Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Development and Characterization of Composite Flour from Sprouted Wheat and Cardaba Banana for Food Applications

Racheal Babalola[1]*, Williams Adejuwon[2], Roseline Adebayo[1], Olubunmi Akindele[3], James Oyedokun[1], Oluwadamilola Ogunsade[1], Oluseye Abiona[1], and Oluwatosin Ponnle[1]

[1]Department of Food Science and Technology, Osun State University, P.M.B. 4494, Osogbo, Osun State, Nigeria.
[2]Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.
[3]Department of Food Engineering, Ladoke Akintola University of Technology, Ogbomosho, Oyo State, Nigeria.
**Corresponding author's E-mail address: racheal.babalola@uniosun.edu.ng*

Received: 20th Mar 2026 | Revised: 9th May 2026 | Accepted: 11th May 2026

Abstract- Demand for instant foods without health implications have caused a paradigm shift from the basic raw material (wheat grains) to composite flour. However, compositing does not provide some of the nutritional values desired by food processors, which has led to the need for alternative means of improving the nutritional value of flour for instant foods. The study explored the functional and pasting properties of sprouted wheat grains and cardaba banana flour.

The WAC (186.51 to 262.38%), bulk density (0.44 to 0.64%), OAC (204.46 to 285.26%), foam capacity (102.68 to 120.92%), foam stability (62.30 to 89.45%), emulsion capacity (0.39 to 0.45%), and emulsion stability (35.74 to 54.64%) were determined. Results for pasting properties showed the peak viscosity (274.50 to 5750.50 RVU), trough viscosity (173.00 to 3684.00 RVU), breakdown viscosity (103.00 to 2066.50 RVU), final viscosity (281.00 to 6191.50 RVU), and setback viscosity (110.00 to 2507.50 RVU), peak time (4.73 to 5.24 minutes), and pasting temperature (0.00 to 85.95 ℃).

The results obtained based on the pasting and functional composition showed that the sample's nutritional assessment was good; however, sample C (90 SWF: 10 CBF) had the best sample formulation based on the assessed nutritional properties.

Keywords— **Sprouted wheat, cardaba banana, composite flour, pasting, functional**

INTRODUCTION

Wheat grain (*Triticum aestivum*) is the most common and the most utilized cereal in the food processing industry, owing to its unique elasticity property, which is attributed to its gluten content. It is a raw material used in the production of flour for baking and pastries; it has been the bedrock of confectioneries, and many processors depend on it for food processing. Nonetheless, Arukwe *et al.* (2021) reported the low protein content (14.70%) of wheat, which has consistently affected the nutritional quality of pastries and confectionery products produced from it.

The paradigm shift from the consumption of home-made meals to the consumption of instantaneous or on-the-go or ready-to-eat foods has caused great concern about the nutritional quality of these foods. Exceptionally, considering the low protein content of the core material (wheat), and the importance of protein to health. Furtherance to this, is the loss of nutritional qualities by some food processors, therefore linking wheat grains to some diseases, which requires the urgency for improved nutritional processing operations like sprouting.

Sprouting is an enzyme-induced operation that results in products with enhanced nutritional, functional, and organoleptic properties of food products. It is a supposedly essential operation for wholesome food security. According to Pagand *et al.* (2017), sprouted grains have improved qualities that could be connected to the chemical and biochemical reactions of the sprouting. It's supplementary benefits: increased bioavailability of minerals and vitamins, enhanced sensory qualities, anti-nutrients reduction, and heightened antioxidant activity (Ahmed *et al.*, 2024).

The molecular structure shifting of grains during sprouting reactivates the metabolism of the grain, triggering the degradation of all antinutritional compounds. Besides the increased nutritional profile imposed on grains by sprouting, it has by extension improved human's health (Ikram *et al.*, 2021). Sprouted wheat grains have successfully been incorporated as composite flour in food processing, and this has been reported by some authors. Arukwe *et al.* (2021) reported the production of cookies from composite flour of sprouted wheat, sorghum and African yam bean seed. Jahan *et al.* (2021) also developed an affordable, enriched weaning food from the composition of sprouted wheat grains and mung-beans. Sprouted wheat grains have been included in flour composition to improve the functional and pasting properties of the end product.

Functional properties are the physicochemical properties that describe the relevance of the bioactive components present in biomaterials. They include water and oil absorption capacities, foam capacity and stability, emulsion capacity and stability, swelling capacity, etc. They are required in predicting and evaluating the behavior of proteins, sugars, starches, fat, and fibre, in specific food

https://doi.org/10.36782/apjsafe.v14i1.649

systems. Functional properties affect the textural attributes and appearance of processed products, which is a reflection of the behavior of the ingredients used (Awuchi *et al.*, 2019).

The pasting properties comprise the different viscosities that describe the behavior of starch with water during heating and cooling processes; these include the peak, trough, breakdown, final, and setback viscosities. Pasting analysis also elucidates the time required for cooking, likewise the energy requirements, as functions of the pasting time and pasting temperature. The knowledge of the pasting properties is applicable in the formulation process and in the quality control unit of food industries.

