Asian Journal of
Biological Sciences

AJBS

OPEN ACCESS

Functional, Pasting and Physical Property of Wheat, Orange Flesh Sweet Potato and Chickpea Flour

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ABSTRACT

Background and Objective: Bakery products traditionally rely on wheat flour, but growing health consciousness has spurred demand for gluten-free options. Chickpea and Orange-Fleshed Sweet Potato (OFSP) flours offer promising alternatives with enhanced nutritional profiles. The objective of this study is to characterize the functional, pasting and physical properties of Orange-Fleshed Sweet Potato (OFSP), chickpea and wheat flour to evaluate their potential as gluten-free alternatives in bakery products. **Materials and Methods:** This study determined the functional, pasting and physical properties of three types of flour: Orange-Fleshed Sweet Potato (OFSP), chickpea and wheat. A comprehensive analysis was conducted to characterize these properties, utilizing statistical analysis through ANOVA ($p<0.05$) to determine significant differences among the flours. **Results:** Chickpea flour demonstrated superior water (2.21 g/g) and oil absorption (1.03 g/g), alongside higher water solubility (25.41%) compared to wheat and OFSP flours. The OFSP flour showed greater dispersibility, bulk density (0.74 g/mL) and tapped density (0.87 mL/g). Wheat flour retained 50% on a 0.1 mm sieve, indicating finer particles and exhibited higher viscosities (2453.33 cp) and longer peak times (6.27 min) than chickpea and OFSP flours. Significant differences were also observed in color properties across the flours. **Conclusion:** This study highlights chickpea and OFSP flours as effective gluten-free alternatives in bakery products, enhancing nutritional profiles and demonstrating their versatile applications.

KEYWORDS

Gluten-free bakery products, functional properties, pasting, physical properties of flour, OFSP, wheat

INTRODUCTION

Bakery products encompass a wide variety of foods, such as cakes, bread, cookies, pastries, crackers and numerous other items, all primarily made from wheat flour as a main ingredient. This product serves as a staple food in many regions worldwide. Depending on its type and origin, bread is one of the bakery products that account for more than 10% of an individual's daily intake of essential nutrients such as protein, vitamins (thiamine, niacin), minerals (iron, zinc, copper) and necessary fiber. The nutritional value of bakery can be further enhanced by incorporating additives or blending wheat flour with other types of flour[1].

ISSN: 1996-3351 (Print)
https://doi.org/10.3923/ajbs.2024.771.784

Received: 09 Jul. 2024
Accepted: 12 Sep. 2024
Published: 31 Dec. 2024

Demand for gluten-free products has increased as a result of growing consumer awareness of health and wellness, particularly in light of the rise in lifestyle diseases. Chickpea flour presents itself as a viable alternative to gluten-free bread (GFB), with a plethora of technological, functional, nutritional and sensory advantages. Chickpea flour, which is high in dietary fiber, vitamins and proteins, may also offer protection against cardiovascular disease and cancer[2]. Additionally, it enhances the health profile of gluten-free bread by reducing glycemic response and improving dough stability, consistency and loaf volume, making it an excellent ingredient for creating healthier, more nutrient-dense and delicious gluten-free bread options for those with gluten intolerance[3].

Sweet potato (*Ipomoea batatas* L. Lam) is a valuable crop in Ethiopia, predominantly cultivated in the eastern, southern and southwestern regions. Among its varieties, the Orange-Fleshed Sweet Potato (OFSP) stands out due to its high β-carotene (pro-vitamin A) content. The OFSP varieties play a crucial role in preventing vitamin A deficiency in Africa, which can lead to blindness and increased mortality among mothers and preschool children. These varieties are affordable, accessible and available year-round, making them a vital staple food[4]. Additionally, orange-fleshed sweet potato is rich in essential nutrients, including various vitamins, minerals, polyphenols and antioxidants. Its high β-carotene content and low dry matter make it an effective and sustainable dietary option to combat vitamin A deficiency worldwide[5]. Therefore, individuals with limited access to expensive vitamin A-rich animal foods like fish oil, eggs, milk and butter can fulfill their daily vitamin A requirements and obtain other essential nutrients by consuming more of these tubers[6]. Researchers have recognized the significant health benefits of OFSP, attributing its rich nutritional profile to its potential in preventing both cancer and cardiovascular diseases[7]. To enhance the nutritional composition, functional, pasting and physical attributes of various bakery products, chickpea and orange-fleshed sweet potato flours can be incorporated with wheat flour. This study aims to characterize the functional, pasting and physical properties of wheat, OFSP and chickpea flours for application in the bakery industry.

MATERIALS AND METHODS

Study area: This study was carried out at the Food Science and Nutrition Department of the Ethiopian Institute of Agricultural Research over a one-year period, from April, 2023 to June, 2024.

Experimental materials: Ten kilograms wheat flour (hard wheat) was obtained from Mia Macaroni and Flour Factory, Dire Dawa Food Complex. Orange-fleshed sweet potato (OFSP) variety "Alamura" (Ukr/Eju-10), known for its high beta carotene content, was obtained from farmers in Chiro, who received it from Haramaya University Research Center. Chickpea "Koka" kabuli variety, released in 2019, was sourced from Debre zeit Agricultural Research Center.

