



Quality attributes and *Chapatti* making property of biofortified wheat as influenced by particle size

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Abstract Biofortified (PBW 1 Zn) wheat flour was fractionated into three fractions (355, 180 and 150 μm) and evaluated for physicochemical, functional, rheological, biochemical and *chapatti* making parameters. With decreasing flour particle size the ash, fat, fibre, phytic acid, antioxidant activity, total phenolic content and pasting properties decreased, whereas carbohydrates, zinc, lightness (L^*) and functional parameters increased. *Chapatti* making quality of flour fraction (180 μm) was observed best on the basis of puffing height (7.64 cm), extensibility (1.83 N) and sensory quality with best overall sensory scores (8.75). The results indicate that reducing the particle size to 180 μm could improve the nutritional, functional and *chapatti* making quality of wheat flour.

Keywords Flour fractions · Phytic acid: *chapatti* · Extensibility · Particle size · Rheology

Introduction

Wheat is the important cereal crop which is consumed in the form of products prepared from flour like pasta, bread, cookies, noodles, *chapatti* and other baked products (Gujral et al. 2019; Angelidis et al. 2016; Panghal et al. 2019). Milling of wheat flour is a grinding process that gives different fractions of flour which affect the quality of baked

products. Flour fractions obtained by various milling methodologies disclosed that particle size of the flour can greatly affect the water absorption, physicochemical properties, pasting properties, damaged starch and thereby significantly affect the dough rheology and baking properties of flour (Angelidis et al. 2016). The fine particles improve the oil or water holding capacity and functional properties by uncovering the large surface area during processing operations (e.g. fermenting, baking or mixing). Effect of particle size on rheological, functional and baking properties of various flours was studied (Yaoguang et al. 2015; Ahmed et al. 2019; Kang et al. 2019; Dhen et al., 2016).

Wheat carry very low amount of important micronutrients i.e. zinc and iron and most of these are removed during milling. Worldwide, more than 3 billion people suffer from micronutrient deficiencies mainly in the regions where foods based on cereals are consumed (Cakmak and Kutman 2018). Zinc (Zn) malnutrition is a global health issue because consumption of cereal based foods with low zinc content and low bioavailability is the main reason behind this problem. Zn has important physiological functions in our body, it interacts with large number of proteins and enzymes in our body and perform critical functional, structural and regulatory roles (Krezel and Maret 2016). Fortifying wheat flour during processing is the common method to increase the micronutrient level but fortified foods often has less public acceptability due to the changes that occur in color or flavor upon adding micronutrients. A new approach to increase micronutrient concentration during developing wheat varieties is by biofortification that increases bioavailability and mineral content of the grains (Gomez and Gomez 2010). Biofortification strategies are used to improve the nutritional quality of crop plants which

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are based on genetic engineering and agronomic methodologies (Cakmak and Kutman 2018).

Multiple interventions have been followed to overcome the deficiencies of micronutrients. Punjab Agricultural University, Ludhiana, India released genetically biofortified PBW 1 Zn wheat variety in 2017 that possesses higher grain Zn concentration (55–60 ppm). Its average plant height is 103 cm and is resistant to brown rust, quite resistant to yellow rust but prone to loose smut disease. The objective of present study was to comprehend how the variation in particle size affects the physicochemical, functional, biochemical, rheological and *chapatti* making properties of biofortified flour.

Materials and methods

Procurement of raw material

Wheat variety PBW 1 Zn was procured from Director (Seeds) Office, Punjab Agricultural University, Ludhiana, India. Grains (moisture content: $13 \pm 0.1\%$, dry basis) of wheat were ground to whole flour in a laboratory hammer mill. Whole wheat flour was fractionated into three fractions through RO-TAP sieve shaker (RX-30) using 150 ± 10 taps per minute fitted with a series of standard sieves having mesh size 355, 180 and $150 \mu\text{m}$ for 15 min. Fractionated samples were filled and sealed in air-tight containers and stored under ambient conditions ($25 \pm 5 \text{ }^\circ\text{C}$) till further use.

