Effect of Flour Particle Size on Chemical and Rheological Properties of Wheat Flour Dough

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ABSTRACT: *The present study evaluates the effect of wheat flour particle sizes on the chemical and rheological properties of flatbread dough. Three wheat flour samples with particle sizes smaller than 125μm, 125-150μm, and 150-180μm were examined for their chemical and rheological attributes. Flour with a particle size of <125μm demonstrated the highest levels of wet gluten, Zeleny number, and Falling number values. In addition, the dough development time and stability of this flour were higher than samples of larger particle sizes. The maximum dough energy and extensibility values of Extensograph tests were obtained at the resting time of 45, 90, and 135 minutes for flour with particle sizes of <125μm. The results have indicated that the flour with particle sizes of 150-180μm has the highest values of ash content, water absorption, and softening degree based on Farinograph parameters. In addition, at all resting times, the maximum values of resistance to extension and ratio of resistance to extension to extensibility were shown in particle sizes of 150-180μm. The results have demonstrated that the flour with particle sizes of <125μm has the best quality in terms of chemical and rheological properties for cooking flatbread, which is inherently influenced by milling.*

KEYWORDS: *Particle size; Wheat; Flour quality; Rheology; Chemical properties.*

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INTRODUCTION

Over 50% of carbohydrates, 1.3% of proteins, and 50-60% of B vitamins are obtained through bread in developed countries. These ratios are higher in developing countries, and in some cases, bread provides 75-85% of the calories and proteins of the people [1]. Cereals belong to the *Poaceae* or *Gramineae* family, which are herbaceous monocotyledons, and not only are suitable sources of salts and minor elements but are also considered suitable carriers for food enrichment in many countries [2, 3]. As the most consumable human food in the world, bread is produced from the flour of wheat or other cereals [4]. Unique viscoelastic behaviors of wheat flour amongst other cereals originate mainly from its constituents and flour production process [5]. Wheat grains endure the complex process of flour milling, which results in the reduction of flour particle size and effective removal of the bran and germ from the wheat endosperm. Amid milling steps, the grinding process which involves the gradual and sequential crushing of particles with a roller milling system and followed by the use of a multi-sieve system determines final flour properties. Aside from wheat grain varieties and constituents, milling gives different fractions of wheat flour which affect the quality of bakery products such as cookies, bread, chapatti, pita, and cakes [6]. Particle sizes obtained from the last step of roller milling vary due to the differences in the hardness of the endosperm in different wheat varieties and flour milling conditions [7]. The flour that is normally prepared in the mill contains a mixture of particles that are different in chemical composition and have particle sizes smaller than 50 and greater than 1200µm [8]. Relationships between flour particles, protein, and ash contents have been investigated in previous studies [9, 10]. Basically, wheat flours are classified on the basis of flour extraction rate which can be estimated based on the ash content, thus determining the type of application such as suitability for specific bread or confectionery products [11, 12]. On the other hand, flour particle size also influences dough properties such as dough softening degree, water absorption, and ultimately the bread texture [13].

Zhang and *Moore* (1997) have investigated the effect of wheat bran particle size on dough rheological properties. The mean bran particle sizes were distributed in three levels as coarse, medium, and fine samples which had 609µm, 415µm, and 278µm sizes, respectively. According to the Extensograph results, wheat bran particle size had significant effects on dough rheological properties. Fine bran resulted in greater dough resistance than coarse bran after a 180 min resting time. They have indicated that increased wheat bran levels resulted in significantly higher water absorption and reduced dough strength [14]. *Blanchard et al.* (2012) investigated the appearance and deformation effect of wheat flour type, particle size, and protein content in the cake-like dough. The results showed that soft wheat flour containing particles with a size >50µm and medium-hard wheat flour (71µm) had significantly higher water absorption and solvent retention capacity [15]. *Chen et al.* (2011) examined the effect of bran content and particle size of flour on the dry white noodle. Their results showed that the addition of 5 to 20% of wheat bran, significantly affected the mixing and stickiness properties of noodle dough and the mixing tolerance was weakened, but the size of the bran particles (0.21 and 0.53 mm) had no significant effect on the dough properties. The hardness, stickiness, and chewiness of cooked noodle products showed a decreasing trend with increasing bran and particle size [16].

