted into an aluminium pan. This process of oil extraction was repeated and allowed to stand for 6 h and the top layer was decanted and the defatted sesame seed flour was air dried for 3 h to evaporate off the solvent's odor completely milled using a blender (Kenwood, model: BY-823) sieved using a 250 µm mesh size sieve. The dried defatted seeds flours was then poured in plastic containers (ZipLock, China) covered with lids and kept at 10 ± 2°C until required for use.

Whole Wheat Flour and Defatted Sesame Seed Flours Composite Blending

Whole wheat and defatted sesame seeds flours at the ratios of 100:0 (WF), 95:5 (WDS1), 90:10 (WDS2), 85:15 (WDS3), and 80:20 (WDS4) were homogenized using a Kenwood Chef Mixer (A901) to achieve a homogenous flour samples. The WF (100% whole wheat flour) served as the control sample.

Determination of Chemical Properties

The proximate and micronutrients composition were the chemical analyses carried out on the flour blends. The AOAC (2012) method was adopted for the determination of the crude protein, crude fat, total ash, moisture, and crude fiber contents of the flour blends. Carbohydrate content (%) was determined by difference using the formula;

$$\%\text{Carbohydrate} = 100 - (\text{Moisture} + \text{Crude fibre} + \text{Crude protein} + \text{Ash} + \text{Crude fat}) \ldots\ldots (1)$$

The energy value (EV) was determined in Kcal/100g using the Atwater factor equation;

$$EV = [(4 \times \text{Crude protein }\%) + (9 \times \text{Crude Fat }\%) + (4 \times \text{Carbohydrate }\%)] \qquad (2)$$

The AOAC (2012) protocol was employed for the micronutrients determination. Essentially, one gram (1 g) of the flour sample was weighed into a 250 ml Kjeldahl distillation glass and wet digested using 20 ml of HNO_3-$HClO_4$ acid solution (2:1 volume). Heat was applied until the mixture turned colorless. Subsequently, the sample solution was poured into a 100 ml calibrated sample bottle and the solution was diluted to the mark with distilled water. The following minerals were measured in the samples: Potassium (K), Sodium, phosphorus (P), zinc (Zn), iron (Fe) magnesium (Mg), and calcium (Ca) using flame atomic absorption spectrophotometer (VARIAN model AA240FS, United State).

Vitamin B1 (thiamine) was determined using the method outlined by Okwu and Josiah (2006),while vitamin B6 (pyridoxine) and B9 (folic acid) were determined using the AOAC (2012) methods and for Vitamins E (tocopherol) determination, Onyesife *et al*. (2014) approach was employed.

Determination of Functional Properties of the Composite Flours

The packed and loose bulk densities were determined using the method outlined by Chinyere *et al*. (2015), while Elkhalifa *et al.* (2005) protocol was adopted for water and oil absorption capacity. The foaming stability and capacity and the least gelation capacity was determined using the method described by Onwuka (2005) and Sathe and Salunkhe (1996) procedures was employed for the determination of the swelling capacity and solubility. The pasting properties of the flour samples was determined using a rapid visco analyzer (RVA Model RVA3D+, Network scientific, Australia) as described by Newport Scientific (1998).

Statistical Analysis

Triplicate experiments were carried out and all the data obtained were subjected to one-way analysis of variance (ANOVA) while Duncan's multiple range test was used to separate the means using Statistical Package for the Social Scientists (SPSS) version 20.