Proximate composition

Whole wheat flour and fractions were evaluated for moisture, ash, protein, fat, crude fibre and carbohydrate content by the approved standard (AOAC 2012) methods. The nitrogen content was estimated by Micro-Kjeldhal method. Obtained nitrogen was multiplied by 6.25 to calculate crude protein content. Crude fat and crude fibre were determined by using soxhlet apparatus with petroleum ether as a solvent and acid/alkali extraction respectively. The weight difference methods were used to determine moisture and ash content. The carbohydrate content was determined by calculation using difference method:

$$\% \text{ total carbohydrate} = [100 - \% (\text{protein} + \text{fat} + \text{moisture} + \text{ash} + \text{fibre})]$$

Minerals were analyzed by an inductively coupled plasma optical emission spectrometer (ICAP-AES). For digestion, one gram sample was taken in digestion flask to which 10 ml diacid (Nitric acid and Perchloric acid in the ratio 3:1) and distilled water (25 ml) was added before

evaluating the mineral elements by ICAP-AES (PYE Unicor, UK).

Functional properties

Water absorption index and water solubility index

The modified method of Singh and Kaur (2019) was used to assess water absorption index (WAI) and water solubility index (WSI). Flour samples (100 mg each) were dispersed in 10 ml of distilled water in a 50 ml centrifuge tube and stirred for 6 h at room temperature. The mixture was then centrifuged at $14,000 \times g$ for 20 min. The WAI (g/g) was calculated as weight of the gel divided by weight of sample and WSI is calculated in terms of percentage as weight of dissolved solids in supernatant divided by original weight of sample.

Oil absorption capacity

Oil absorption capacity (OAC) was determined using the method described by Ghavidel and Prakash (2007). Sample (0.5 g) was mixed with 6 ml of corn oil and centrifuged for 20 min at $3500 \times g$. Contents were stirred for 1 min with a brass wire, hold for 30 min and tubes again centrifuged for 25 min at $3500 \times g$. The oil absorption capacity was calculated in terms of percentage as weight of absorbed oil to the weight of sample.

$$\text{Oil absorption capacity (\%)} = \frac{\text{Wt. of absorbed oil}}{\text{Wt. of sample}} \times 100$$

Swelling power and sedimentation value

The swelling power (SP) was calculated as weight of wet mass of sediment divided by weight of dry matter in the gel. For sedimentation value (SV) flour was mixed with lactic acid and isopropyl alcohol and the volume in ml of sediment was noted (AOAC 2012).

$$\text{Swelling power (\%)} = \frac{\text{Wt. of wet mass sediment}}{\text{Wt. of dry matter in the gel}}$$

Rheological properties

Rheological properties of flour were determined by RVA (Rapid Visco-Analyzer, model 3D; Newport Scientific, Sydney, Australia). Wheat flour sample (3.0 g) was mixed with 25 ml of distilled water to form a slurry. Flour slurry was held at 50–95 °C at 6 °C/min after equilibrium time of 1 min at 50 °C and a holding time of 5 min at 95 °C. Cooling of sample was carried out from 95 to 50 °C at 6 °C/min with a holding period of 2 min. Parameters

measured were pasting temperature, peak viscosity (maximum hot paste viscosity), hold viscosity (holding strength at minimum hot paste viscosity), final viscosity (viscosity at 50 °C), breakdown viscosity (peak viscosity–hold viscosity) and set back viscosity (final viscosity–hold viscosity).

Preparation of *chapattis*

The method of Rehman et al. (2007) with little modifications was used to prepare *chapattis*. Wheat flour was made into dough by addition of measured quantity of water. Then the dough was rested for about 30 min. Dough balls, 40 g each were placed on rolling board, rolling done in one direction, inverted, rotated at 90 degree and rerolled to a diameter of 15 cm. Raw *chapatti* was placed on preheated griddle having temperature 225 °C. Cooking of *chapatti* was done for 30 s on one side, pressed with a soft cloth and was allowed to puff, flipped and then cooked for 30 s on other side. Cooling of the *chapatti* was done at room temperature.