Cardaba banana is a hybrid crop that is very cold-hardy, starchy, vigorous, and disease-resistant. It is used for cooking but can also be eaten raw. It is relatively abundant all year-round in Nigeria, making it a low-cost commodity. It is, however, grossly under-utilized, thereby contributing to high postharvest losses.

Reported research on cardaba banana include: Babalola and Taiwo (2019) on the antioxidant properties, sensory evaluation, and mineral content. Falodun *et al.* (2019) on the resistant starch, bioactive components, physicochemical, and pasting properties. Ayo-Omogie *et al.* (2021) on the effect of fermentation and blanching on nutritional and functional properties. Babalola *et al.* (2024) on the acceptability, antioxidative, linoleic inhibition, and FTIR characterization of *chinchin* and peanut burger snacks enriched with cardaba banana flour.

However, these reports have not considered compositing cardaba banana and sprouted wheat flour, despite the individual nutritional properties reported for each. It is believed that incorporating cardaba banana in compositing can reduce wastage and also enhance its usage as a functional ingredient in various food products (Ayo-Omogie and Odekunle, 2017). This study therefore, focuses on determining the functional and pasting properties of sprouted wheat grains and cardaba banana.

MATERIALS AND METHODS

Materials

Fresh bunches of cardaba banana fruits were procured from Kajola Market, Osun State. Wheat grains, refined wheat flour, and other ingredients such as baking powder, sugar and butter were obtained from Shasha Market, Oke Baale, Osogbo.

Methods

Production of cardaba banana flour

The method of Babalola and Taiwo (2019) was employed in the production of cardaba banana flour. A bunch of cardaba banana fruit was harvested manually, peeled, cut manually into 5mm thickness which was ascertain using a Vernier calliper. After hot water immersion blanching at 60 ˚C for 10 min, the samples were drained, and dried inside a cabinet drier at 70 ˚C for 7 hours. The dried samples were milled with a hammer mill, sieved with a 500 µm sieve aperture, packaged and stored.

Production of sprouted wheat flour

Sprouted wheat was produced using the modified method of Arukwe *et al.* (2021). 5000g of wheat grain was sorted, cleaned in running water for 5 min repeatedly to remove contaminants and foreign materials. The grains were steeped in water at 20-22 ℃ in a container and covered for 24 h. After steeping, the grains were dripped out gradually on a germination tray as one of the steps involved in sprouting, then sprouting took 48 hours at 20-22 ℃. During this time, the seeds were sprayed with water at intervals of 12 hours until the last day of sprouting. The sprouted wheat was removed from the tray after achieving 90% sprouting. The sprouted wheat grain was milled using a hammer mill until a stable particle size was obtained. It was sieved with a mesh aperture of 500 µm diameter, packed inside a polyethylene bag, labelled and stored.

Table 1. Sample formulation from refined wheat, cardaba banana and sprouted wheat flour blend

Sample	Refined wheat flour, RWF (%)	Cardaba banana flour, CBF (%)	Sprouted wheat flour, SWF (%)
A	100	0	0
B	0	0	100
C	0	10	90
D	0	50	50
E	0	100	0

Functional properties of the composite flour

The water absorption capacity (WAC), oil absorption capacity (OAC), bulk density (BD), foam capacity (FC) and foam stability (FS) were determined by following the method of Onwuka (2018).

Water absorption capacity (WAC)

To a 1.0 g sample in a centrifuge tube, 10 ml of distilled water was added, and the tube was placed on a vortex for 2 mins agitation. The tube was centrifuged at 4000 rpm for 20 minutes, after which the supernatant was decanted, and the adhering water was removed. WAC was calculated using this equation:

$$\%\,\mathrm{WAC} = \frac{\mathrm{W_3 - W_2}}{\mathrm{W_1}}\ \mathrm{X}\,100$$

Where W_3 = weight of tube + sample after centrifuging and decanting

W_2 = weight of tube + sample before centrifuging

W_1 = weight of sample

Oil absorption capacity (OAC)

In determining the OAC, 10 ml of refined oil was mixed with 1.0 g of the sample inside a centrifuge tube. After agitating in a vortex, the tube was centrifuged at a speed of 3500 rpm for 15 mins, the supernatant was discarded and all adhering water was removed. OAC was calculated using the equation below;

$$\%\,\mathrm{OAC} = \frac{\mathrm{W_3 - W_2}}{\mathrm{W_1}}\ \mathrm{X}\,100$$

https://doi.org/10.36782/apjsafe.v14i1.649

Where

W_3= weight of tube + sample after centrifuging and decanting

W_2= weight of tube + sample before centrifuging

W_1= weight of sample

Bulk Density (BD)

In calculating the BD, a known weight of sample was poured into a 10 ml measuring cylinder, and the measuring cylinder was gently tapped on the workbench top 50 times. The volume of the tapped measuring cylinder was taken, and BD was calculated using this formula: Bulk density (g/ml) = Weight of sample / Volume of sample after tapping.