RESULTS AND DISCUSSION

Chemical Properties of Whole Wheat and Defatted Sesame Seeds Composite Flours

The chemical properties of the different flours are as shown in Table 1. The moisture content ranged between 8.10 to 10.50 g/100 g for WF and WDS4 respectively. Lower moisture content than the control was observed in all the composite blends, this could imply more dry solids in the flours. Additionally, the moisture content reported for all the flour samples is lower than the permissible level of 14.5 % which ensures stability at room temperature and extended shelf life during storage (Bodor *et al*., 2024). Generally, there was a significant (p≤0.05) difference in the flour samples and higher values of crude protein, crude fibre and ash were recorded in the composite flours. This observation could be due to enhancement of the flours because of high amount of crude protein, crude fiber, ash, and mineral contents in sesame seeds after defatting as observed by Abbas *et al*. (2022). The protein content for the composite flour blends ranged between 12.93 to 22.07 g/100g signifying a 26.60 to 70.69 % increase and the highest value was at 20 % defatted sesame seeds flour substitution. The same trend was followed for the fat, ash, and fibre contents. Ocheme *et al*. (2018) reported similar observation in wheat and groundnut protein concentrate flour composite blends and Bolaji *et al*. (2022) in whole wheat and watermelon seeds composite flour blends.

Table 1. Chemical properties of Whole Wheat and Defatted Sesame Seeds Composite Flour Blends

Parameters	WF	WDS1	WDS2	WDS3	WDS4
Moisture content (g/100g)	10.50±0.30[a]	9.00±0.00[b]	8.43±0.01[c]	8.40±0.02[c]	8.10±0.01[d]
Crude protein (g/100g)	12.93±0.00[e]	16.37±0.00[d]	17.25±0.0[c]	18.63±0.01[b]	22.07±0.00[a]
Crude fat (g/100g)	2.82±0.00[e]	4.25±0.00[d]	5.03±0.00[c]	6.17±0.08[b]	6.97±.00[a]
Ash (g/100g)	1.90±0.00[e]	2.05±0.25[d]	2.35±0.05[c]	2.64±0.20[b]	3.06±0.11[a]
Crude fiber (g/100g)	8.03±0.25[ab]	8.15±0.00[b]	8.71±0.40[ab]	9.06±0.05[a]	9.45±0.10[a]
Carbohydrate	63.82±0.30[a]	60.34±0.25[d]	58.23±0.12[d]	55.09±0.12[c]	50.35±0.10[b]
EV(Kcal/100g)	332.42±0.15[e]	345.09±0.10[d]	347.19±0.08[c]	350.41±0.14[b]	352.41±0.02[a]
Calcium (mg/100g)	26.74±0.01[e]	102.52 ±0.01[d]	132.85 ±0.01[c]	134.86 ±0.01[b]	158.45 ±0.01[a]
Iron (mg/100g)	2.18 ±0.01[e]	3.35 ±0.01[d]	4.05 ±0.01[c]	4.25 ±0.01[b]	4.30 ±0.02[a]
Magnesium (mg/100g)	33.25 ±0.01[e]	35.31 ±0.01[d]	39.82 ±0.01[c]	44.37 ±0.01[b]	46.05 ±0.01[a]
Sodium (mg/100g)	3.11 ±0.01[e]	13.6 ±0.01[d]	15.62 ±0.01[c]	16.65 ±0.01[b]	17.87 ±0.01[a]
Potassium (mg/100g)	79.84 ±0.01[e]	148.52 ±0.10[d]	208.65 ±0.10[c]	238.54 ±0.07[b]	260.75 ±0.11[a]
Zinc (mg/100g)	1.44 ±0.01[e]	2.42 ±0.02[d]	3.04 ±0.01[c]	3.61 ±0.01[b]	4.06 ±0.01[a]
Phosphorous (mg/100g)	72.51 ±0.01[e]	72.86 ±0.01[d]	77.61 ±0.12[c]	79.57 ±0.01[b]	88.03 ±0.01[a]
Vitamin B1(mg/100g)	0.11 ±0.00[d]	0.22 ±0.01[c]	0.22 ±0.01[c]	0.25 ±0.01[b]	0.31 ±0.01[a]
Vitamin B6 (mg/100g)	0.20 ±0.01[d]	0.64 ±0.01[c]	1.01 ±0.01[b]	1.02 ±0.01[b]	1.24 ±0.03[a]
Vitamin B9 (µg/100g)	45.30 ±0.02[e]	46.20 ±0.03[d]	47.10 ±0.02[c]	50.07 ±0.01[b]	53.45 ±0.02[a]
Vitamin E (mg/100g)	2.30 ±0.00[e]	8.05 ±0.01[d]	10.07 ±0.01[c]	13.20±0.02[b]	13.84 ±0.02[a]