Extensibility

The extensibility of *chapattis* was determined by the method of Gujral and Gaur (2005). The *chapattis* were stored in airtight container for 24 h in an airtight container at room temperature (25 °C) and later subjected to extensibility test. In this method 90 × 18 mm rectangular strips of *chapattis* were cut from the centre with a metal template. Each strip was tested for extensibility on Instron Texture Analyzer. The *chapatti* strip was inserted between two clamps; both clamps were aligned and set at 40 mm apart. A load cell of 100 N at a crosshead speed of 50 mm/min was used to pull the *chapatti* strip until its rupture. *Chapatti* strips that were ruptured from centre were considered to obtain the force displacement curve. From this curve extensibility (peak force, N) to rupture the *chapatti* was obtained.

Biochemical constituents

Antioxidant activity using DPPH method

The method described by Kaur et al. (2019) was used for determining antioxidant activity using reagent 1, 1-diphenyl-2-picryl-hydrazyl (DPPH). The absorbance was recorded at 517 nm using spectrophotometer (Thermo Scientific Spectronic-200). Methanol was used as control. DPPH scavenging activity was calculated as % inhibition of DPPH.

$$\% \text{ Inhibition} = \frac{\text{Control OD} - \text{Sample OD}}{\text{Control OD}} \times 100$$

Total phenols

Total phenols were estimated using modified method of Yaoguang et al. (2015) using Folin–Ciocalteu reagent with gallic acid as a standard. Flour samples (1 g) were extracted for 4 h at 30 ± 1 °C with 50 ml of methanol in orbital shaker, extract was centrifuged at 10,000 rpm for 10 min. Supernatant (0.5 ml) was dispersed in test tubes and 5 ml of 10% (v/v) Folin–Ciocalteu reagent was added. After 5 min, 4 ml saturated sodium carbonate was added, mixed, vortexed and allowed to stand for 15 min in dark conditions. The absorbance was recorded using spectrophotometer (Thermo Scientific Spectronic-200) at 765 nm and the results were expressed as µg GAE/g.

Phytic acid determination

The method of Verma et al. (2018) was used to determine phytic acid content. For extract preparation, 500 mg sample was taken in conical flask with 20 ml nitric acid (0.5 M) and kept on shaker for 3 h at room temperature. The centrifugation was done for 15 min at 800 rpm. Further, 0.5 ml supernatant was pipetted in the test tube and diluted with distilled water followed by pipetting 1 ml of ferric ammonium sulphate solution. The contents were mixed and kept for 20 min in boiling water-bath, later tube was cooled under running water. To it, 5 ml of iso-amyl alcohol was pipetted, thoroughly mixed, 0.1 ml of ammonium thiocyanate (NH₄SCN) solution was added into it and centrifuged for 10 min. Absorbance was taken at 465 nm against iso-amyl alcohol blank. Phytic acid was used as standard and the results were expressed as mg/100 g.

The phytic acid was calculated by the formula:

$$\text{Phytic acid (mg/100 g)} = \frac{\text{Conc. of sample (graph)} \times \text{Vol. of extract made} \times 100}{\text{Sample wt} \times \text{Vol. of aliquot taken} \times 1000}$$

Color measurement

Flour color was measured using Color Flex colorimeter using 45°/0° geometry with standard illuminant C (Hunter Lab Color Flex 150 Hunter Associates Inc. USA) by estimating L* (0 to 100, dark 95 to light), a* (±, green/red), and b*(±, blue/yellow) values.

Sensory evaluation

Sensory evaluation of *chapattis* prepared from different wheat fractions was conducted after 3 h of preparation for appearance, texture, aroma and over all acceptability by a panel of minimum twelve semi trained judges on 9 point

hedonic scale by standard procedure (Meilgaard et al. 2006). Research scholars and faculty, all consumers of *chapattis* (6 male and 6 female) of Department of Food Science and Technology, PAU, Ludhiana were briefed individually for sensory characteristics of *chapatti* and score card. The *chapattis* were distributed in coded Low density polyethylene bags with score sheets.

