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Evaluation of Functional and Pasting Properties of Wheat–Malted Sorghum Flour Blends

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Abstract

This study investigated the functional and pasting properties of composite flours formulated from wheat flour (WF), malted white sorghum flour (MWSF), and malted red sorghum flour (MRSF) for bread production. A control sample was prepared from 100% commercial wheat flour, while six blends were produced at substitution ratios of 80:20:0, 60:40:0, 80:0:20, 60:0:40, 80:10:10, and 60:20:20 (WF: MWSF: MRSF). Standard analytical methods were employed to evaluate functional and pasting characteristics. Results revealed that water absorption capacity ranged from 1.31 to 1.74 g/g, oil absorption capacity from 0.90 to 1.37 g/g, swelling capacity from 4.74 to 6.52 ml/g, foaming capacity from 17.34 to 22.16%, and gelatinization temperature from 61.02 to 71.02 °C, with values generally increasing with sorghum substitution. Pasting properties showed significant ($p < 0.05$) variation, with pasting temperature (63.57–68.59 °C), peak viscosity (210.05–250.25 RVU), peak time (5.01–5.49 min), minimum viscosity (95.05–115.08 RVU), final viscosity (190.45–215.08 RVU), and breakdown viscosity (100.05–120.10 RVU). Specific loaf volume ranged from 75.38 to 95.48 cm^3/g. Among the blends, the 60% WF:40% MRSF formulation exhibited the most desirable functional and pasting characteristics, suggesting its potential as a suitable alternative for pastry production. The study indicates that flour of high quality can be produced from composite flour of wheat and malted sorghum. The incorporation of malted sorghum flours into wheat flour enhances hydration, foaming, and pasting properties, demonstrating their potential as functional ingredients for bakery applications. These flour substitutions in baked products can alleviate the problem of wheat importation in Nigeria and also promote the utilization of Sorghum and similar underutilized crops, thus enhancing food security.

Keywords: Composite Flour, Pasting Properties, Functional Properties, Wheat, Sorghum.

Introduction

Composite flour is created by partially substituting wheat flour with flours from other sources, such as tubers, pulses, or other grains. This blending technique enhances the nutritional content and functional properties of the flour, allowing it to be used in products typically made from wheat while promoting the use of diverse raw materials (Alamu *et al* 2023).

The functional characteristics of flour represent the basic physical and chemical attributes that demonstrate the intricate relationships among ingredient composition, structural organization, molecular configuration, and physicochemical behaviors of food constituents, in conjunction with the environmental conditions under which these interactions occur and are evaluated. Pasting characteristic is important in predicting the behaviour of food paste during and after cooking. Attainment of the pasting temperature is essential in ensuring swelling, gelatinization and subsequent gel formulation during processing (Dhull *et al* 2021).

The blending of wheat flour with malted sorghum varieties represents a sustainable approach to production that not only reduces dependence on imported wheat but also supports the utilization of locally available grains. Previous studies have explored the use of composite flours in baking and reported varying impacts on the sensory, nutritional, and textural properties of the resulting baked product (Adebowale *et al* 2023).

The near-total dependence on wheat flour for baked product presents a major economic and food security challenge, as wheat is not widely cultivated in tropical regions and must be imported at substantial cost (Ayoade *et al*., 2021). This heavy reliance on imported wheat undermines the sustainability of the baking industry and increases vulnerability to global price fluctuations and supply chain disruptions. Based on the foregoing, this study was carried out to elucidate the effect of supplementing wheat flour with malted sorghum on the quality characteristics of its functional and pasting properties.

Wheat (*Triticum spp.*) remains a cornerstone of global food security, serving as a primary source of calories, protein, and essential nutrients for a large portion of the world's population. Recent analyses confirm its status as the most widely cultivated crop, underpinning agricultural economies and international trade (Shewry and Hey, 2023). The research landscape, as mapped by bibliometric studies, shows a strong focus on enhancing yield, quality, and sustainability in the face of climate change and growing demand (Giraldo *et al*., 2021). A significant body of recent research continues to elucidate the molecular basis of wheat's unique functionality. The gluten proteins, glutenin and gliadin, are responsible for the viscoelastic dough essential for leavened bread and other bakery products. Studies have advanced the understanding of how the ratio and polymer structure of these proteins dictate dough strength, mixing tolerance, and gas retention (Li *et al.,* 2023). Concurrently, the drive to meet diverse consumer needs has spurred innovation in gluten-free wheat alternatives and the reformulation of products to enhance their nutritional profile, such as increasing dietary fiber content (De Arcangelis *et al.,* 2021).