Raw material preparation

Preparation of orange-flesh sweet potato and chickpea flours: To prepare Orange-Flesh Sweet Potato (OFSP) flour, the method by Kindeya *et al.*[8] was used. Sorted OFSP tubers were cleaned, washed, peeled and washed again with tap water before slicing to a thickness of 0.5 mm and blanching in a water bath at 65°C for 10 min to prevent browning. The treated slices were dried in a hot air oven (4lab Tech, Daihan Labtech Co., Ltd. Gyeonggi-Do, Korea) at 60°C for 8 hrs, then ground into flour using a laboratory hammer miller (Kinematic made by Switzerland, POLYMIX® PX-MFC 90 D) and sieved with a 710 μm sieve. The flour was sealed in a polyethylene plastic bag and stored in a cool, dark place. For chickpea flour, seeds were manually cleaned to remove foreign matter, broken grains and impurities, then washed thoroughly until free from dirt and dried under sunlight for 24 hrs. The dried chickpeas were milled with the seed coat removed, sieved through a 710 μm mesh screen, packed in an airtight plastic bag and stored at room temperature[9].

Determination of functional properties of flour

Dispersibility of flour: Using the AACC method, the dispersibility of chickpea and Orange-Fleshed Sweet Potato (OFSP) flour was evaluated[10]. A 100 mL measuring cylinder was filled with 10 g of each flour sample and the remaining volume was filled with distilled water. The mixture was stirred vigorously and then left to settle for 3 hrs. The percentage dispersibility was calculated by taking the volume of the settled particles and subtracting it from 100:

$$\text{Dispersibility (\%)} = 100\text{-Volume of settled particle} \tag{1}$$

Water absorption capacity: The method outlined by Chikpah *et al.*[11] was used to determine the water absorption capacity (WAC). A clean 15 mL centrifuge tube was weighed before adding 2 g of flour. The combined weight of the tube and flour was recorded as W1. Then, 10 mL of distilled water was added and the tube was vortexed for one minute. The mixture was allowed to sit at room temperature (25°C) for 30 min before being centrifuged at 4000 rpm for 30 min. The supernatant was carefully poured into a beaker and the tubes were inverted on filter paper to drain any excess water. The final weight of the centrifuge tube containing the sample was recorded as W2. The WAC was calculated as grams of water absorbed per gram of flour using the following formula:

$$\text{WAC (\%)} = \frac{\text{W2} - \text{W1}}{\text{Initial sample weight (g)}} \times 100 \tag{2}$$

where, W1 is the weight of the tube with the sample and W2 is the weight of the centrifuge tube containing the sample after draining water.

Oil absorption capacity (OAC): The oil absorption capacity (OAC) of the flours was calculated using the procedure described by Murlidhar *et al.*[12] Ten milliliters of soybean oil were added to a clean, empty centrifuge tube containing 1 g of flour (W1) and a known weight (W2). The mixture was centrifuged for 30 min at 4000 rpm after being vortexed for 30 sec and allowed to sit at room temperature (25°C) for 30 min. Weight of the tube and sample were recorded after the unabsorbed oil was carefully drained (W3). Using the following formula, OAC was determined.

$$\text{OAC} = \frac{\text{W3-(W1+W2)}}{\text{W1}} \times 100 \tag{3}$$

where, W1 is the weight of the sample, W2 is the weight of empty centrifuge tube and W3 is the weight of the tube and the sample.

Swelling power and water solubility index: Horwitz and AOAC[13] method was used to calculate the flour's swelling power. A 25 mL centrifuge tube was filled with 3 g of the flour sample, 10 mL of distilled water and gently mixed. To avoid clumping, the slurry was heated for 30 min at 80°C in a water bath (DAIHAN SCIENTIFIC Bath manufactured by DAIHAN Scientific Co., Ltd., Korea) with gentle stirring. Following heating, the paste-containing tube was centrifuged for 10 min at 300 rpm. Immediately following centrifugation, the supernatant was poured off and the sediment's weight was noted:

$$\text{SP} = \frac{\text{Weight of sediment}}{\text{Weight of sample}} \times 100 \tag{4}$$

where, SP is swelling power in percentage.

The water solubility index was determined using a method described by Yousf *et al.*[14]. The crucible was dried in the oven at 105°C for 20 min and allowed to cool in desiccators, after cooling, the crucible was weighed. One gram of flour sample was weighed into the test tube and 10 mL of distilled water was added and stirred gently with a stirring rod for 30 min. The supernatant was decanted into crucibles and dried in the oven at 105°C for 12 hrs until the supernatant was dried off the crucible. Water solubility index was calculated as shown:

$$\text{WSL (\%)} = \frac{\text{Weight of dry supernatant}}{\text{Weight of sample}} \times 100 \quad (5)$$

where, WSL is water solubility index

Determination of physical properties of flour

Particle size distribution: Particle size distribution reflects how easily the material segregates within a system or the distribution of particles in a powder sample. The particle size distribution for the three types of flour was determined using sieve analysis as described by Patwa *et al.*[15]. Sieves with varying aperture sizes (2, 1, 0.5, 0.25, 0.1, 0.075 and <0.075 mm) were stacked in decreasing order of size. After placing a standard 50 g flour sample in the top sieve, the sieves were fastened and shaken for 10 min. The flour retained on each sieve was then collected, weighed and the weight percentage was calculated as follows:

$$\text{Retained (\%)} = \frac{W_{\text{sieve}}}{W_{\text{total}}} \times 100 \quad (6)$$

where, W_{sieve} is the weight of aggregate in the sieve and W_{total} is the weight of the total aggregate.