Means and standard deviation of triplicate replicates. Values with the same superscript letters within a row are not significantly (p<0.05, n =3) different. EV = Energy Value, WF = 100% Whole wheat flour, WDS1 = 95% Whole wheat flour; 5% Defatted Sesame flour, WDS2 = 90% Whole wheat flour; 10% Defatted Sesame flour, WDS3 = 85% Whole wheat flour; 15% Defatted sesame flour and WDS4 = 80% Whole wheat flour; 20% Defatted sesame seeds flour

The fat contents of the flours ranged between 2.82 – 6.97 g/100 g with higher fat content than the control in the composite blends which could be as a result of residual fats in the defatted sesame seeds. Residual oil after defatting using different methods was reported by Melo *et al*. (2021). Similarly, Shahid (2016) also observed a higher fat content in defatted sesame seeds substituted flours. A lower fat content with high polyunsaturated fatty acids in defatted sesame seeds than the seeds has been reported by Afzal *et al*. (2022). The low fat content in these samples could be beneficial during storage because and for most foods, unsaturated fatty acids are generally found in all fatty foods and hence their susceptibility to oxidative rancidity. Though, sesame seeds oils are classified as polyunsaturated and has been reported to be resistance to oxidation (Afzal et al., *2022*) hence this may likely not pose a problem. The ash and crude fibre content ranged from 1.90 – 3.06 % and 8.03 – 9.45 % respectively. A high-fiber diet has been reported to reduce constipation and could be suggested for individuals who are at risk of diabetes and heart disease (Iqbal *et al*., 2022). The carbohydrate content decreased as defatted sesame seeds substitution rate increased (63.82 to 50.35 %) which is remarkable as this could imply slow or reduced rate of absorption of carbohydrates resulting in a flatter blood sugar which could be applicable to the non-insulin dependent diabetic individuals. The energy value ranged between 332.42- 352.41 Kcal/100g, this compare favourably with the findings of Bouhlal *et al*. (2019) with energy values ranging from 342.15 – 351.01 Kcal/100 g in wheat and lentils composite flour blends. The composite flours' energy values fell between 344 and 425 kcal/day, which is the recommended range according to the WHO/FAO Consultation of 2003. Hence these composite flours if used in food preparations can meet up to about 50 – 80 % energy requirements for both children and adults. These results also justify the use of defatted sesame seeds as a means of improving nutritional value of food systems.