Sorghum (*Sorghum bicolor* (L.) Moench) is a critical cereal crop for global food security, particularly in semi-arid regions of Africa and Asia. Recent literature consistently highlights its resilience to abiotic stresses, such as drought and heat, making it a vital crop for climate-smart agriculture in the face of increasing climate variability (Tadele, 2021). Its low water requirement and ability to thrive in marginal soils have renewed interest in its potential to contribute to sustainable food systems. A significant focus of contemporary sorghum research is on its nutritional and nutraceutical value. Sorghum is recognized as a rich source

of bioactive compounds, including polyphenols (such as tannins and anthocyanins), phytosterols, and dietary fiber. Recent studies have linked these compounds to various health benefits, including antioxidant, anti-inflammatory, and prebiotic activities, which may help in managing non-communicable diseases like diabetes and obesity (Xiong *et al.*, 2021). The gluten-free nature of sorghum also solidifies its status as a key ingredient in the development of safe and nutritious foods for individuals with celiac disease or gluten sensitivity.

Malting, a controlled process of germination followed by drying, is a well-established biotechnological technique used to enhance the nutritional and functional properties of cereals. For sorghum, a vital climate-resilient crop, malting has been extensively researched to improve its application in food products. A primary benefit of sorghum malting is the significant improvement in its nutritional profile. The germination process activates endogenous enzymes, most notably α-amylase, protease, and phytase. These enzymes catalyze the breakdown of complex macronutrients: amylases hydrolyze starch into simpler sugars, and proteases break down storage proteins into peptides and free amino acids, thereby improving protein digestibility (Olagunju *et al.*, 2021). Concurrently, malting is highly effective in reducing anti-nutritional factors. Research confirms a substantial decrease in phytate and tannin content, which chelate minerals like iron and zinc. This reduction significantly enhances the bioavailability of these essential micronutrients (Adebiyi *et al.*, 2021).

Materials and Method

Source of Materials

Commercial wheat flour, white grain, red sorghum grain was bought from Itam Market a local market in Uyo metropolis, Akwa-Ibom State.



WHEAT FLOUR



RED SORGHUM SEED



WHITE SORGHUM SEED

Preparation of Malted Sorghum Flour

Sorghum grain bought from the market were manually sorted to remove stones, damaged grains, other contaminants. Method described by Singh and Singh (2020) was use in processing the grain into flour. The grains were washed and steeped for 12 hours. The grains were spread and covered on a jute bag to germinate. The grains were oven dried at 60 °C for 24hrs in a hot air oven. The grains were winnowed and then dry milled using hammer mill, the flour was sieved using 75µm mesh sieve (British standard) to obtain a smooth flour

(Adebiyi *et al* 2021). The flour was packed in an air tight high density polyethylene bag and stored at ambient temperature for use.

Formulation of Flour Blend

Blends formulations of flours were considered as 100:0:0 = A, 80:20:0 = B, 60:40 = C, 80:20 = D, 60:40 = E, 80:10:10 = F and 60:20:20= G in Wheat: malted red sorghum: Malted white sorghum blends (Oluwajuwan and Ijarotimi 2022). The mixture was blended in a Ken Wood food processor operated at full speed for 10 minutes. The blending was done for all samples. The flour blends were stored in high density polyethylene bags prior for use.

Table 1: Formulation of wheat, malted white sorghum and malted red sorghum flour blend

Sample	CWF	MWSF	MRSF
A	**100**	**0**	**0**
B	**80**	**20**	**0**
C	**60**	**40**	**0**
D	**80**	**0**	**20**
E	**60**	**20**	**20**
F	**80**	**10**	**10**
G	**60**	**20**	**20**

KEY: **CWF** = Convectional Wheat Flour, **MWSF** = Malted White Sorghum Flour, **MRSF** = Malted Red Sorghum Flour. A = 100% CWF, B = 80 % CWF: 20 % MWSF, C = 60 % CWF: 40 % MWSF, D = 80% CWF: 20% MRSF, E = 60% CWF: 20% MWSF: 20 % MRSF, F = 80% CWF: 10% MWSF: 10 % MRSF.
Source: Field Work (2024)

Analysis of Functional Properties

The functional properties of the most accepted composite semolina sample were determined using the methods described in the study of Adewumi and Patel (2024).