Angle of repose: The angle of repose is defined as the angle between the horizontal base of a flour pile and the inclined surface of its cone-like heap. A cylinder with a diameter of 10 cm and a height of 15 cm was placed vertically on a flat surface and filled with flour samples from the top. Tapping during filling ensured uniform packing and minimized any wall effects. The cylinder was then carefully lifted off the surface, allowing the flour to form a cone-shaped pile. The height of the heap's peak above the surface and the diameter of its base were measured. The angle of repose (Φ) was then calculated using the following formula[16].

$$\text{Angle of repose } (\Phi°) = \tan^{-1}\left(\frac{2h}{r}\right) \quad (7)$$

where, Φ is angle of repose (°), h is height of the heap (mm) and r is radius of the base of the heap (mm).

Bulk and tapped density of flours: Bulk density of flour indicates storage space requirements and shows expansion and changes in cell structure, such as pores and voids. To measure the bulk density, 2 g of each sample were placed in a 10 mL graduated cylinder and the volume was recorded. The bulk density was calculated by dividing the mass by the volume (g m^{-3}). Tapped density was determined by tapping the cylinder with the sample 20 times and then calculating the mass divided by the volume after tapping[17].

$$\text{Bulk density } (\rho b) = \frac{M}{V_b} \quad (8)$$

$$\text{Tapped density } (\rho t) = \frac{M}{V_t} \quad (9)$$

where, M is mass of flour and V_b and V_t are volumes of bulk and tapped flour, respectively.

Color of the flours: The color of the flour was assessed using the CIE Lab* color space system based on tristimulus values. Measurements of lightness (L), redness (+a), greenness (-a), yellowness (+b), blueness (-b) and total color difference (DE) were taken by placing the samples on the colorimeter port. A positive a* value indicates redness, while a negative a* value indicates greenness. Similarly, a positive b* value indicates yellowness, while a negative b* value indicates blueness. The L*, a* and b* values were recorded according to Mengistu[16]:

$$\text{Hue angle} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \tag{10}$$

$$\text{Chroma} = \sqrt{(a^*)^2 + (b^*)^2} \tag{11}$$

where, Hue angle is color perceived by the naked eye and the color measure in degree and Chroma is chromaticity coordinate which is perpendicular to the distance from lightness.

Pasting properties of flours: Using a Rapid Visco-Analyzer (model No. 4500 Perten Instrument, Australia), the pasting profile of the flour was evaluated. A suspension was prepared by mixing 3.5 g of flour (adjusted to a 14% moisture basis) with 25 mL of distilled water in the sample-holding cup. After 13 min of heating and cooling, the viscosity was determined. The sample was heated from 50 to 95°C over 3.5 min, held at 95°C for 3 min, cooled back to 50°C over 3.5 min and then held at 50°C for an additional 2 min during this cycle. Thermocline for Windows version 3 was used to analyze the pasting properties, such as peak, trough, breakdown, final, set-back and pasting temperature viscosities[18].

Statistical analysis: The data reported in all the tables are averages of triplicate observations. The data were subjected to Analysis of Variance (ANOVA) using SAS statistical software version 9.4. Statistical differences among samples were tested at $p<0.05$ and differences between means were compared using the least significance difference (LSD) test.

RESULTS AND DISCUSSION

Functional properties of flour: Water absorption capacity refers to the ability of flour to absorb water under conditions where water is limited and it is useful for assessing flour's ability to take up water and swelling to increase food uniformity. Chickpea flour exhibited a higher water absorption capacity (2.21 g/g) than the 0.82 and 1.53 g/g of wheat and orange-fleshed sweet potato flours, respectively. This is due to more hydrophilic constituents, like polysaccharides and it is possible that the proteins found naturally in chickpea flours contributed to this ability[19]. On the other hand, chickpea flour and orange-fleshed sweet potato flour contain less gluten and more fiber, which allows them to absorb more water compared to wheat flour. The water absorption capacity of chickpea flour in this study is the same as (2.21 g/g) the result obtained from the study reported by Solanke *et al.*[20]. The water absorption capacity of orange-fleshed sweet potato flour of this study was lower than the 1.56 g/g reported by Chikpah *et al.*[11].

Oil absorption capacity of flour refers to the amount of oil that can be absorbed or physical entrapment of oils. Oil absorption capacity is useful in food formulation where oil-holding capacity is needed for bakery products to enhance mouth sensation and texture and retain flavors of the final product[21] oil absorption capacity of chickpea and orange-fleshed sweet potato flours were 1.03 and 1.05 g/g, respectively. The record for the chickpea flour was much higher than the 0.77 g/g reported by Badia-Olmos *et al.*[22]. The oil absorption capacity of orange-fleshed sweet potato flour in this study agreed with the 0.94-1.06 g/g reported by Dereje *et al.*[21].