Despite the fact that micronutrients are needed in low concentration for proper growth and development of the human body, wheat is not able to meet up especially with up key dietary micronutrients such as zinc (Zn) and iron (Fe) (Daud *et al.,* 2023). The result of the micronutrients composition as presented in Table 2 showed a significant ($p \leq 0.05$) difference in the flour blends. The calcium, sodium, and pottasium content ranged from 26.74- 158.45 mg/100 g, 3.11 – 17.87 mg/100g and 79.84- 260.75 mg/100 g signifying about 283.40 - 492. 56 %, 337.00-474.60 % and 88.02-226.59 % increase respectively. Also, iron, zinc, phosphorus and magnessium ranged between 2.18 - 4.30 mg/100g, 1.44 – 4.06 mg/100g, 72.51 88.03 mg/100g and 33.25- 46.05 mg/100g . Phosphorus had 0.48 – 21.40 % marginal increase and composite flour blends formulated using 80 % wheat flour and 20 % defatted sesame seeds flour (WDS4) had the highest mineral value. This is expected as defatted sesame seed is reported to be a rich of source essential minerals and vitamins such as calcium, phophorus, iron, zinc, magnesium and sodium (Ayo-Omogie, 2023; Wei *et al*., 2022). Similar increase in calcium, iron, magnesium, potassium, sodium and zinc was also observed by Ayo-Omogie (2023), Makinde and Eyitayo (2019) and Bouhlal *et al*. (2019), in defatted sesame seed flour, banana and sorghum composite flour blends, wheat-coconut flour blends and wheat and lentils composite flours respectively. However, Bolaji *et al*. (2022) on the contrary reported a decrease in mineral content as the water melon seeds flour increases in whole wheat flour while Makinde and Eyitayo (2019), also observed higher values of mineral and Ogunlakin *et al*. (2022) observed lower minerals content in wheat, mushroom (*Pleurotus ostreatus*) and unripe plantain (*Musa paradisiaca*) flour blends. Daud *et al*. (2023), also reported lower values for magnesium and zinc in wheat and defatted peanut composite flour. The mineral values in this study can supply 25 – 50 % of the Recommended Daily Allowance (RDA) for iron, calcium and magnesium for infants and adults as values falls below the of 8 mg and 18mg/day, 360 mg/100g and 1200mg/100g, for children and adults 420 mg/day for men and 310 mg/day for women respectively (Ibeabuchi *et al*., 2020; Emmanuel-Ikpeme *et al.,* 2012; Wayo *et al.,* 2021).

The vitamin content of the flour samples were substantial in amount, ranging from 0.11 – 0.31 mg/100g, 0.20 – 1.24 mg/100g, 45.30 – 53.45 µg/100g and 2.30- 13.84 mg/100g for vitamin B1, B6, B9 and E respectively. Vitamin B6 and E had a fivefold increase of 520 %, and 501.74 % at 20 % defatted sesame seeds flour substitution when compared with the control WF (100 % Wheat flour). These vitamins are significant due to beneficial roles they play in the human body (Emmanuel-Ikpeme *et al.,* 2012). Vitamin B1 is required for the maintenance of the nervous system and helps in releasing energy from carbohydrates during metabolism, the daily requirement of thiamine for adults is >63µg/day (Raji *et al.,* 2018) while vitamin E acts as antioxidant; protecting the body tissue from damage due to free radicals, it also strengthens the immune system, supports the production of red blood cells, prevents blood clotting and widening of blood vessels (Ibeabuchi *et al.,* 2020). Vitamin B6 is important in several metabolic activities in the body especially in reactions involving nitrogen containing compounds (Ogunlakin *et al.,* 2022) while vitamin B9 plays a pivotal role in foetal development and its demand increases during pregnancy (Xu *et al*., 2024). The vitamin B1 and B6 contents in this study are lower than the findings of Ogunlakin *et al.*(2022) in wheat, mushroom and unripe plantain composite flours while the vitamin B9 content is higher than the result of Emojorho and Okonkwo (2022). The recommended folic acid intake for adults and pregnant women ranges from 200-400 µg (Paucean*et al.,* 2018), and as such the researched samples will be able to meet the 10 – 20 % folate requirements for both adults and pregnant women.

Functional Properties of Whole Wheat and Defatted Sesame Composite Flour Blends

Functional properties of flours play a crucial role in the development of new food products and food manufacturing generally. Table 2 shows the results of the flours' functional properties. The 100 % whole wheat flour (WF) had the highest bulk density of 0.77 g/ml while WDS4 (80 % wheat and 20 % defatted sesame seeds flour blend) was the lowest at 0.66 g/ml. Bulk density, which also referred to as packing density is used in determining the heaviness of a flour sample, packaging requirements and it also play a significant role in food formulations. The bulk densities of composite flour deceased with increase in the level of substitution of whole wheat flour with defatted sesame seeds

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flour. Reduction of the bulk density in the composite flours compared to the wheat could be as a result of the low carbohydrate content, particle size and density of the composite flours (Kakar *et al*., 2022). Bulk density reflects the volume of packaging material required, flours with high bulk density indicates high porosity which is desirable in packaging as its can reduce cost of packaging and transportation. While low bulk.