Determination of Water Absorption Capacity

One (1) gram of the sample was weighed into a conical graduated centrifuge tube, a warring whirl mixer was used to mix the sample, and 10 ml of distilled water was added and thoroughly mixed for 30 seconds. The sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 5000×g for 30 minutes. The volume of free water (supernatant) was read directly from the graduated centrifuge tube. The water absorbed (total minus free) was multiplied by the density of water (1 g/ml)

Determination of Oil Absorption Capacity

One (1) gram of the sample was weighed into a conical graduated centrifuge tube, a warring whirl mixer was used to mix the sample, and 10 ml of vegetable oil was added and thoroughly mixed for 30 seconds the sample was allowed to stand for 30 minutes at room

temperature and then centrifuged at 5000×g for 30 minutes. The volume of free oil (supernatant) was read directly from the graduated centrifuge tube. The oil absorbed (total minus free) was multiplied by the density of oil (1 g/ml).

Swelling Capacity

2g of flour sample was mixed with 10ml of distilled water in a calibrated cylinder at room temperature. After equilibration for 18hrs; the bulk volume was recorded and swelling capacity expressed as volume occupied by sample per gram of original sample dry weight.

Foaming Capacity and Stability

2g of flour sample was weighed and added to 50ml distilled water in a 100ml measuring cylinder. The suspension was mixed and properly shaken to foam and the total volume after 30 seconds was recorded. The percentage increase in volume after 30 seconds is expressed as foaming capacity.

Gelatinization Temperature

2g of flour sample was weighed accurately in triplicate and transferred to 20ml screw capped tubes. Ten (10) ml of water was added to each sample. The samples were heated slowly in a water bath until they formed a solid gel. At complete gel formation, the respective temperature was measured and taken as gelatinization temperature.

Determination of Pasting Properties

Pasting characteristics of the most accepted composite semolina sample was determined with a Rapid Visco Analyzer (RVA), as reported in the study of Kumar *et al.* (2023). The pasting properties determined included: pasting temperature, peak viscosity, peak time, hot and cold viscosity breakdown, set back, and final viscosity which are read from the pasting profile with the aid of thermocline for windows software connected to a computer. Three and a half (3.5) gram of the samples was weighed into a dried empty canister, and then 25 ml of water was dispensed into the canister containing the sample. Paddle was placed inside the canister; this was placed centrally onto the paddle coupling and then inserted into the RVA machine. The measurement cycle was initiated by pressing the motor tower of the instrument. The profile was seen as it is running on the monitor of the computer connected to the instrument. The 13-minutes profile was used, and the time–temperature regime was also used. The result obtained was expressed as RVU (Relative Visco Analyzer Unit).

Statistical Analysis

The data obtained were made in triplicates and analysed using one way analysis of variance (ANOVA) of Statistical Package for Social Sciences (SPSS version 27.0). Significant means were separated using the New Duncan Multiple Range Test (NDMRT) at 95% confidence interval.

Results and Discussion

Functional Properties of wheat Malted Sorghum Flour Blend

Table 3 shows the result of functional properties of the flour blends. The water absorption capacity values ranged from 1.31 g/g (100% wheat flour) to 1.74 g/g (60% wheat: 40% malted red sorghum flour composite). The statistical analysis revealed significant differences ($p < 0.05$) between all formulations, indicating that the substitution level of malted sorghum flour substantially influences the water absorption characteristics of the composite flours. Oluwajuyitan and Ijarotimi (2022) reported a water absorption capacity increase from 1.56 ml/g to 2.24 ml/g in wheat-malted sorghum blends. Similarly, research on wheat-acha composites showed a range from 1.60 ml/g to 2.10 ml/g (Adeboye *et al.*, 2023). This consistent pattern across studies confirms that the incorporation of non-wheat flours, particularly those that have been bioprocessed like malted sorghum, significantly enhances the water-holding capacity of the composite matrix. The water absorption capacity (WAC) of a flour is a vital functional property that directly influences processing efficiency and product quality, affecting factors such as dough yield, texture, softness, and shelf-life (Adebiyi *et al.*, 2024). Red malted sorghum consistently demonstrates a higher WAC than both white malted sorghum and wheat flour. This is primarily due to the high concentration of hydrophilic phenolic compounds, specifically condensed tannins, in its pigmented bran, which effectively bind water molecules (Olagunju and Arueya, 2023).