Foam capacity (FC) and Foam stability (FS)

A 250 mg sample was mixed with 250 ml of distilled water, and the mixture's pH was adjusted to 2, 4, 6,8 and 10. The solution formed was then whipped for 30 mins inside a stainless GS Blender (model 38 BL45, Dynamic Corporation, Auburn Hills, USA). The whipped solution was afterwards poured into a 100 ml graduated cylinder, and the total sample volume was taken at 0 min for the foam capacity. The foam stability volume was taken at an interval of 10 mins for a period of 1 hour.

Foam capacity and Foam stability were calculated thus:

$$\%\ \mathrm{FC} = \frac{V_{aw} - V_{bw}}{V_{bw}} \times 100$$

$$\%\ \mathrm{FS} = \frac{V_{as} - V_{bw}}{V_{bw}} \times 100$$

Where

FC = Foam Capacity (%)

FS = Foam Stability (%)

V_{aw} = volume after whipping (ml)

V_{bw} = volume before whipping (ml)

V_{as} = volume after standing (ml)

Pasting properties of the composite flour

Rapid Visco Analyzer (RVA), also known as amylograph, was used to determine the pasting properties of the flour samples. Thirty grams (30 g) of the flour samples and 50 ml of distilled water were mixed in a paddle. The paddle was placed into a canister containing the samples and water. The samples were then inserted into the rapid viscous analyser. The analysis was carried out at a programmed heating and cooling cycle where the samples were held at 50℃ for 1 min, heated at 95 ℃ for 3 to 8 min and held at 50 ℃ for 1 to 4 mins. The pasting performance of the samples was automatically recorded on the graduated sheet of the instrument.

Statistical Analyses

All analyses were performed in triplicate, data obtained were subjected to analysis of variance (ANOVA) using SPSS 16.0. Duncan Multiple test was used for the data grading.

RESULTS AND DISCUSSIONS

Functional properties of composite flour from sprouted wheat and cardaba banana formulation

The results of the functional properties of the composite flour samples are presented in Table 2. Significant differences ($p < 0.05$) were observed for all the samples across all the parameters determined. However, a similar trend was observed for the WAC, OAC, FC, BD, and EC, while the FS, and ES followed the same trend. Sample C (90% SWF, 10% CBF) had the highest percentage of WAC, OAC, FC, BD, and EC.

With sample A (100 % RWF) serving as the control for all samples, the composite flour mixtures had higher percentages of WAC, OAC, FC, BD, and EC than the control sample. Li *et al.* (2023) and Alim *et al.* (2024) also reported a similar trend, with composite flour exhibiting higher functional properties than the RWF. This, according to Alim *et al.* (2024), could be due to the addition of more nutritious properties imparted by the individual flour constituting the composite.

The WAC of the composite flour is higher than the RWF, which agrees with the work of Sofi *et al.* (2020) on chickpea germination, that sprouting increases WAC. The biochemical and structural changes that resulted from sprouting could have caused the partial loosening of starch and protein structures, exposing more hydrophilic groups for more water binding (Sofi *et al.*, 2020). A high WAC is of good importance in processing, because it enhances the hydration and blending properties of the flour, resulting in swelling of the dough, thereby increasing the profit margin of the food processor.

Sample C (90% SWF, 10% CBF) ranked higher in WAC amidst the composite flours, in addition to the effects of sprouting from SWF, CBF is rich in dietary fibre, resistant starch, and hydroxyl groups (Falodun *et al.*, 2019), which could increase the water-binding capacity of the flour (Dhillon *et al.*, 2020). The increase in WAC with either composition of "high SWF with low CBF" or composition of "low SWF with high CBF" substitution, might be attributed to the low protein, high carbohydrate contents and particle size of the CBF, coupled with the increased nutritional properties of the SWF. Ohizua *et al.* (2017) stated that carbohydrates are a great way to influence the water absorption capacity of foods.

The OAC of the composite flour samples were higher the RWF sample. According to Abd-Elmoneim and Bernhardt (2010), sprouting causes the exposure of the hydrophobic protein sites, thereby causing more available binding sites, this coupled with the raised fat-binding due to the fibre and damaged starch of cardaba banana could be responsible for the high OAC recorded. Increased OAC, is a greatly desired attribute in food processing, because it imparts better sensory attributes and enhances mouthfeel and improved flavour. It could be noted that both SWF and CBF inclusion contributed to this increase; nonetheless, the percentage inclusion also affected it.

Oil absorption capacity (OAC) is essential because it retains flavour and increases the mouth feel of foods (Ubbor *et al.*, 2022). This result indicates that the blends would be useful in structural interaction in food, especially in flavour retention, improvement of palatability and extension of shelf life, particularly in bakery or meat products where oil absorption property is of prime importance.