Statistical analysis

Data obtained was analyzed statistically using one-way analysis of variance. The results were expressed as means ± S.D. of three replicates (Gomez and Gomez 2010). The data was subjected to ANOVA (CRD) followed by Duncan’s multiple range tests with $p \leq 0.05$ significance level on SPSS 18.0 statistical software (SPSS Inc.).

Results and discussion

Proximate and functional analysis of wheat fractions

Three wheat fractions (355 µm, 180 µm and 150 µm) were assayed for proximate composition and functional characteristics and results are represented in Table 1. Composition of flour fractions are greatly influenced by the sieving and size reduction of wheat grains. Moisture and ash content decreased significantly ($p < 0.05$) with decrease in particle sizes. Ahmed et al. (2019) also reported a reduction

in moisture and ash content with reduction in particle size for the quinoa flours which was due to heat generation and friction during the milling of fine fractions that resulted in increase in moisture loss and more bran fractions in coarser particles resulted more ash content. The observed value of protein content in whole wheat meal was 8.55 ± 0.21 per cent. Our results were comparable to the findings of Nowak et al. (2016), who reported protein value in the range of 9.1 to 15.7 per cent. The least value of protein was noticed in 355 µm (8.12 ± 0.31 per cent) fraction of wheat flour, which significantly ($p < 0.05$) increased with decrease in particle size. Breakdown of endosperm with successive milling resulted into increase in protein content (Dhen et al. 2016). The fat and fibre content significantly decreased with reduction in particle size and the values varied from 1.53 ± 0.03 to 1.45 ± 0.01 percent and from 1.78 ± 0.21 to 1.25 ± 0.05 percent respectively. The results were in contrary to the findings of Russin et al. (2007), who reported an increase in fat and fibre content with decrease in particle size. The carbohydrate content ranged 78.41 ± 0.06 to 81.64 ± 0.05 per cent. The value of carbohydrate content in fraction 150 µm (81.64 ± 0.05 per cent) was significantly ($p < 0.05$) higher than other fractions i.e. 180 µm (81.04 ± 0.08 per cent) and 355 µm (78.41 ± 0.06 per cent). The results were in contrast to the findings of Pande et al. (2017) who reported carbohydrate content of 73.73 per cent. Zn and Fe content improve the nutritional and nutraceutical properties of wheat flour. Zn content increased significantly ($p \leq 0.05$) with decrease in

Table 1 Proximate and functional analysis of whole wheat flour with different particle size fractions