Swelling power refers to the ability of a flour to absorb water and increase in volume and it is an important property in determining the gelatinization and viscosity of starches[21]. Onabanjo *et al.*[23] reported swelling power of wheat flour of 5.82 g/g which was higher than the records in this study. According to a study by Singh *et al.*[24] the swelling power of chickpea flour ranged from 1.75-9.54 g/g, which was in line with the results of this study. The swelling power of orange-fleshed sweet potato flour was 7.47 g/g and is comparable to the records 5.7-23.5 g/g reported by Dereje *et al.*[21] as obtained from different sweet potato varieties.

Water solubility index measures the portion of flour components that can dissolve in water. Wheat flour has a lower water solubility index due to gluten structure than chickpea and orange-fleshed sweet potato flour. The water solubility index of chickpea (25.41%) was higher than the 11.45 and 5.56% of the OFSP and wheat flours as presented in Table 1. The water solubility index of the chickpea flour was lower than the 26.75% recorded for similar flour by Solanke *et al.*[20] which could be attributed to various reasons including variety, soil type of growing area and agronomic practices conducted during cultivation. The solubility of OFSP flour (11.45%) was in line with the finding of Gitanjali and Lakhawat[25], who reported water solubility values which ranged from 8.56 to 19.97% in for flours extracted from different varieties of sweet potato. The variation in water solubility of OFSP flours can be due to the different processing method of flour production.

The dispersibility of flour refers to the ability of flour to evenly disperse with a liquid medium such as water or another liquid medium. Dispersibility is a key parameter for determining how well flour will rehydrate with water without forming swellings. In this report, OFSP flour had higher dispersibility than wheat and chickpea flour. The dispersibility of 75% of OFSP flour reported by Eke-Ejiofor *et al.*[26] was similar to the finding in the current study. The dispersibility value for wheat flour was reported by Melese and Keyata[27] was 73%, which is higher than the record in this study. In another study, Kindeya *et al.*[8] reported 65% dispersibility of haricot bean flour, which is higher than the present study for chickpea flour. Generally, higher dispersibility indicates stronger reconstitution property and is used to make a fine dough consistency during mixing.

Physical properties of flour

Bulk and tapped densities: The particle size of the flour has an impact on the bulk and tapped density, which is crucial for determining packaging needs, material handling and use in the wet-processing food industry. The bulk density of wheat, chickpea and OFSP recorded were 0.67, 0.5 and 0.74 g/mL, respectively, in Table 1. In this study, the bulk density of wheat flour was lower than the 0.70 g/mL recorded by Ocheme *et al.*[28]. Bulk density of OFSP flour in this study agreed with the 0.74 g/mL reported by Tiruneh *et al.*[29] In a similar study by Kumar *et al.*[30] the bulk density of taro flour ranged from 0.66 to 0.89 g/mL, which is consistent with the bulk density obtained for OFSP flour in this study. The high bulk density is essential for use in food preparation (liquid, semi-solids, or solids) and low-density flour would be beneficial for preparing weaning foods[20]. Bulk density (0.74 g/mL) of wheat flour reported by Kindeya *et al.*[8] was higher than the 0.67 g/mL recorded in this study. The bulk density of chickpea flour reported by Hasmadi *et al.*[31] ranged from 0.536 to 0.571 g/mL, which supports this study.

Table 1: Functional properties of wheat, chickpea and OFSP flour

Material	WAC (g/g)	OAC (g/g)	SP (g/g)	WSI (%)	DS (%)	BD (g/mL)	TD (mL/g)	AR
Wheat	0.82±0.01^{c}	1.23±0.07^{a}	4.41±0.17^{b}	5.56±0.06^{c}	69.50±0.50^{b}	0.67±0.00^{b}	0.84±0.01^{b}	45.13±1.28^{a}
Chickpea	2.21±0.02^{a}	1.03±0.06^{b}	4.15±0.41^{b}	25.41±0.52^{a}	52.17±0.76^{c}	0.54±0.00^{c}	0.77±0.00^{c}	42.48±0.61^{b}
OFSP	1.53±0.01^{b}	1.05±0.02^{a}	7.47±0.06^{a}	11.45±0.11^{b}	75.00±0.50^{a}	0.74±0.00^{a}	0.87±0.01^{a}	40.41±0.22^{c}
CV (%)	0.85	8.35	4.81	2.19	0.92	0.28	0.84	1.94
LSD	0.03	0.18	0.51	0.62	1.20	0.004	0.01	1.66

All values are means of Triplicate±Standard Deviation. Means within the same column with different letters are significantly different ($p \leq 0.05$), WAC: Water absorption capacity, OAC: Oil Absorption capacity, SP: Swelling power, WSI: Water solubility index, DS: Disperisability, BD: Bulk density, TD: True density, AR: Angle of repose, CV: Coefficient variation and LSD: Least significant difference among treatments

Table 2: Particle size distribution (%) of wheat, chickpea and OFSP flour

	Particle size (mm)						
Material	2	1	0.5	0.25	0.1	0.075	<0.075
Wheat	0.67±0.23^{a}	0.72±0.51^{a}	0.82±0.01^{c}	35.55±0.00^{a}	50.00±0.01^{a}	11.46±1.34^{b}	0.61±0.14^{c}
Chickpea	0.21±0.23^{b}	1.12±0.39^{a}	50.03±0.01^{a}	27.00±0.00^{b}	19.41±2.16^{b}	1.30±0.28^{c}	0.92±0.02^{b}
OFSP	0.00±0.00	0.00±0.00	23.53±1.29^{b}	13.53±0.00^{c}	18.62±0.00^{b}	20.21±0.00^{a}	37.04±0.00^{a}
CV (%)	62.72	60.4	3.01	0.00	4.25	7.17	0.64
LSD	0.37	0.74	1.49	0.00	2.49	1.57	0.17