Flour has the capacity to produce foam due to surface-active proteins present in it. FC is enhanced and stabilized by small peptides. The increased FC recorded for the flour samples, agrees with the findings of Ocheme *et al.* (2015). The increase was attributed by Siddiqua *et al*. (2019) and Zhu *et al*. (2025) to have been caused by the repercussive sprouting activities. This include, the activation of protease, leading into partial hydrolysis of proteins, which would result in soluble peptides and amino acids formation.

The increase in FC is advantageous in food processing, according to Wang *et al.* (2024), it improves the softness and the texture of the processed food product. It is a mostly desirable property in confectionery products that requires aeration. According to Zhu *et al*. (2017), foaming capacity measures the amount of interfacial area created by protein during foaming.

Emulsion capacity values reported in this study are lower than the values of 42.50, 56.78, and 56.67% for rice, cowpea, and AYB flours, respectively, reported by Iwe *et al*. (2016). EC of the composite flours increased due to sprouting, which agrees with the findings of Amina *et al.* (2018), Marchini *et al.* (2021), and Acheampong *et al.* (2024) on sprouted corn, sorghum, and finger millet-maize, respectively.

Increase in EC of sprouted flour samples could be caused by increased protein solubility and more surface-active peptides (Navarro *et al.,* 2024); exposure of hydrophobic groups (Di *et al.,* 2022); Production of amphiphilic breakdown products (Medhe *et al.*, 2019); Changes in non-protein matrix (Berk *et al.*, 2025); and reduced anti-nutrients, and improved functional availability (Kushwaha and Said, 2020). Increased EC of flour samples causes improved texture and mouthfeel, enhances the stability of the product, improves the fat utilization and retention, enhances nutritional and sensory properties, and most importantly, it is of industrial cost and possesses formulation benefits.

Sprouting increased the BD of the composite flour, which does not agree with the work of Hussain and Uddin (2012), who reported a decrease in BD due to the sprouting operation. According to Abd Elmoneim, and Bernhardt (2010), the BD increase could be caused by the drying, milling, and sieving processes undertaken after the sprouting unit operation. During the germination/sprouting process, porous structures are usually formed, which are subsequently compressed into denser matrices during the drying process. The drying process further collapsed the structures to produce compact particles, which are further compacted by the sieving process, thereby increasing the bulk density.

BD is crucial in determining the required packaging, handling of material, and how it can be applied in wet processing in the food industry (Orisa and Udofia, 2020). Higher BD is generally desirable for greater ease of dispersibility and paste thickness reduction. On the other hand, the low BD values of flour are good physical attributes when determining transportation and storability since the products could be easily transported and distributed to required locations.

Table 2. Functional properties of composite flour from sprouted wheat and cardaba banana formulations

SAMPLE	A	B	C	D	E
WAC (%)	186.51 ±0.6^{e}	232.38 ±0.21^{c}	262.38 ±3.00^{a}	187.18 ±2.46^{d}	253.85 ±0.10^{b}
OAC (%)	204.46 ±0.8^{e}	244.76 ±0.14^{c}	285.26 ±0.65^{a}	232.07 ±0.37^{d}	259.35 ±0.34^{b}
FC (%)	102.68 ±0.21^{e}	114.65 ±0.10^{c}	120.92 ±0.96^{a}	109.48 ±0.15^{d}	119.08 ±0.42^{b}
FS (%)	89.45 ±0.10^{a}	76.55 ±0.20^{c}	62.30 ±0.03^{e}	81.45 ±0.26^{b}	65.63 ±0.19^{d}
BD (g/ml)	0.44 ±0.02^{e}	0.54 ±0.01^{c}	0.64 ±0.03^{a}	0.48 ±0.03^{d}	0.63 ±0.01^{b}
EC (g/m^{2})	0.39 ±0.00^{e}	0.42 ±0.00^{c}	0.45 ±0.01^{a}	0.41 ±0.00^{d}	0.43 ±0.00^{b}
ES (%)	54.64 ±0.48^{a}	48.64 ±0.08^{c}	35.74 ±0.26^{e}	51.17 ±0.11^{b}	48.29 ±0.04^{d}

Values reported are means ± standard deviation of triplicate determinations. Mean values with different superscripts within the same row are significantly ($p<0.05$) different

Key:
A: 100% RWF
B: 100% SWF: 0% CBF
C: 90% SWF: 10% CBF
D: 50% SWF: 50% CBF
E: 0% SWF: 100% CBF

RWF: Refined Wheat Flour
SWF: Sprouted Wheat Flour
CBF: Cardaba Banana Flour
WAC: Water Absorption Capacity
OAC: Oil Absorption Capacity
FC: Foaming Capacity
FS: Foaming Stability
BD: Bulk Density
EC: Emulsion Capacity
ES: Emulsion Stability

Pasting properties of composite flour from sprouted wheat and cardaba banana formulation

The results of the pasting properties of the composite flour are presented in Table 3, for the peak, trough, breakdown, final, and setback viscosities, likewise for the peak time and pasting temperature. The results of these viscosities (peak, trough, and breakdown) are higher than those reported by Eke-Ejiofor *et al*. (2018) on functional and pasting properties of *acha*, defatted soybean, and groundnut flour blends.