Parameters	Whole	355 µm	180 µm	150 µm
Moisture (%)	7.78 ^b ± 0.11	10.65 ^a ± 0.31	8.34 ^b ± 0.19	7.88 ^b ± 0.34
Ash (%)	1.65 ^a ± 0.02	1.29 ^b ± 0.01	0.98 ^c ± 0.11	0.73 ^d ± 0.21
Protein (%)	8.55 ^a ± 0.21	8.12 ^c ± 0.31	8.14 ^c ± 0.01	8.30 ^b ± 0.20
Fat (%)	1.50 ^b ± 0.04	1.53 ^a ± 0.03	1.50 ^b ± 0.02	1.45 ^c ± 0.01
Fibre (%)	1.66 ^b ± 0.04	1.78 ^a ± 0.21	1.39 ^c ± 0.01	1.25 ^d ± 0.05
Carbohydrates (%)	80.52 ^c ± 0.21	78.41 ^d ± 0.06	81.04 ^b ± 0.08	81.64 ^a ± 0.05
Fe (ppm)	99.75 ^a ± 0.20	78.40 ^c ± 0.21	86.34 ^b ± 0.14	77.28 ^d ± 0.11
Zn (ppm)	38.73 ^c ± 0.31	37.98 ^d ± 0.11	39.85 ^b ± 0.01	40.43 ^a ± 0.21
Water absorption index (g/g)	2.27 ^b ± 0.01	2.25 ^b ± 0.02	2.27 ^b ± 0.05	2.53 ^a ± 0.02
Water solubility index (%)	5.17 ^b ± 0.21	6.10 ^a ± 0.10	6.20 ^a ± 0.05	6.30 ^a ± 0.11
Swelling power	5.74 ^b ± 0.14	5.55 ^b ± 0.08	6.66 ^a ± 0.11	6.72 ^a ± 0.10
Oil absorption capacity (%)	228.5 ^a ± 1.17	179.5 ^d ± 0.40	187.9 ^c ± 1.42	197.3 ^b ± 1.47
Sedimentation value (ml)	38 ^b ± 0.08	38 ^b ± 1.01	41 ^a ± 0.09	42 ^a ± 1.01
Color				
L*	87.24 ^b ± 0.21	88.07 ^b ± 0.63	89.75 ^a ± 0.54	90.38 ^a ± 0.56
a*	1.74 ^{ab} ± 0.19	1.45 ^b ± 0.04	1.50 ^b ± 0.08	1.93 ^a ± 0.10
b*	11.36 ^a ± 0.70	10.17 ^b ± 0.10	10.44 ^{ab} ± 0.24	11.23 ^a ± 0.05

Values are expressed as means of three replications ± standard deviation
 Values with different letters in superscript differ significantly ($p \leq 0.05$)

particle size i.e. from 37.98 ± 0.11 to 40.43 ± 0.21 ppm whereas in case of Fe content, it was observed highest in fraction $180 \mu\text{m}$ i.e. 86.34 ± 0.14 ppm. Araujo et al. (2008) reported the average contents of mineral in wheat flour for Zn and Fe as 9.4 and 37.8 $\mu\text{g/g}$ respectively.

WAI is an indicator for starch gelatinization. It determines the amount of water absorbed by the granule or starch polymer after swelling in excess water. WAI increased with decrease in particle size. Wheat fraction with least particle size had the WAI of 2.53 ± 0.02 g/g and the fraction with maximum particle size had the WAI of 2.25 ± 0.02 g/g. This increase could have happened due to more absorption of water by fine particles as they possess large surface area. Similar results were observed between particle size and WAI of barley and rye flours by Drakoset al. (2017). WSI can be used as an indicator for the dextrinization. It determines the quantity of free polysaccharide or polysaccharide released from the granule after addition of excess water. WSI also increased as the particle size decreased i.e. from 6.10 ± 0.10 to 6.30 ± 0.11 per cent. Non-significant ($p \leq 0.05$) difference was observed for WSI of different wheat fractions. This increase could be due to the more leaching of hydrophilic components from fine fractions. The results were in accordance with Ahmed et al. (2019), who reported that WSI of quinoa flour fractions increased as the particle size decreased. SP indicates the water holding capacity of starch. SP of wheat fractions increased as the particle size decreased. SP of finest particle i.e. $150 \mu\text{m}$ (6.72 ± 0.10) was significantly ($p \leq 0.05$) higher than the particle size of $355 \mu\text{m}$ (5.55 ± 0.08) but was non-significant with particle size of $180 \mu\text{m}$ (6.66 ± 0.11). The results were similar to the findings of Sandoval et al. (2012) for wheat flour. OAC of different wheat fractions increased with decrease in particle size and ranged from 179.5 ± 0.40 to 197.3 ± 1.47 per cent. OAC of fraction $150 \mu\text{m}$ (197.3 ± 1.47 per cent) was significantly ($p \leq 0.05$) higher than other wheat fractions. The results contradicted with the findings of Chandra et al. (2015), who reported oil absorption capacity in wheat flour as 146 per cent. SV is an approximate measure of baking quality. Rate of sedimentation of a flour suspension in the lactic acid medium is affected by the swelling of gluten fraction of flour in lactic acid solution. SV increased with decrease in particle size. There is a correlation between the SV and protein content. As protein content increased with decrease in particle size that resulted in increase in SV. SV of fraction $150 \mu\text{m}$ (42 ± 1.00 ml) is observed higher as compared to other fractions i.e. $180 \mu\text{m}$ (41 ± 0.09 ml) and $355 \mu\text{m}$ (38 ± 1.01 ml). This was similar to the findings of Rao and Manohar (2003), who reported sedimentation value in the range to 25–35 ml.