All values are means of Triplicates±Standard Deviation. Means within the same column with different letters are significantly different ($p<0.05$). CV: Coefficient variation, LSD: Least significant difference and OFSP: Orange flesh sweet potato

Orange-fleshed sweet potato has a higher bulk (0.74 g/mL) and tapped density (0.87 mL/g) compared to chickpea (0.77 mL/g) and wheat (0.84 mL/g) flour due to its higher starch content. The higher bulk and tapped density are due to the small particle size and high density of sweet potato flour, which results in a higher packing requirement. According to the study by Amankwah *et al.*[32] the tapped density of wheat flour was 0.74 mL/g, which is lower than the present study.

Angle of repose: The angle of repose indicates the flow ability and cohesiveness of the flour. Highest angles of repose were recorded for wheat (45.13°), chickpea (42.48°) and OFSP (40.41°). The wheat flour was found in the range of passable to flowing (can easily flow), chickpea in the range of passable and OFSP in the range of fair flowing ability based on the angle of repose flow characters[33]. Materials having higher moisture content have a higher angle of repose. The lower the angle of repose is the more free flowing of the powder[16].

Particle size distribution: The flour's particle size distribution demonstrates the various ranges of particle sizes that are present in a sample of flour. In the current study calculation of the weight percentage of millimeter-sized flour particles was done using the sieve analysis techniques. The size distribution of the flour's particles determines whether the flour is fine or coarse. The highest percent of wheat flour retained on the sieve was 50.00 on a sieve size of 0.1 mm and the lowest was 0.61% on a sieve size of <0.075. For chickpea flour the highest value was 50.03% on sieve size 0.5mm and the lowest value was 0.21% on sieve size 2 mm. Similarly, for orange-fleshed sweet potato, the highest was 37.04% of sieve size <0.075 mm and lowest value was 0.00% of sieve size 2 and 1 mm, as presented in Table 2.

Materials exhibit greater cohesive behavior because the particle surface area per unit mass increases with decreasing particle size, which shows having more points of contact. The protein, maltose and ash contents of specific flours are correlated with their particle size. In addition, as the particle size is reduced, the ash content increases due to the large particle having a lower surface area and the greater particle size has an advantage. Larger particles flow more smoothly than fine or smaller particles and smaller particles with a lot of surface area have a stronger attraction to one another and are more likely to stick together and resist flow. As the size of small particles increases with increase in the surface area to volume ratio there is strong attraction among them which results in friction of particulates inducing resistance to flow[34,35].

Color of flour: Color is an essential quality attribute of food products as it affects consumer acceptability. Particularly, flour color is vital to note because it affects the crumb color of the product[36]. The color values of wheat, chickpea and orange-fleshed sweet potato flour are presented in Table 3. The highest L* the value was 96.39 for wheat flour and the lowest value was 89.62 for chickpea flour. According to the study by Sidhu *et al.*[37] reported the L* the values for white wheat and chickpea flour were 66.3 and 60.8, respectively, which is higher than the present study. According to the study by Zahirul Islam *et al.*[38], the L* value for OFSP flour was 90.54 reported, which is the closest value with the present study. Chickpea flour had the lowest L* value (89.62), which means that it was the darkest flour as compared to wheat OFSP flours. Wheat flour has a lighter color due to naturally occurring carotenoid pigments than chickpea and orange sweet potato flour because it contains less pigments such as carotenoids and anthocyanin that are responsible for the color of chickpea and OFSP flours.

The a* value represents the red or green color (positive value represents for red and negative value indicates for green). The a* the value of wheat, chickpea and OFSP flour were -1.85, 3.43 and 1.21 calculated, respectively. The a* values for12 varieties of Ghanaian sweet potatoes were ranged between (-2.52 to 1.22), which agreed with this study. The a* the values for both wheat and sweet potato flour were 1.78 and 1.95 as reported by Alviola and Monterde[36], which are higher values than with the present study.

The b* the values for wheat, chickpea and OFSP flour were significantly ($p<0.05$) different among all treatments as shown in Table 3. The b* value for wheat, chickpea and OFSP flour were 6.86, 11.78 and 13.03, respectively. The highest b* value was recorded for OFSP flour and lowest value was for wheat flour. According to the study of Alviola and Monterde[36] the b* value of wheat flour was 7 which is higher than that reported in this study. According to the report of Chikpah *et al.*[39], the b* value of OFSP flour was 35 which is much higher than the current study. The b value chickpea flour reported by Fenn *et al.*[40] was 19, which is higher value than this finding. The chromaticity coordinates or chroma, is the perpendicular distance from the lightness. The recorded values of chroma of wheat, chickpea and OFSP flours were 7.11, 12.27 and 13.09, respectively. The chroma value for three chickpea varieties reported by Mengistu[16] ranged from 22.06-25.01, which is a higher value than present study. The hue angle of wheat, chickpea and OFSP flour were 74.96, 73.77 and 84.70° recorded in Table 3. The highest hue angle recorded for OFSP flour was 84.70 and lowest was 73.77 for chickpea flour. The hue angle for desi and kabuli chickpea flour were 87.56 and 86.07°h reported respectively, which are higher value than to this study. Azzahra *et al.*[41] reported that the hue angle of OFSP flour was 80.75°h, which is lower value than this study.