The Oil Absorption Capacity (OAC) of the flour samples demonstrated a significant progressive increase with malted sorghum incorporation, ranging from 0.90 g/g in the control sample (100% wheat flour) to 1.37 g/g (60% wheat and 40% malted red sorghum flour). Oyeyinka *et al*. (2021) reported an increase in OAC from 1.05 g/g to 1.32 g/g with a 20% substitution of wheat flour with malted finger millet. Similarly, Oluwajuyitan and Ijarotimi (2022) found that malted sorghum flour itself possessed a high OAC of 1.85 g/g. The increase in OAC is often attributed to the exposure of hydrophobic protein groups and the unique structure of dietary fibers following the malting process, which enhances the entrapment of lipid molecules. A high oil absorption capacity is a crucial functional property in food formulation, as it improves mouthfeel, flavor retention, and shelf-life by stabilizing emulsified fats and preventing syneresis (Adebiyi et al., 2024). The pigmented bran of red sorghum is rich in both fibrous components and hydrophobic phenolic compounds like tannins. During malting, the enzymatic breakdown of the cell wall increases the porosity of this bran, creating a more extensive network for the physical entrapment of oil, a structural advantage less pronounced in white sorghum (Olagunju and Arueya, 2023). In contrast, the protein matrix of wheat flour, dominated by gluten, has a different structural conformation and lower overall bran content compared to whole-grain red sorghum, resulting in a comparatively lower capacity for physical oil entrapment (Adebiyi *et al*., 2024).

Swelling capacity value ranged from 4.74 g/ml for 100% wheat flour to 6.52 g/ml for the 60% wheat:40% malted red sorghum blend. The statistical analysis revealed significant differences ($p < 0.05$) between the control sample and the composite flour blends, indicating that the addition of malted sorghum substantially enhanced the water absorption and swelling properties of the flour system. Oyeyinka *et al.* (2021) reported a 27.2% increase in swelling capacity when wheat flour was substituted with 20% malted finger millet. The observed increase can be attributed to the enzymatic pre-gelatinization and partial hydrolysis of starch during the malting process, which disrupts the granular structure and enhances water penetration and retention within the composite flour matrix. Malted grains typically contain modified starch structures due to the malting process, which involves controlled germination that activates enzymes responsible for breaking down complex carbohydrates. The swelling capacity (SC) of flour is a critical functional property that measures the volume increase of starch granules and other components when heated in water, directly influencing the viscosity, texture, and consistency of final products like porridges, baked goods, and pastes (Adebiyi *et al.,* 2024).

The foaming capacity of the flour samples demonstrated a significant progressive increase with malted sorghum incorporation, ranging from 17.34% in the control sample (100% wheat flour) to 22.36% (60% wheat and 40% malted white sorghum flour). Oluwajuyitan and Ijarotimi (2022) reported that 100% malted sorghum flour exhibited a high foaming capacity of 24.10%, indicating its inherent potential to improve this functional property in composites. Furthermore, the magnitude of increase observed in this study is consistent with research on other composite flours; for example, Adebowale *et al.* (2022) found that substituting wheat with 20% Bambara groundnut flour increased FC from 15.80% to 21.50%. The foaming capacity of a flour is a key functional property that indicates its ability to form and stabilize a foam, which is crucial for the texture and volume of products like baked goods, whipped toppings, and aerated foods. This capacity is largely governed by the presence and nature of proteins that can rapidly adsorb at the air-water interface, reduce surface tension, and form a cohesive film around air bubbles (Adebiyi et al., 2024). The malting process partially hydrolyzes sorghum proteins, increasing their solubility and flexibility, which allows them to migrate and align more effectively at air-water interfaces to create foam (Adebo et *al.,* 2022). Crucially, white sorghum lacks the high levels of condensed tannins found in red sorghum. These tannins are known to bind strongly to proteins, making them less soluble and less available to stabilize air bubbles, thereby significantly suppressing foaming in red malted sorghum (Olagunju and Arueya, 2023). In contrast, wheat flour, while containing gluten proteins, has a lower foaming capacity than white malted sorghum because its gluten-forming proteins are less soluble and more prone to forming a cohesive, elastic network better suited for dough formation than for creating and stabilizing fine, discrete foam bubbles (Adebiyi et al., 2024).