The color values of flour obtained from different wheat fractions i.e. $355 \mu\text{m}$, $180 \mu\text{m}$ and $150 \mu\text{m}$ were

determined and are presented in Table 1. Color is an important parameter that can affect consumers quality perceptions. Flour color is determined by measuring the whiteness of a flour sample. Flour color results are reported in terms of 3-dimensional color values i.e. L^* , a^* and b^* . The L^* value, a^* and b^* value increased with decrease in particle size i.e. from 88.07 ± 0.63 to 90.38 ± 0.56 , 10.17 ± 0.10 to 11.23 ± 0.05 and 1.45 ± 0.04 to 1.93 ± 0.10 respectively. It means fine fraction $150 \mu\text{m}$ was more white and yellow as compared to other fractions. Whiteness may be due to increased surface area in fine fractions and yellowness is due to the presence of carotenoid pigments. The results of L^* and b^* value were in agreement with Ahmed et al. (2019) who reported that L^* and b^* value for quinoa flour fractions increased with the decrease in particle size.

Pasting properties of flour obtained from wheat fractions

Wheat fractions i.e. $355 \mu\text{m}$, $180 \mu\text{m}$, and $150 \mu\text{m}$ are assessed for paste temperature, peak viscosity (PV), hold viscosity (HV), final viscosity (FV), breakdown viscosity (BV) and setback viscosity (SV). Table 2 shows the pasting profile of wheat flour obtained from different wheat fractions.

The pasting profile of a food refers to the variations occurring in the food when heat is applied in the presence of water and it depicts digestibility, texture and end use of the food product. The paste temperature, PV, HV, FV and SV decreased with decrease in particle size. Peak viscosity is the maximum viscosity achieved during gelatinization by the starch molecules before cooling of sample takes place. It indicates the degree of starch swelling prior to rupturing of starch molecules. The peak viscosity of coarse fraction $355 \mu\text{m}$ (878 ± 1.05 cP) was significantly higher as compared to other fine fractions. Similar results were observed for corn flour by Singh et al. (2013) and reasoned that finer particles had large surface area with more water holding capacity which contributed to lower pasting viscosities. Breakdown viscosity measures the degree of rupture of starch molecules during the holding period that indicates starch paste stability; high value indicates low starch paste stability. Contrary to the observation made by Aluwi et al. (2017) and Kaur et al (2018), a decrease in HV was observed and BV for wheat flour was recorded (311 ± 1.20 to 269 ± 1.10 cP). Setback viscosity determines the affinity of retrogradation of starch after gelatinization and cooling at 50°C and hence increase in viscosity of slurry takes place to a final viscosity. Low value indicates low tendency of retrogradation of starch and syneresis. SV decreased significantly from 895 ± 1.06 to 649 ± 0.40 cP. This decrease in SV was in consistent with Ahmed et al.