Pasting properties of flour: The Pasting properties are characteristic of the intensity of changes that occur during starch alteration[42,43]. The alterations that occur in food because of applying heat while water is present is pasting properties of the food. These changes have an impact on the food product's final texture, digestion and usability[28]. The pasting property of flour shown in Fig. 1.

Pasting temperature: The pasting temperature is the lowest temperature at which the viscosity begins to raise[21]. The pasting characteristic of the wheat, chickpea and orange-fleshed sweet potato flour is shown in Table 4. The pasting temperatures for wheat, chickpea and OFSP flours were 87.47, 78.25 and 75.05°C, respectively.

Ocheme *et al.*[28] reported that the pasting temperature of wheat flour was 88.03°C, which was close to the result in this study. Higher pasting temperature value indicates a greater ability to prevent starch granules from swelling and breaking[44]. Pasting temperature of chickpea starch was 72.35°C found by Singh *et al.*[24], which is lower value than the present study. The study by Aguilar-Raymundo and Vélez-Ruíz[45] reported the pasting temperature of raw chickpea variety flour which ranged between

Table 3: Color values of wheat, chickpea and OFSP flour

Material	L*	a*	b*	Hue angle (h°)	Chroma
Wheat	96.39±0.04^a	-1.85±0.29^b	6.86±0.15^c	74.96±1.94^b	7.11±0.21^c
Chickpea	89.62±0.18^c	3.43±0.09^a	11.78±0.21^b	73.77±0.19^b	12.27±0.22^b
OFSP	92.75±0.03^b	1.21±0.12^c	13.03±0.31^a	84.70±0.62^a	13.09±0.30^a
CV (%)	0.12	19.91	2.19	4.24	2.28
LSD	0.22	0.37	0.46	2.36	0.49

All values are means of Triplicates±Standard Deviation. Means within the same column with different letters are significantly different ($p<0.05$). L*: White (+) and black (-), a*: Red (+) and green (-) and b*: Yellow (+) and blue (-)