The gelatinization temperature of the flour samples demonstrated a significant progressive increase with malted sorghum incorporation, ranging from 61.02°C in the control sample (100% wheat flour) to 71.02°C in the formulation containing 60% wheat and 40% malted red sorghum flour. *Adebowale et al. (2023) observed that the gelatinization temperature of*

pearl millet flour increased from 69.5°C to 78.2°C after malting. The gelatinization temperature is a critical thermal property of starch that determines the energy input required during cooking and significantly influences the texture, digestibility, and shelf-life of starchy foods. A higher gelatinization temperature indicates a more organized and resistant starch granule structure that requires more heat to swell and lose its crystallinity (Adebiyi *et al.*, 2024). red malted sorghum typically exhibits a higher gelatinization temperature than both white malted sorghum and wheat flour. This disparity is primarily attributed to the intrinsic composition of the starch and its interaction with other grain components. The starch granules in red sorghum are often more rigid due to a higher proportion of amylose and stronger associative bonds within the granule, providing greater structural resistance to heat and swelling (Olagunju and Arueya, 2023).

Table 2. Functional Properties of Wheat Flour Fortified with Two Varieties of Malted Sorghum Flour

Sample	SC (ml/g)	WAC (g/g)	OAC (g/g)	FC (%)	GT (^{O}C)
A	$4.74^{g} \pm 0.02$	$1.31^{f} \pm 0.01$	$0.90^{e} \pm 0.01$	$17.34^{e} \pm 0.23$	$61.02^{g} \pm 0.03$
B	$5.24^{f} \pm 0.01$	$1.39^{e} \pm 0.01$	$1.01^{d} \pm 0.01$	$20.35^{c} \pm 0.21$	$65.04^{f} \pm 0.03$
C	$5.74^{c} \pm 0.01$	$1.56^{c} \pm 0.01$	$1.12^{c} \pm 0.02$	$22.36^{a} \pm 0.20$	$68.07^{c} \pm 0.05$
D	$5.51^{d} \pm 0.01$	$1.51^{c} \pm 0.01$	$1.16^{c} \pm 0.01$	$19.35^{d} \pm 0.22$	$67.05^{d} \pm 0.08$
E	$6.52^{a} \pm 0.02$	$1.74^{a} \pm 0.02$	$1.37^{a} \pm 0.02$	$21.36^{b} \pm 0.21$	$71.02^{a} \pm 0.03$
F	$5.34^{e} \pm 0.01$	$1.46^{d} \pm 0.01$	$1.03^{d} \pm 0.04$	$20.20^{c} \pm 0.00$	$66.05^{e} \pm 0.07$
G	$5.94^{b} \pm 0.01$	$1.65^{b} \pm 0.01$	$1.26^{b} \pm 0.01$	$22.16^{a} \pm 0.09$	$69.08^{b} \pm 0.07$

Values are means ± standard deviation of triplicate samples. Means values bearing different superscript in the same column are significantly ($P < 0.05$) different. SC- Swelling Capacity, WAC- water Absorption Capacity, OAC- Oil Absorption Capacity, FC – Foaming Capacity, GT – Gelatinization Temperature, A=100:0:0 (Control), B=80:20:0, C=60:40:0, D=80:0:20, E=60:0:40, F=80:10:10, G=60:20:20

Source: Field Work (2024)

Pasting Properties of Wheat-Malted Sorghum Flour Blend

Table 3 shows the pasting properties of the flour blend. The pasting temperature results obtained in this study showed significant variation across different flour blend compositions, ranging from 63.57°C for 100% wheat flour to 68.59°C for the 60% wheat: 40% malted red sorghum blend. This 5.02°C difference represents a statistically significant increase ($p < 0.05$) that demonstrates the substantial impact of malted sorghum incorporation on the thermal properties of wheat-sorghum flour blends. *Oyeyinka et al. (2023) reported an increase in the pasting temperature from 75.1°C to 82.5°C when wheat flour was substituted with 50% germinated sorghum flour. Similarly, Adebowale et al. (2023) observed that the gelatinization temperature of pearl millet flour increased from 69.5°C to 78.2°C after malting.* A higher pasting temperature reflects greater structural integrity and resistance to swelling within the starch granule, often resulting in products that better

maintain their structure during thermal processing (Adebiyi *et al.,* 2024). In comparative analyses, red malted sorghum consistently demonstrates a higher pasting temperature than both white malted sorghum and wheat flour. This phenomenon is primarily due to the unique biochemical interactions in red sorghum. The starch granules in red sorghum are intrinsically more robust, often characterized by a higher degree of crystallinity and stronger associative bonds, which require more thermal energy to initiate swelling (Olagunju and Arueya, 2023).