It was observed that the viscosity (peak, trough, and breakdown) of the RWF was higher than that of SWF, a

https://doi.org/10.36782/apjsafe.v14i1.649

similar trend was reported by Simsek *et al.* (2014). This could be due to the less starch hydrolysis in unsprouted grain. The availability of more soluble sugars and dextrin’s in sprouted flour, which reduced these viscosities (Simsek *et al*., 2014). However, Sharanagat *et al*. (2019) reported that it might be caused by the presence of preserved granule integrity in the unsprouted flour.

Furthermore, Sample E (100% CBF) and sample D (50% SWF, 50% CBF) had higher viscosities than the control sample, A (100% RWF). This implied that increasing the SWF lowered these viscosities, which might be due to the consequences of high amylase activity in the SWF. It could be suggested that CBF be utilized as a composite flour for functional foods requiring non-starchy foods to improve their starch content.

It was observed that an increase in CBF incorporation increased these viscosities (peak, trough, and breakdown). This increase might be due to the availability of more natural starch granules provided by the CBF, allowing for more granule swelling. High peak viscosity is an index of high starch content, and it also reflects the extent of granule swelling (Eke-Ejiofor and Owuno, 2012). High peak viscosity offers better thickening ability, good puffing/expansion, improved texture and mouthfeel, making such flour suitable in food formulations.

High breakdown could be described as experiencing a high peak followed by a moderate drop. It is an indicator of strong swelling capacity, a property required in the processing of instant and convenience foods. Through viscosity, also known as the hold period, is the minimum viscosity point during either heating or cooling; it is the minimum viscosity value that measures the ability of a paste to withstand breakdown. The lower the trough viscosity value, the more stable the starch gel is. Hence, to obtain a stable paste, the percentage inclusion of SWF should be higher than that of CBF.

The results of the final and setback viscosities showed that increasing CBF inclusion increased these viscosities, whilst increasing the inclusion of SWF lowered these viscosities. This could be due to the enzymatic activities, which had altered the starch granule in SWF, whereas, more stable starch granules were supplied by the CBF. The final viscosity values obtained were higher than the range reported by Ofia-olua (2014) for wheat and walnut blends (95.51 – 252 RVU). The final viscosity is the most commonly used parameter to identify the particular starch-based sample quality. According to Li *et al.* (2019), it measures the viscosity of starch paste after a cooling process, indicating its gel-forming ability and stability.

Adebowale *et al*. (2025) reported that setback viscosity is a key indicator of the retrogradation process of starches, thereby affecting the final product's texture and stability. Setback viscosity values correlate with the ability of starches to gel into semi-solid pastes. The setback viscosity values are higher than those reported by Eke-Ejiofor *et al*. (2018). High setback viscosity is an indicator of strong gel formation during cooling, and good binding properties in processed foods. It is a desirable property in for foods designed to harden or set after cooling.

It was observed that sprouting reduced the peak time by 9.7 %. This might be caused by the rise in α-amylase activity, which led to faster starch hydrolysis. According to Simsek *et al.* (2014), germination activates α-amylases, which hydrolyse starch into dextrin’s and soluble sugars. This starch breakdown, heightened the paste reaching its maximum viscosity sooner, thereby shortening the peak time. It could also be due to the lower gelatinization from the enzymatic and compositional changes, causing an earlier temperature window for rapid viscosity rise. Navarro *et al.* (2024) reported that sprouted flour samples often paste at slightly lower temperatures, shortening the time to peak.

The inclusion of CBF reduced the peak time by 1.33 %, a value lower than the value (9.7 %) recorded for the sprouted flour. This could be due to the lesser availability of swellable starch (SWF), which was further diluted with native starch (CBF). Iliyasu *et al*. (2019) reported that CBF is rich in components that bind water and alter dispersion viscosity (fibre, pectin, and resistant starch), which also limits the swelling of starch granules. Peak time indicates the duration for samples to reach their peak viscosity; a lower peak time implies that the food will require a shorter cooking time.

It was observed that Sample B (100 % SWF) had no pasting temperature, this might be caused by a lack of swellable starch for viscosity. This is because the starch granules have been degraded into sugars and dextrin’s, meanwhile, RVA pasting temperature is detected at the first increase in viscosity of the starch granules. Navarro *et al*. (2024) reported that germinated wheat showed very low or undefined pasting temperature due to excessive α-amylase activity and reduced intact starch.

Pasting temperature is referred to as the temperature at which viscosity starts to rise Eke-Ejiofor *et al*. (2018), low pasting temperature implies lower energy consumption, and vice versa. Samples B (100% SWF, 0% CBF) and C (90% SWF, 10% CBF) with low CBF inclusion had reduced pasting temperatures. This implies that compositing for short cook time and low energy requirement will require low inclusion of CBF and high inclusion of SWF.