Table 2 Effect of wheat flour fractions on pasting properties

Sample	Paste temp. (°C)	Peak viscosity (cP)	Hold viscosity (cP)	Final viscosity (cP)	Breakdown viscosity (cP)	Setback viscosity (cP)
Whole	92.9 ^{ab} ± 0.06	846 ^b ± 0.12	547 ^b ± 0.09	1366 ^b ± 1.05	299 ^c ± 0.50	819 ^b ± 0.09
355 µm	93.9 ^a ± 0.31	878 ^a ± 1.05	564 ^a ± 1.02	1459 ^a ± 0.09	311 ^b ± 1.20	895 ^a ± 1.06
180 µm	93.6 ^a ± 0.12	631 ^c ± 0.50	320 ^c ± 0.08	1024 ^c ± 1.30	314 ^a ± 0.50	704 ^c ± 0.60
150 µm	92.0 ^b ± 0.15	493 ^d ± 1.20	224 ^d ± 1.20	873 ^d ± 0.60	269 ^d ± 1.10	649 ^d ± 0.40

Values are expressed as means of three replications ± standard deviation

Values with different letters in superscript differ significantly ($p \leq 0.05$)

(2019) for quinoa flour fractions. The pasting properties of particle fractions indicated the important role played by the composition, as the protein contents increased with decrease in particle size and starch content decreased while fiber and fat remained constant.

Phytic acid, antioxidant and total phenolic content of wheat fractions

The phytic acid, antioxidant and total phenolic content of different wheat fractions (355 µm, 180 µm and 150 µm) were estimated and presented in Table 3.

Phytic acid, antioxidant and total phenolic content of wheat fractions decreases with decrease in particle size. Phytic acid is an anti-nutritional component which reacts with starch, protein and divalent cations such as Fe, Zn and Ca to form insoluble complexes which reduce their bioavailability, functionality, absorption and nutritional value. From Table 3, it can be seen that phytic acid in the whole flour and finest particle i.e. 62.10 ± 0.10 mg/100 g and 44.62 ± 0.31 mg/100 g respectively, showed significant variations. The results were in contrary to the findings of Turksoy et al. (2010) who reported increase in phytic acid with increase in extraction rate of flour. Antioxidants are the molecules that prevent oxidative stress. They are mostly present in bran fraction. Higher value of antioxidant content is recorded for fraction 355 µm (44.95 ± 0.21 per cent), which is significantly ($p \leq 0.05$) higher than 180 µm

(42.42 ± 0.16 per cent) and 150 µm (41.41 ± 0.61 per cent). The results were similar to the findings of Sharma and Gujral (2014) for wheat flour. Phenolic compounds are secondary metabolites synthesized during plant development. They are mostly present in wheat bran fractions and play an important role in plant reproduction and growth, sensory and color characteristics of plant. The least value of total phenolic content was recorded for fraction 150 µm (41.86 ± 0.51 µg/g), which was significantly ($p \leq 0.05$) lower than 180 µm (45.85 ± 0.09 µg/g) and 355 µm (59.89 ± 0.51 µg/g). The results were in agreement with the findings of Vaher et al. (2010), who reported the range for total phenolic content of wheat flour as 44–140 µg/g.

Chapatti making and sensory quality of wheat fractions

Chapatti making quality and mean panel scores (Max 9) for sensory evaluation of chapattis prepared from wheat fractions (355 µm, 180 µm, and 150 µm) was studied and are presented in Table 4. Figure 1 depicts the chapattis prepared from different wheat fractions.

Softness and puffing height serves as an indicator for evaluation of chapatti quality. Non-significant ($p \leq 0.05$) difference was observed in puffing height of chapattis prepared from different wheat fractions. Dough handling of fractions 355 µm and 180 µm was very smooth. Similar results were reported by Panghal et al. (2019), who

Table 3 Phytic acid, antioxidant and total phenolic content of wheat fractions

Sample	Phytic acid (mg/100 g)	Antioxidant activity (% DPPH inhibition)	Total phenolic content (µg GAE/g)
Whole	60.41 ^b ± 0.21	42.42 ^b ± 0.41	40.99 ^d ± 0.11
355 µm	62.10 ^a ± 0.10	44.95 ^a ± 0.21	59.89 ^a ± 0.51
180 µm	50.05 ^c ± 0.11	42.42 ^b ± 0.16	45.85 ^b ± 0.09
150 µm	44.62 ^d ± 0.31	41.41 ^c ± 0.61	41.86 ^c ± 0.51