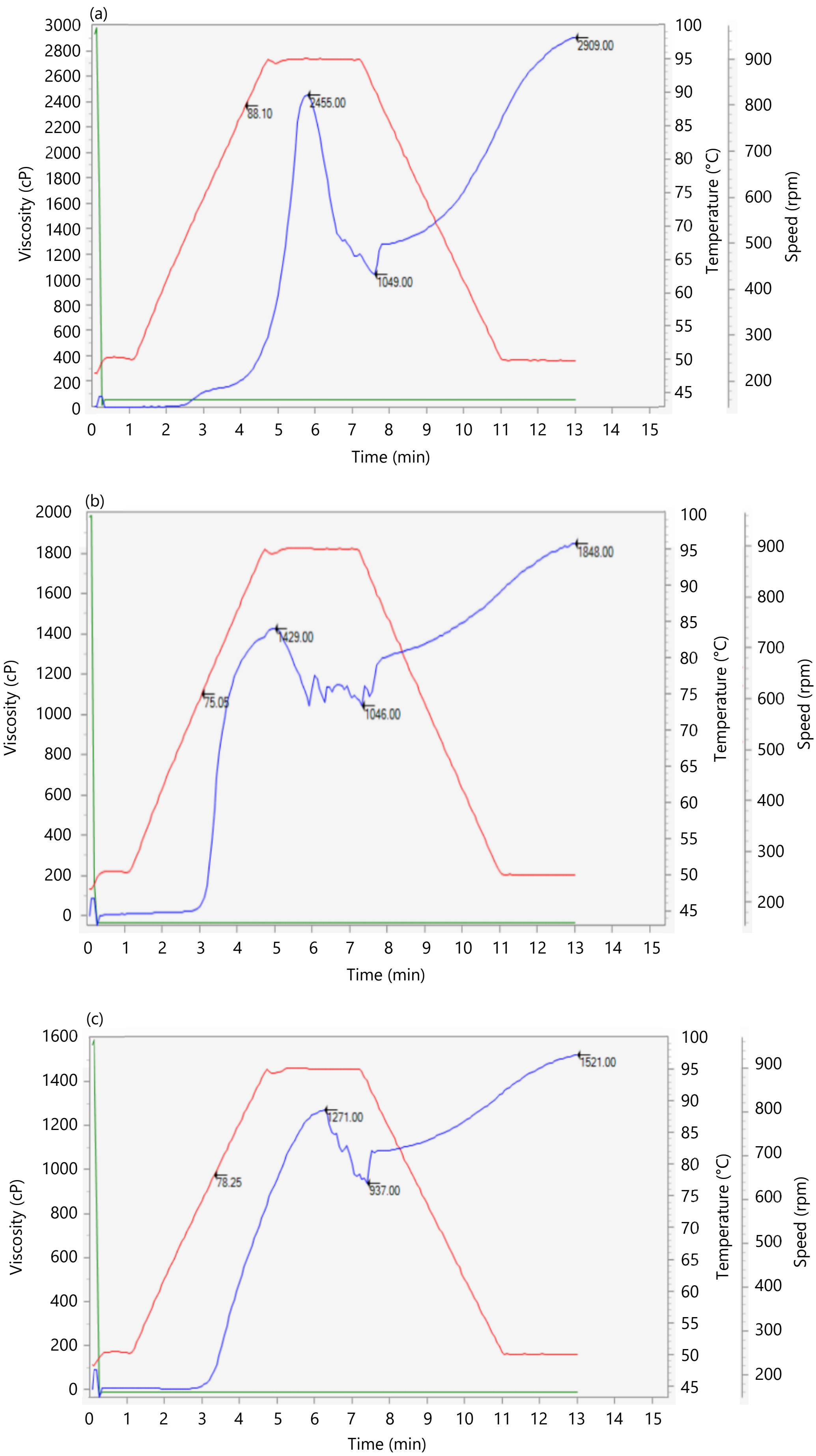

Fig. 1(a-c): Pasting property of (a) Wheat, (b) Chickpea and (c) OFSP flour

Table 4: Pasting properties of wheat, chickpea and OFSP flour

Material	PT(°C)	PV(CP)	TV (CP)	BDV(CP)	FV(CP)	SBV(CP)	Pt(min)
Wheat	87.47±0.57^{a}	2453.33±1.53^{a}	1048.00±1.00^{a}	1405.33±0.58^{a}	2908.33±0.58^{a}	1859.83±0.76^{a}	5.80±0.01^{b}
Chickpea	78.25±0.01^{b}	1270.67±0.58^{c}	937.17±0.29^{c}	333.97±0.06^{c}	1520.93±0.12^{c}	584.00±0.00^{c}	6.27±0.01^{a}
OFSP	75.05±0.01^{c}	1428.67±0.58^{b}	1046.00±0.00^{b}	383.33±0.58^{b}	1847.97±0.06^{b}	802.30±0.52^{b}	4.97±0.06^{c}
CV (%)	0.41	0.06	0.06	0.07	0.02	0.05	0.59
LSD	0.66	2.00	1.20	0.94	0.68	1.07	0.07

Values are Means±Standard Deviation of three determinations. Means in the same row with different superscript are significantly different ($p<0.05$). PT: Pasting temperature, PV: Peak viscosity, TV: Trough viscosity, BDV: Breakdown viscosity, FV: Final viscosity, SBV: Setback viscosity and Pt: Pasting time

74.6-85.9°C, which agreed with the result of this study. According to the study by George *et al.*[46], the gelatinization temperature for different varieties of sweet potato flour ranged from 55.50 -75.50°C, which agreed with this study. A higher amylose content could be the cause of the lower pasting temperature value[47,48].

Peak viscosity: The peak viscosity indicated by the maximum viscosity that can be attained when making starch paste and measure of the starch granule's ability to bind water[42]. In this study, the peak viscosity of wheat, chickpea and OFSP flour were 2453.33, 1270.67 and 1428.67 cp, respectively. The peak viscosity of wheat flour reported by Julianti *et al.*[49] was 2433 cp, which was almost similar value with this study. According to the report by Dereje *et al.*[21] the peak viscosity of sweet potato flour for different varieties ranged from 826 to 3039 Cp, which is in agreement with this study. The peak viscosity of chickpea starch reported by Singh *et al.*[24] was 4453 cp, much higher than the present study.

The peak viscosity of desi chickpea flour reported by Dhillon *et al.*[44], was 732.27 cp, which is much lower value than the peak viscosity of chickpea flour from this study, due to different factors such as variety, environmental and soil fertility effect.

Trough viscosity: The trough viscosity (hos paste viscosity) is an indicator of the ability of paste to withstand high temperature conditions[44]. Trough viscosity of wheat, chickpea and OFSP flour were 1048, 937.17 and 1046 cp, respectively. The report by Jan *et al.*[48], on trough viscosity of wheat flour was 1254 cp, which is higher than recorded in this study. According to the finding of Dereje *et al.*[21] the trough viscosity of sweet potato variety ranged from 826-3039 cp, which is in agreement with the current study. The trough viscosity of sweet potato flour reported by Julianti *et al.*[49] was 1002 cp, which is close to the value of the present study. The trough viscosity of chickpea (Desi variety) flour value was 617.73 cp, reported by Dhillon *et al.*[44], which is lower than to this study the difference in trough viscosity is may be due to chickpea variety. High trough viscosity values could be an indication of excellent eating quality and minimal cooking losses[21].

Breakdown viscosity: The breakdown viscosity is a metric that indicates how much the viscosity decreases during heating and assessing the level of starch stability during heating and shearing is crucial in starch water systems. The breakdown viscosity of wheat, chickpea and OFSP flour were 1405.33, 333.97 and 383.33 cp, respectively, as presented in Table 4. According to the report of Julianti *et al.*[49] the breakdown viscosity of wheat and sweet potato flour were 1151 and 829 cp, respectively, of which the value of wheat flour was lower and that of sweet potato was higher than the present study. Kaur and Singh[50] reported breakdown viscosity of different chickpea flour that ranged between 71-269 cp, which was lower than in this study. In a study reported by Dhillon *et al.*[44] the breakdown viscosity of chickpea (Kabuli variety) flour was 113.27 cp which is lower than the present study, the difference may be due to chickpea variety. Lower breakdown viscosity of chickpea flour indicates its paste stability of the flour and decrease in the rate of rupturing of starch granules. The higher breakdown viscosity OFSP flour indicates lower ability of the sample to withstand heating during cooking.