The values of peak time and pasting temperatures obtained from this study are lower than that reported by Eke-Ejiofor *et al*. (2018). Flour blends with higher pasting temperature may not be recommended for certain products due to the high cost of energy, since pasting temperature measures the minimum temperature required to cook a given food sample.

https://doi.org/10.36782/apjsafe.v14i1.649

Table 3. Pasting properties of composite flour from sprouted wheat and cardaba banana formulation

Samples	A	B	C	D	E
PEAK (RVU)	1077.50 ±13.4^{c}	274.50 ±3.5^{e}	448.00 ±52.3^{d}	1668.50 ±140.7^{b}	5750.50 ±45.9^{a}
T. (RVU)	600.50 ±24.8^{c}	177.60 ±2.8^{d}	173.00 ±26.9^{d}	1173.00 ±112.4^{b}	3684.00 ±42.4^{a}
B.D. (RVU)	477.00 ±11.3^{c}	103.50 ±0.7^{e}	173.00 ±26.9^{d}	520.00 ±7.1^{b}	2066.50 ±3.5^{a}
F.V. (RVU)	1317.00 ±28.8^{c}	281.00 ±4.2^{e}	447.50 ±40.3^{d}	1884.50 ±37.5^{b}	6191.50 ±41.7^{a}
S.B. (RVU)	707.50 ±16.6^{b}	110.00 ±1.4^{e}	172.50 ±14.9^{d}	651.00 ±9.9^{c}	2507.50 ±84.2^{a}
P.T. (min)	5.24 ±0.5^{a}	4.73 ±0.0^{c}	4.73 ±0.0^{c}	5.17 ±0.5^{b}	5.17 ±0.5^{b}
P.P (˚C)	85.95 ±0.6^{a}	0.00 ±0.0^{d}	84.83 ±1.2^{c}	85.63 ±0.4^{b}	84.83 ±1.1^{c}

Values reported are means ± standard deviation of triplicate determinations. Mean values with different superscripts within the same row are significantly ($p<0.05$) different
Key:
A: 100% RWF
B: 100% SWF: 0% CBF
C: 90% SWF: 10% CBF
D: 50% SWF: 50% CBF
E: 0% SWF: 100% CBF

RWF: Refined Wheat Flour
SWF: Sprouted Wheat Flour
CBF: Cardaba Banana Flour
PEAK – Peak Viscosity
T. – Trough Viscosity
B. D. – Break Down Viscosity
F. V. – Final Viscosity
S.B. – Setback Viscosity
P.T. – Pasting Time
P.P. - Pasting Temperature

CONCLUSIONS

The nutritionally improved composite flour was efficaciously produced from sprouted wheat flour, and cardaba banana flour. In terms of the WAC, OAC, FC, BD, and EC, sample C had the highest percentage. This implies that targeting higher functional properties of the flour composition will require low CBF and high SWF. This flour composition could be used in the production of pastries and confectionery. A cost-effective product could be obtained with the flour composition having low CBF and high SWF. The pasting time and temperature were low for samples with low CBF and high SWF. Companies or industries might leverage this for enhanced nutritional values and good profitability from the production.

REFERENCES

Abd Elmoneim, O. E., and Bernhardt, R. (2010). Influence of grain germination on functional properties of sorghum flour. *Food chemistry*, *121*(2), 387-392.

Acheampong, R., Osei Tutu, C., Amissah, J. G. N., Danquah, A. O., and Saalia, F. K. (2024). Physicochemical and sensory characteristics of a breakfast cereal made from sprouted finger millet-maize composite flour. *Cogent Food & Agriculture*, *10*(1), 2363003.

Adebowale, O.J, Adeyanju, A.A, Mokhele, T., Bamidele, O. P. (2025). Chemical Composition of Composite Flour from Okara Powder and Whole Wheat Flour and the Sensory Evaluation of the Biscuits Made from the Composite Flour. *Food Science Nutr*ition 17;13 (6): e70450. doi: 10.1002/fsn3.70450. PMID: 40529526; PMCID: PMC12171634.

Ahmed, W. E., Ragab, I., Gadallah, M. G., Alhomaid, R. M. and Almujaydil, M. S. (2024). Effect of sprouting whole wheat grain on the sensory quality, physicochemical properties, and antioxidant activity of cupcakes. *Applied Food Research*, *4*(1), 100412.

Alim, M. A., Abedin, M. Z., Al Reza, M. S., Huq, A. O., Bari, L., Esrafil, M., and Zubair, M. A. (2024). Development and characterization of composite wheat flour incorporated with psyllium husk (*Plantago ovata*) and peanut (*Arachis hypogea*) and sensory properties of composite flour noodles. *Food and Humanity*, *2*, 100279.

Amina, M., Djamel, F., and Djamel, H. (2018). Influence of fermentation and germination treatments on physicochemical and functional properties of a corn flour. *Bulgarian Journal of Agricultural Science*, *24*(4).

Arukwe, D. C., Ezeocha, V. C. and Ubbor, S. C. (2021). Production and evaluation of cookies from composites of sprouted wheat, sorghum and African yam bean seed flours. *Nigeria Agricultural Journal*, *52*(2), 277-283.