Table 2. Functional Properties of Whole Wheat and Defatted Sesame Seeds Composite Flour Blends

Parameter	WF	WDS1	WDS2	WDS3	WDS4
BD (g/ml)	0.77±0.01[a]	0.75±0.00[b]	0.72±0.00[c]	0.69±0.01[d]	0.66±0.01[e]
WAC (%)	150.50±1.00[d]	152.80±0.10[c]	167.15±0.00[b]	193.41±0.10[a]	193.90±0.6 [a]
OAC (%)	98.20±0.40[d]	98.50±0.50[d]	153.10±0.10[c]	180.10±0.10[a]	180.32±0.00[a]
FC(%)	20.00±1.00[d]	20.00±1.00[d]	35.00±1.00[c]	39.00±1.00[b]	41.00±1.00[a]
FS(%)	1.83±0.01[e]	2.06±0.00[d]	4.89±0.06 [c]	6.91±0.01[b]	10.93±0.43[a]
LGC	4.00±0.00 [b]	4.00±0.00 [b]	6.00±0.00 [a]	6.00±0.00 [a]	6.00±0.00 [a]
SL(%)	10.88 ± 0.01[a]	10.68 ±0.01[b]	9.58 ± 0.01[d]	10.04± 0.02 [c]	9.35 ± 0.01[e]
SC(g/g)	9.03± 0.02[a]	8.45 ± 0.02[b]	8.04 ± 0.02[e]	8.15 ± 0.20[d]	8.41 ± 0.02[c]

Mean and standard deviation of triplicate replicates. Values with the same superscript letters within a row are not significantly ($p<0.05$, n =3) different. WF = 100% Whole wheat flour, WDS1 = 95% Whole wheat flour; 5% Defatted Sesame flour, WDS2 = 90% Whole wheat flour; 10% Defatted Sesame flour, WDS3 = 85% Whole wheat flour; 15% Defatted sesame flour and WDS4 = 80% Whole wheat flour; 20% Defatted sesame seeds flour, BD= Bulk density, WAC= Water absorption capacity, OAC= Oil absorption capacity, FC= Foaming capacity, FS= Foam stability, LGC= Least gelation concentration, SL= Solubility and SC= Swelling capacity

density flour are more important in flour flowability, higher volume pack advantageous because of the increase. The water absorption capacity of WF (100 % whole wheat flour) was 150.50 % and the WAC increased significantly ($p\leq0.05$) as the substitution with defatted sesame seeds flours increased. This could be attributed to higher content of soluble proteins in the defatted sesame seeds. Higher values in the composite flour blends could be due to enhancement of the structural matrix for holding sugars, water and other food components. This also indicate the ability of these flours to associate more with water in conditions where water is limiting such as in dough and pastries (Hasmadi *et al*., 2020).

In this study, no significant ($p<0.05$) difference was observed between the control and at 5 % inclusion of defatted sesame seeds flours for the oil absorption, foaming, emulsification and least gelation capacity. However, at 10 % addition of defatted sesame seeds flours significant ($p\leq0.05$) increase were observed in the functional properties of the composite flour blends. The oil absorption capacity (OAC) ranged between 98.20 % (WF) - 180.32 % (WDS4). There was a significant ($p<0.05$) increase in OAC as the defatted sesame seeds flours substitution increases, though at 15 and 20 % substitution there was no significant ($p<0.05$) difference in the OAC probably due to higher fat content in the composite flours (Chandra *et al*., 2015). The OAC is an indication of the ability of the flour to retain flavour, improve palatability and it also determines the shelf life extension of products where oil absorption capacity is of major importance for instance in bakery and. battered food products. The oil absorption capacities (OAC) were generally lower than those of the WAC. This implies the presence of a higher proportion of hydrophilic (non-polar side chains) than hydrophobic groups on the protein molecules surfaces (Caruso *et al.,* 2020).