Final viscosity: The ability of a substance to produce a viscous paste is indicated by its final viscosity (cold paste viscosity and this ability correlates with the viscosity of foods during consuming food). The final viscosity of wheat, chickpea and OFSP flour were 2908.33, 1520 and 1847.97 cp respectively, are presented in Table 4. The aggregation of amylose indicates a high final viscosity and low value indicates the resistance of the paste to shear stress during stirring[21]. The final viscosity of wheat flour reported by Jan *et al.*[48] was 2199 cp, which is lower value than this study. According to the report of Kaur and Singh[50], the final viscosity of different chickpea flour was in the range from 1515-2704 cp, which is higher value than the present study. The study by Julianti *et al.*[49] the final viscosity of sweet potato was 1565 cp, which is lower value than the current study.

Setback viscosity: The setback viscosity indicates the tendency of the starch paste to dehydrate or retrograde after cooling. Setback viscosity of wheat, chickpea and OFSP flour were 1859.83, 584 and 802.30 cp, respectively. In comparison, to other flour, chickpea exhibited lower setback viscosity indicating its lower tendency to retrograde and higher setback viscosity of wheat flour indicates a reasonable amount of retrogradation of granules during cooling[21]. According to the study reported by Kaur and Singh[50], setback viscosity of both wheat and sweet potato flour were 1131 and 563 cp, respectively, which are lower value than the current study. According to the report of Dereje *et al.*[21] the setback viscosity of different varieties of sweet potato ranged between 62-865 cp, which is in agreement with this study. The setback viscosity of chickpea flour reported by Dhillon *et al.*[44] was 287.37 cp, which is lower value than the present study. In general, chickpea flour has lower viscosity and lower swelling power than wheat and OFSP flour due to the difference in size and shape of starch granules.

Peak time: It is a measure of how long it takes for each type of flour to attain its maximum viscosity. The peak time for wheat, chickpea and OFSP flour were 5.80, 6.27 and 4.97 min scored for this study. The peak time of chickpea flour reported by Maurya *et al.*[51] was 6.20, which is a higher value than in this study. Chickpea flour has a higher pasting time than wheat and orange-fleshed sweet potato flour due to its higher protein content and lower starch content. The protein in chickpea flour forms a stronger network during cooking, resulting in a longer pasting time. According to the report of Jan *et al.*[48] the peak time of wheat flour was 5.93 min, which is almost similar to this study. Peak time for sweet potato flour was found in the range from 3.3 to 9.76 min[21], which supported the current study. The longest peak time was 6.27 min recorded for chickpea flour and the shortest was 4.97 min of the OFSP flour. This is due to gluten free flours requiring more energy and a longer cooking time to form a paste. In addition, they are more resistant towards swelling and higher protein flours in general need more time to reach their peak viscosity[36]. In addition, the high starch content shortens the pasting time and long peak time is not suitable in baking industries because it related to requirement of long dough development time and high energy input[21,52]. The study provides insights into the functional and physical properties of wheat, chickpea and Orange-Fleshed Sweet Potato (OFSP) flours, revealing their potential for various food industry applications. Chickpea flour's high water and oil absorption capacities make it suitable for moisture-retentive and texture-enhancing products. The OFSP flour's properties, including its vibrant color, are advantageous for improving the appeal and functionality of foods like gluten-free bakery products. However, limitations such as a focus on only functional and physical properties, not accounting for varietal differences and the lack of processing effects suggest the need for further research. These findings promote the exploration of chickpea and OFSP flours in gluten-free and nutritional products.

CONCLUSION

This study emphasizes the potential of incorporating chickpea and Orange-Fleshed Sweet Potato (OFSP) flours alongside wheat as promising alternatives for gluten-free bakery products, enhancing their nutritional profiles. By characterizing the functional, pasting and physical properties of wheat, chickpea and OFSP flours, significant differences were identified, showcasing their versatility in bakery applications. Chickpea flour's superior water absorption capacity, along with OFSP flour's higher water solubility index and dispersibility, positions these alternatives favorably. Variations in density and particle size distribution further distinguish their physical attributes. Pasting properties varied among the flours, with wheat generally displaying higher viscosities, accompanied by varying peak times. This comprehensive characterization emphasizes the potential of chickpea and OFSP flours to meet diverse consumer demands for healthier, gluten-free bakery options, thereby enhancing the nutritional quality of bakery products.

SIGNIFICANCE STATEMENT

This research provides a comprehensive analysis of the functional, pasting and physical properties of chickpea and Orange-Fleshed Sweet Potato (OFSP) flours compared to traditional wheat flour. With the rising demand for gluten-free options driven by health-conscious consumers, chickpea and OFSP flours emerge as promising alternatives, offering superior water and oil absorption, higher water solubility and distinct physical characteristics. Chickpea flour shows exceptional water absorption and oil absorption, while OFSP flour demonstrates better dispersibility and density due to its starch content. The findings underscore the potential of these flours to enhance gluten-free bakery products, offering improved nutritional profiles and versatile applications.

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