Awuchi, C. G., Igwe, V. S. and Echeta, C. K. (2019). The functional properties of foods and flours. *International Journal of Advanced Academic Research*, *5*(11), 139-160.

Ayo-Omogie, H. N., Jolayemi, O. S., & Chinma, C. E. (2021). Fermentation and blanching as adaptable strategies to improve nutritional and functional properties of unripe Cardaba banana flour. *Journal of Agriculture and Food Research*, *6*, 100214.

Ayo-Omogie, H. N. and Odekunle, O. Y. (2017). Substituting wheat flour with banana flour: Effects on the quality attributes of doughnuts and cookies. *Applied Tropical Agriculture*, 22(2), 134-137.

Babalola, T. R., and Taiwo, K.A. (2019). Antioxidant properties, sensory evaluation and mineral content of

Cardaba banana and plantain flours. *Open Agriculture*, *4*(1), 52-64.

Babalola, R. T., Lawal, M. A., Adesina, A. B., Olowookeere, R., & Ganiyu, S. A. (2024). The Acceptability, Antioxidative, Linoleic inhibition and FTIR characterization of Chinchin and Peanut Burger Snacks Enriched with Cardaba Banana Flour. *Ife Journal of Science and Technology*, *8*(1), 1-15.

Berk, B., Glaue, Ş. Ö., Bayram, Ö. Y., and Ünlütürk, S. (2025). Investigating the impact of sprouting on starch properties of wheat flour and non-linear rheological behavior of bread dough. *Food Hydrocolloids*, *164*, 111180.

Dhillon, B., Choudhary, G., and Sodhi, N. S. (2020). A study on physicochemical, antioxidant and microbial properties of germinated wheat flour and its utilization in breads. *Journal of Food Science and Technology*, *57*(8), 2800-2808.

Di, Y., Li, X., Chang, X., Gu, R., Duan, X., Liu, F., and Wang, Y. (2022). Impact of germination on structural, functional properties and in vitro protein digestibility of sesame (*Sesamum indicum L.)* protein. *Lwt*, *154*, 112651.

Eke-Ejiofor J., Wordu G.O. and Bivan S.K. (2018). Functional and pasting properties of *acha*, deflated soybean and groundnut flour blends. American *Journal of Food Science and Technology,* 6(5); 215-218.

Eke-Ejiofor, J., and Owuno, F. (2012). Functional and pasting properties of wheat/three-leaf yam (*Dioscorea dumentorcem*) composite flour blend. *Global Research Journal of Agriculture and Biological Science,* 3(4), 330-335.

Falodun, A. I., Ayo-Omogie, H. N., and Awolu, O. O. (2019). Effect of different drying techniques on the resistant starch, bioactive components, physicochemical and pasting properties of *Cardaba* banana flour. *Acta Universitatis Cinbinesis, Series E: Food Technology*, *23*(1).

Hussain, I., and Uddin, M. B. (2012). Optimization effect of germination on functional properties of wheat flour by response surface methodology. *International Research Journal of Plant Science*, *3*(3), 31-37.

Ikram, A., Saeed, F., Afzaal, M., Imran, A., Niaz, B., Tufail, T., and Anjum, F. M. (2021). Nutritional and end-use perspectives of sprouted grains: A comprehensive review. *Food science & nutrition*, *9*(8), 4617-4628.

Iliyasu, R., Ayo-Omogie, H. N., Adamu, H. D., and Adamu, M. A. (2019). Effect of ripening and pretreatment on the physical, pasting and sensory properties of cardaba banana (*Musa ADD*) flour. *Bayero Journal of Pure and Applied Sciences*, *12*(1), 651-656.

Iwe, M. O., Onyeukwu, U., and Agiriga, A. N. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. *Cogent Food & Agriculture*, *2*(1), 1142409.

Jahan, S., Bisrat, F., Faruque, M. O., Ferdaus, M. J., Khan, S. S. and Farzana, T. (2021). Formulation of nutrient-enriched germinated wheat and mung-bean based weaning food compared to locally available similar products in Bangladesh. *Heliyon*, *7*(5).

Kushwaha, V. S., and Said, P. P. (2020). Characterization of functional flour from germinated grains. *Indian Journal of Pure & Applied Biosciences*, *8*(6), 46-55.

Li, M., Zhang, Y., You, X., Wang, Y., Zhou, K., Wei, P., and Wei, L. (2023). Assessment of Functional Properties of Wheat–Cassava Composite Flour. *Foods*, *12*(19), 3585.

Li, S., Ye F., Zhou Y., Lei L., and Zhao G. (2019). "Rheological and Textural Insights into the Blending of Sweet Potato and Cassava Starches: In Hot and Cooled Pastes as Well as in Fresh and Dried Gels." Food Hydrocolloids.

Marchini, M., Arduini, R., and Carini, E. (2021). Insight into molecular and rheological properties of sprouted sorghum flour. *Food Chemistry*, *356*, 129603.