Values are expressed as means of three replications ± standard deviation

Values with different letters in superscript differ significantly ($p \leq 0.05$)

Table 4 Chapatti making and sensory quality of whole wheat flour with different particle size fractions

Sample	Puffing height (cm)	Water absorption (%)	Dough handling	Extensibility (N)	Appearance	Texture	Taste	Aroma	Overall acceptability
Whole	7.58 ^a ± 1.48	75 ^a ± 0.61	Smooth	1.12 ^d ± 0.01	8.07 ^b ± 0.04	8.03 ^b ± 0.05	7.50 ^{bc} ± 0.20	7.80 ^b ± 0.17	7.85 ^b ± 0.09
355 µm	7.57 ^a ± 1.00	76 ^a ± 1.20	Very Smooth	1.56 ^c ± 0.21	8.17 ^{ab} ± 0.29	8.02 ^b ± 0.17	8.20 ^{ab} ± 0.10	7.80 ^b ± 0.11	8.05 ^b ± 0.07
180 µm	7.64 ^a ± 0.94	76 ^a ± 0.60	Very Smooth	1.83 ^a ± 0.41	8.83 ^a ± 0.39	8.83 ^a ± 0.24	8.67 ^a ± 0.05	8.67 ^a ± 0.25	8.75 ^a ± 0.35
150 µm	7.37 ^a ± 0.96	75 ^a ± 1.0	Smooth	1.72 ^b ± 0.01	7.82 ^b ± 0.37	7.67 ^b ± 0.21	7.36 ^c ± 0.48	7.78 ^b ± 0.03	7.66 ^b ± 0.20

Values are expressed as means of three replications ± standard deviation

Values with different letters in superscript differ significantly ($p \leq 0.05$)

**Fig. 1** Chapattis prepared from different wheat fractions

reported puffing height of *chapattis* in the range of 5.2 to 6.2 cm and *chapattis* made from wheat varieties (C 306, HD 2687, WH 912, etc.) were very smooth. Water absorption has been correlated with the amount of gluten proteins and the bran fraction which contains arabinoxylans which are responsible for hydration capacity of wheat flour. Non-significant ($p \leq 0.05$) difference was recorded in water absorption of different fractions. Similar results were recorded by Gujral et al. (2019), who stated water absorption of dough for *chapatti* making as 80 per cent. The extensibility of fraction 180 µm was significantly ($p \leq 0.05$) higher i.e. 1.83 ± 0.41 N as compared to other fractions 150 µm (1.72 ± 0.01 N) and 355 µm (1.56 ± 0.21 N). The results were in contrary to the findings of Cheng and Bhat (2015), who stated the peak force and extensibility of wheat *chapattis* as 3.26 N and 4.58 mm respectively.

Sensory quality of *chapattis* revealed that the appearance, texture, taste, aroma and overall acceptability of the *chapatti* prepared from fraction 180 µm got higher scores than the *chapattis* prepared from other fractions of flour. Light brown spots were uniformly distributed on the surface of *chapattis* prepared from 180 µm fraction with typical wheaty aroma and soft texture. The overall acceptability score of fraction 180 µm observed was 8.75 ± 0.35 , which was significantly higher than other fractions. Similar results were recorded by Sakhare et al.

(2014), who stated the *parottas* made from fine fractions showed highest sensory scores than coarse fractions. Thus, this study suggested that 180 µm flour fraction was best for *chapatti* making quality.

Conclusion

Wheat flour fractions obtained from PBW 1 Zn variety showed wide variation in proximate composition, biochemical and rheological parameters of flour. Decrease in particle size showed better functional properties and color of flour. Finest particles were rich in Zn content as compared to coarse flour. *Chapatti* making quality of flour fraction II (180 µm) was best as compared to whole flour and other fractions. Thus, it can be concluded that the millers and processors should keep a critical size of the flour (180 µm) to obtain desired nutritional and product profile.

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Compliance with ethical standards

Conflict of interest Authors declare that there is no conflict of interest.

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