Foaming capacity (FC) and Foaming stability (FS) are directly proportional to one another, and are both used to describe the foaming properties of flours. Increase in foaming capacity (FC) was observed between 10- 20 % defatted sesame seeds flour substitution. The FC ranged between 20.00 (WF) - 41.00 % (WDS4) and about 100 % increase was observed at 20 % sesame seeds flour substitution. The foaming capacity of a flour measures the quantity of the interfacial area produced when flour is whipped (Awuchi *et al*., 2019). Foaming capacity and foaming stability is positively correlated with protein content Brou *et al*. (2013) and this is evident in this study. Similar trend were observed by Ocheme *et al*. (2018) and Chandra *et al*. (2015). The foam stability (FS) was in the order WDS4> WDS3>WDS2>WDS1 >WF. The FS ranged from 1.83 (WF)-10.93(WDS4). The foam stability is enhanced by protein-protein interplay at the air-water interface and this is further aided by the protein content of the flours (Hasmadi *et al*., 2020). Functional properties such as foaming, emulsification, oil, and water absorption are greatly influenced by the protein content. The hydrophilic and hydrophobic nature of protein enables their interaction with water and oils in foods (Suresh *et al*., 2015). By and large, the results of the functional properties were influenced by the defatted sesame seeds flour substitution and this is in consonance with previous reports of Abbas *et al*. (2022) and Egbekun and Ehieze (1997), on defatted sesame seed flour having an appreciable water absorption, foaming properties, and emulsification capacity. However, the presence of high amount protein contents causes reduced oil absorption ability and bulk density. The least gelation capacity ranged between 4-8 %. Noticeably, WF formed gel at a low concentration of 4.00 % while samples WDS2, WDS3 and WDS4 formed gel at higher concentration of 6.00, 6.00 and 8.00 % respectively. Gelation capacity involves a contest for water between starch gelatinization and protein gelation (Kaushal *et al*., 2012). Low gelation capacity of WF and WDS1 could be an added asset as it implies a better gelling capacity (Chandra *et al*., 2015). The solubility (SL) and swelling capacity (SC) ranged between 9.35 % (WDS4) to 10.88 % (WF) and 8.04 (WDS2) to 9.03 (WF) respectively. There was a significant ($p>0.05$) difference in the flours with lower solubility and swelling capacity observed in the composite flours compared to the control. Solubility measures the ability of water to penetrate flour granules, measured by the percentage of heated flour dissolved in the solution (Ikegwu *et al.*, 2010). It is influenced by the hydrophobicity of fats, starch content and extent of starch degradation (Itagi and Singh, 2012). The SC, also termed hydration capacity of food measures the ability of the food to imbibe water when heated in an aqueous suspension. This finding is in agreement with the report of Onabanjo *et al*. (2020) on wheat, yellow maize and beni seed composite flour.

The pasting property result is as shown in Table 3. The control (WF) recorded the highest peak viscosity (PV) of 3265 cP whilst WDS4 was the lowest at 2596 cP. High peak viscosities are associated with high starch and extent of interactions between the starches, fat and protein contents of the blends. This could probably have resulted in the decrease in peak viscosity in the composite blends. Peak viscosity is correlated with water binding capacity of starch and resistance to swelling and rupture (Okafor *et al*., 2021). There was no significant ($p<0.05$) difference in the trough viscosity values of the WF (control), WDS3 and WDS4 composite flour sample. The trough viscosity (TV) is the lowest viscosity that the flour can attain during heating or cooling process. The TV ranged between 1831- 1931 cP , this indicates the ability of the flour paste to withstand breakdown during cooling. This result is in agreement with Ocheme *et al*. (2018), however higher values were reported by Cornejo-Ramirez *et al*. (2018). The breakdown viscosity ranged between 715 -1414 cP, the highest value was recorded for WF and the lowest value was WDS4. High breakdown viscosity is indicative of the ability of the starch in the flour samples to withstand stress and heating, flour samples with high breakdown would be desirable in products that will be kept or held in high temperature for a long period of time (Princewill-Ogbonna and Ezembaukwu, 2015). The final viscosity (FV) ranged between 3111(WDS1) – 3470 cP (WDS2) and there was no observable trend in the values. The FV usually determines a starch-based sample's ability to form gel during processing after cooking (Liang and King, 2003). The values obtained were above the range reported by Okafor *et al*. (2021) and Ofia-olua (2014) for wheat and walnut blends (95.51-252 RVU). The setback viscosity ranged between 1281-1958 cP, high setback values have