The peak viscosity measurements obtained in this study demonstrated a significant decreasing trend with increasing malted sorghum incorporation, ranging from 250.25 RVU for 100% wheat flour to 210.05 RVU for the 60% wheat: 40% malted red sorghum blend. The findings are in strong agreement with Olagunju *et al*. (2021), who reported a more pronounced decrease in peak viscosity from 285.10 RVU to 167.33 RVU with a 30% substitution of malted sorghum. A similar trend was reported by Oyeyinka *et al.* (2021) for malted finger millet composites. Peak viscosity is a critical pasting property that represents the maximum viscosity reached during the heating and holding cycle. It indicates the starch's water-binding capacity and its inherent ability to swell freely before physical breakdown. A high peak viscosity is generally desirable for products requiring a thick, cohesive gel structure and is a key predictor of final product quality in applications like soups, sauces, and baked goods (Adebiyi *et al.*, 2024).

The peak time measurements obtained revealed a significant increasing trend with malted sorghum incorporation, ranging from 5.01 minutes for 100% wheat flour to 5.49 minutes for the 60% wheat: 40% malted red sorghum blend. *Olagunju et al. (2021) reported an increase in peak time from 5.10 min to 5.63 min with the inclusion of 30% malted sorghum in wheat flour. A similar trend was observed by Adebowale et al. (2022), where the addition of African walnut flour to wheat delayed the peak time from 5.43 min to 6.10 min.* A longer peak time indicates a slower rate of starch granule swelling and hydration, which can influence the thermal processing requirements and the textural stability of food products like porridges and pastes (Adebiyi *et al.,* 2024). The pigmented bran of red sorghum contains high levels of condensed tannins, which are known to form strong complexes with starch molecules and proteins. These complexes create a robust physical barrier that impedes water penetration into the starch granules, thereby significantly slowing down the rate of swelling and the time to reach peak viscosity (Olagunju and Arueya, 2023).

The Trough viscosity measurements obtained demonstrated a significant decreasing trend with increasing malted sorghum incorporation, ranging from 115.08 RVU for 100% wheat flour to 95.05 RVU for the 60% wheat: 40% malted red sorghum blend. Olagunju *et al.* (2021), who reported a drastic decrease in the trough viscosity of pure sorghum flour after malting, from 147 RVU to 27 RVU. Similarly, Adebowale *et al.* (2023) observed a near-complete loss of trough viscosity in malted pearl millet. Trough viscosity represents the minimum viscosity value after the initial breakdown and indicates the ability of the swollen starch granules to withstand shear and maintain structural integrity during cooking (Adebiyi *et al.,* 2024). A higher trough viscosity is desirable for products requiring heat and shear stability, such as canned sauces or infant porridges, as it predicts better final texture.

white malted sorghum lacks significant tannin levels, resulting in a weaker granular structure that is more easily broken down, leading to a lower trough viscosity (Ndifon *et al* 2022).

The final viscosity measurements obtained demonstrated a significant decreasing trend with increasing malted sorghum incorporation, ranging from 220.10 RVU for 100% wheat flour to 190.45 RVU for the 60% wheat: 40% malted red sorghum blend. Oyeyinka *et al.* (2023) reported a more pronounced decrease, from 303 RVU to 155 RVU, with a 30% substitution of wheat with germinated sorghum. The primary mechanism for this reduction is the enzymatic activity of α-amylase, which is activated during the malting process. This enzyme partially hydrolyzes the starch molecules, reducing their ability to swell and form a viscous network during the pasting cycle, an effect starkly demonstrated by Adebowale *et al.* (2023) where malting alone reduced the final viscosity of pearl millet flour from 524 RVU to 98 RVU. Final viscosity is a critical parameter from Rapid Visco Analyzer (RVA) testing that measures the viscosity of the starch paste after cooling. It indicates the starch's ability to retrograde and form a gel structure, which is a primary determinant of the final texture, stability, and eating quality of products like porridges, noodles, and baked goods (Adebiyi *et al.*, 2024).