Medhe, S., Jain, S., and Anal, A. K. (2019). Effects of sprouting and cooking processes on physicochemical and functional properties of moth bean (*Vigna aconitifolia*) seed and flour. *Journal of Food Science and Technology*, *56*(4), 2115-2125.

Navarro, J. L., Losano Richard, P., Moiraghi, M., Bustos, M., León, A. E., and Steffolani, M. E. (2024). Effect of different wheat sprouting conditions on the characteristics of whole-wheat flour. *Food Technology and Biotechnology*, *62*(2), 264-274.

Ocheme, O. B., Adedeji, O. E., Lawal, G., and Zakari, U. M. (2015). Effect of germination on functional properties and degree of starch gelatinization of sorghum flour. *Journal of Food Research*, *4*(2), 159.

Offia-Olua, I. B. (2014). Chemical, functional and pasting properties of Wheat (*Triticum spp*)- Walnut (*juglansregia*) flour. *Food and Nutritional Sciences*, 1591-1604.

Ohizua, E. R., Adeola, A. A., Idowu, M. A., Sobukola, O. P., Afolabi, T. A., Ishola, R. O., Ayansina, S. O., Oyekale, T. O., and Falomo, A. (2017). Nutrient composition, functional, and pasting properties of unripe cooking banana, pigeon pea, and sweet potato flour blends. *Food Science and Nutrition,* 5(3), 750-762.

Onwuka G.I. (2018). Food analysis and instrumentation. Theory and practices. Revised edition. Naphtali Prints Lagos, Nigeria. 2018;10-20.

Orisa, C. A., and Udofia, S. U. (2020). Functional and pasting properties of composite flours from *Triticum durum, Digitaria exilis, Vigna unguiculata* and *Moringa oleifera* powder. *Asian Food Science Journal*, 19(2), 40-49.

Pacheco, A. F. C., Pacheco F. C., dos Santos F. R., Cunha J. S., and Paiva P. H. C. (2024). "Starch Paste Properties." In Standardized Procedures and Protocols for Starch, edited by Banger S. P., 123–143. Springer US

Pagand, J., Heirbaut, P., Pierre, A. and Pareyt, B. (2017). The magic and challenges of sprouted grains. *Cereal Foods World*, *62*(5), 221-226.

Sharanagat, V. S., Kumar, P., Patro, S., Ghule, P. D., Naryal, S., Meena, S., and Nema, P. K. (2019). Influence of germination on physicochemical, thermo-pasting, and

https://doi.org/10.36782/apjsafe.v14i1.649

antioxidant properties of moong grain (*Vigna radiata*). *Journal of Food Processing and Preservation*, *43*(5), e13922.

Siddiqua, A., Ali, M. S., and Ahmed, S. (2019). Functional properties of germinated and non-germinated cereals: A comparative study. *Bangladesh Journal of Scientific and Industrial Research*, *54*(4), 383-390.

Simsek, S., Ohm, J. B., Lu, H., Rugg, M., Berzonsky, W., Alamri, M. S., and Mergoum, M. (2014). Effect of pre-harvest sprouting on physicochemical properties of starch in wheat. *Foods*, *3*(2), 194-207.

Sofi, S. A., Singh, J., Muzaffar, K., Mir, S. A., and Dar, B. N. (2020). Effect of germination time on physico-chemical, functional, pasting, rheology and electrophoretic characteristics of chickpea flour. *Journal of Food Measurement and Characterization*, *14*(5), 2380-2392.

Taiwo, B. R., & Kehinde, T. A. (2019). Antioxidant Properties, Sensory Evaluation and Mineral Content of Cardaba Banana and Plantain Flours. *Open Agriculture*, *4*(1).

Ubbor, S. C., Ekeh, J. I., Agwo, O. E., Iguh, B. N. and Egwu, S.N. (2022). Physicochemical and sensory properties of cookies produced from composite flour of wheat, *acha* and whole orange fleshed sweet potato. *Nigerian Agriculture Journal*, 53(1): 248-259.

Wang, X. H., Tai, Z. J., Song, X. J., Li, Z. J., and Zhang, D. J. (2024). Effects of germination on the structure, functional properties, and in vitro digestibility of a black bean (*Glycine max (L.*) protein isolate. *Foods*, *13*(3), 488.

Zhu, L., Xie, Q., Qin, D., He, Y., Yuan, H., Mao, Y., and Xia, X. (2025). Germination-Induced Biofortification: Improving Nutritional Efficacy, Physicochemical Properties, and In Vitro Digestibility of Black Rice Flour. *Foods*, *14*(16), 2912.

Zhu, S.M., Lin, S.L., Ramaswamy, H.S., Yu, Y. and Zhang, Q.T. (2017). Enhancement of functional properties of rice bran proteins by high pressure treatment and their correlation with surface hydrophobicity. *Food Bioprocess Technology*, 10, 317–327 (2017). https://doi.org/10.1007/s11947-016 -1818-7.