Table 3. Pasting properties of whole wheat and defatted sesame seed composite flour blends

Pasting Parameters (cP)	WF	WDS1	WDS2	WDS3	WDS4
PV	3265±78.00^{a}	2864±48.50^{b}	2700±86.50^{bc}	2713±179.00^{bc}	2596±26.00^{c}
TV	1850±71.50^{b}	1675±55.50^{cd}	1711±15.50^{c}	1931±75.50^{a}	1881±4.50^{b}
BV	1414±6.50^{a}	1189±9.00^{b}	989±71.00^{c}	781.50±103.50^{d}	715±21.50^{d}
FV	3131±44.50^{b}	3111±93.50^{b}	3470±51.00^{a}	3383±309.50^{ab}	3328±3.50^{ab}
SB	1281±97.00^{c}	1436±38.00^{bc}	1758±35.50^{a}	1452±234.00^{bc}	1447±11.00^{bc}
PTm (min)	5.90±0.03^{c}	5.93±0.06^{bc}	6.06±0.13^{bc}	6.63±0.36^{a}	6.26±0.06^{b}
PTemp(°C)	68.87±0.40^{c}	68.90±0.37^{c}	69.75±0.40^{b}	69.70±0.35^{b}	73.25±0.05^{a}

Mean and standard deviation of triplicate replicates, values with the same superscript letters within a row are not significantly ($p<0.05$, n =3) different. WF = 100% Wheat Flour, WDS1= 95% Wheat Flour; 5% Defatted Sesame, WDS2 = 90% Wheat Flour; 10% Defatted Sesame, WDS3 = 85% Wheat Flour; 15% Defatted Sesame and WDS4 = 80% Wheat Flour; 20% Defatted Sesame, PV= Peak viscosity, TV= Trough viscosity, BV= Breakdown viscosity, FV= Final viscosity, SB= Setback viscosity, PTm= Pasting time and PTemp = Pasting temperature

been correlated with reduced digestibility (Wu and Warren, 2023). High setback values in the composite flours could be advantageous as reduced digestion rate is a possible route to lower post-prandial glycaemic responses in individual with metabolic disorders. The pasting time and pasting temperature ranged between 5.90 – 6.26 min and 68.87 – 73.25 ºC respectively. Pasting time predicts the cooking time. Slightly higher temperature was observed at 10 – 20 % defatted sesame seeds flour substitution. This could be as a result of increase in protein which limits starch gelatinization (Ocheme *et al*., 2018) and also, competition with starch for water by sugars resulting in delayed gelatinization and increase in the final temperature required to achieve gelatinization. Higher pasting time and lower pasting temperature was observed in this work when compared with the values reported by Bolaji *et al*. (2022) with pasting time and temperature ranging between 5.47 to 5.87 min and 84.70 to 91.85 °C for whole wheat and watermelon seeds flour blends.

CONCLUSION

This study showed that the substitution of whole wheat with defatted sesame seeds flour improved the crude protein, crude fat, crude fibre, ash content and the energy value while the total carbohydrates content decreased. Increase in micronutrients which evident in the ash content and desirable functional properties were observed with increase in defatted sesame seeds substitution. Generally, the composite flours show a better alternative for food production, improved wheat based new product can be obtained from the whole wheat and defatted sesame seeds flour blends especially in pasta production and in the bakery industries.

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