The breakdown viscosity of the flour samples demonstrated a significant and measurable decrease with the incorporation of malted sorghum, ranging from 120.10 RVU in the control flour prepared from 100% wheat to 100.05 RVU in the composite flour formulated with 60% wheat and 40% malted red sorghum. The finding aligns directly with Olagunju *et al.* (2021), who reported a drastic reduction in the breakdown viscosity of sorghum flour after malting, from 125 RVU to 42 RVU, due to the activation of endogenous α-amylase. Similarly, studies on composite flours containing other malted cereals, such as pearl millet, show a comparable trend of significant viscosity reduction (Adebowale *et al.*, 2023). Breakdown viscosity is a key Rapid Visco Analyzer (RVA) parameter that quantifies the decrease in viscosity from the peak to the trough during the high-temperature holding phase, reflecting the susceptibility of swollen starch granules to disintegrate under shear stress (Adebiyi *et al.*, 2024). A high breakdown value indicates poor shear stability, which can lead to undesirable thinning in products like sauces and porridges during prolonged cooking (Li and Gong 2022).

Table 3: Pasting Properties of Wheat Flour Fortified with Two Varieties of Malted Sorghum Flour

SAMPLE	PTT (°C)	PV (RVU)	PT (Min.)	TV (RVU)	FV (RVU)	BDV (RVU)
A	$63.57^{e} \pm 0.09$	$250.25^{a} \pm 0.35$	$5.01^{e} \pm 0.01$	$115.08^{a} \pm 0.11$	$220.10^{a} \pm 0.14$	$120.10^{a} \pm 0.14$
B	$65.58^{d} \pm 0.11$	$240.20^{b} \pm 0.28$	$5.19^{d} \pm 0.01$	$110.05^{b} \pm 0.07$	$210.05^{b} \pm 0.07$	$115.08^{b} \pm 0.11$
C	$67.59^{b} \pm 0.12$	$220.10^{e} \pm 0.14$	$5.39^{b} \pm 0.01$	$100.05^{e} \pm 0.07$	$195.48^{e} \pm 0.67$	$105.03^{e} \pm 0.04$
D	$66.58^{c} \pm 0.11$	$230.15^{d} \pm 0.21$	$5.29^{c} \pm 0.01$	$105.03^{d} \pm 0.04$	$205.03^{d} \pm 0.04$	$110.05^{d} \pm 0.07$
E	$68.59^{a} \pm 0.14$	$210.05^{g} \pm 0.07$	$5.49^{a} \pm 0.01$	$95.05^{g} \pm 0.07$	$190.45^{g} \pm 0.64$	$100.05^{g} \pm 0.07$
F	$68.59^{a} \pm 0.13$	$235.18^{c} \pm 0.25$	$5.19^{d} \pm 0.01$	$107.04^{c} \pm 0.05$	$208.04^{c} \pm 0.06$	$112.06^{c} \pm 0.09$
G	$67.59^{b} \pm 0.12$	$215.08^{f} \pm 0.11$	$5.39^{b} \pm 0.01$	$97.035^{f} \pm 0.05$	$192.46^{f} \pm 0.65$	$102.01^{f} \pm 0.01$

Values are means ± standard deviation of triplicate samples. Means values bearing different superscript in the same column are significantly (P <0.05) different. PTT- Pasting temperature, PV - Peak viscosity, PT- Peak Time, TV - Trough Viscosity, FV – Final Viscosity, BDV - Breakdown Viscosity. Blending ratio: A=100:0:0 (Control), B=80:20:0, C=60:40:0, D=80:0:20, E=60:0:40, F=80:10:10, G=60:20:20

Source: Field Work (2024)

Conclusion

The result of this study has shown that incorporation of malted sorghum in wheat adversely affect the functional and pasting properties of flour sample. The flour blends of wheat-malted sorghum flour showed that it can be a good raw material for food that requires high swelling capacity, water absorption capacity, oil absorption capacity, foaming capacity, gelatinization temperature, pasting temperature, peak time. The inclusion of Malted sorghum seed (*Sorghum bicolor*) flour into the conventional wheat flour in production would greatly enhance the utilization of this crop in developing countries like Nigeria in particular and West Africa in general. Since the crop has not been optimally utilize. Wheat-malted malted sorghum flour will be a good alternative for food that requires high swelling and water absorption capacity such as cakes and bread. The addition of malted sorghum as supplement will also provide varieties of flavour, texture and colour in baked product. Sample E (60% Wheat, 40% Malted red sorghum) was rated above average. I would recommend that further analysis be carried out on the microbial safety of the flour, the efficiency of its use in baked products, and the nutritional and sensory acceptability claim of the product produced from this flour.

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