Considering the requirements for producing flour appropriate for each high-quality bakery product, the present study investigated the effect of wheat flour particle size on the chemical (including ash content, wet gluten content, Zeleny number, and falling number) and rheological (including Farinograph and Extensograph tests) properties of dough.

EXPERIMENTAL SECTION

Materials

The wheat flour *(Triticum aestivum)* was obtained from Russian Hard Red Winter (HRW) at the flour factory with the Roller Mill System. Extensograph-E and Farinograph-E (Brabender-Germany) were utilized for rheological experiments. Other materials required for chemical evaluation were analytical grade and obtained from Merck, Germany.

Sample preparation

Wheat grains were milled at the flour factory with the Roller Mill System according to flatbread milling protocol. This protocol is designed to reach the extraction rate of Iranian flatbread. Flatbread is one of the most common and oldest types of bread in Iran which has the highest consumption

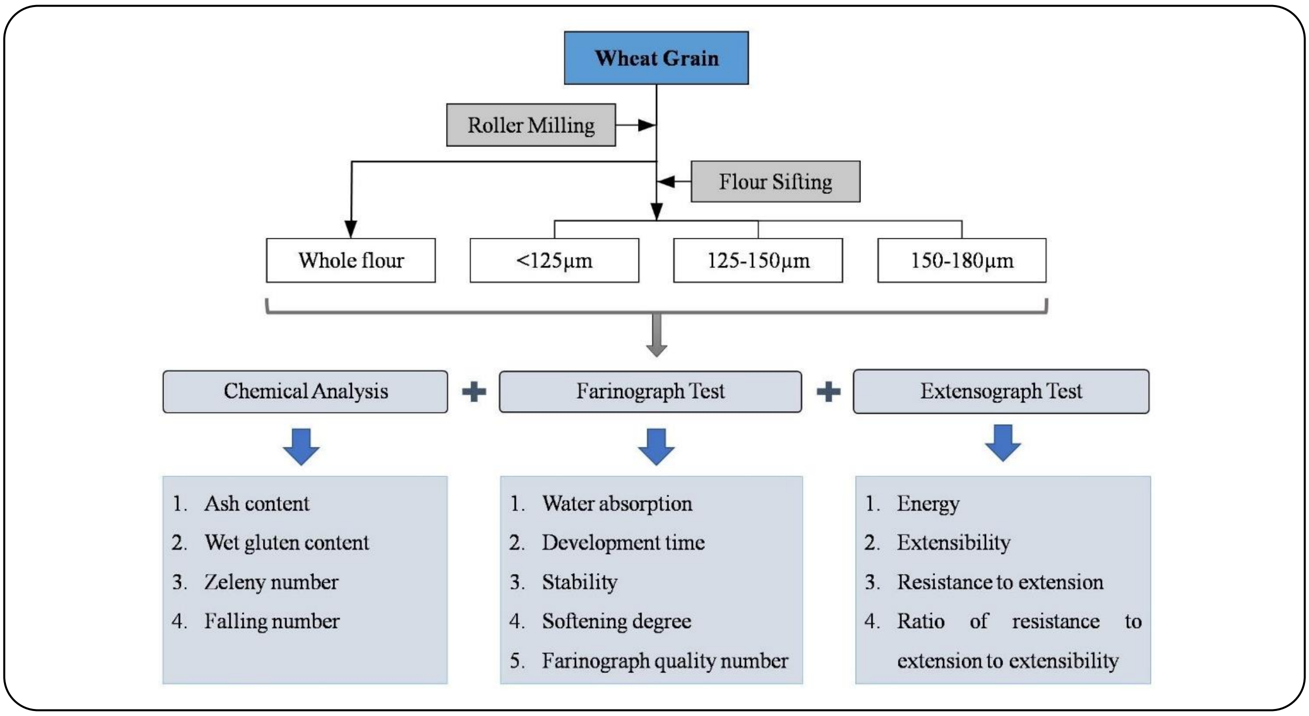

Fig. 1: Schematic diagram of experimental design.

and has the highest shelf life, which is why it is more popular among people. Because this kind of bread is thin and fragile, therefore the bread waste is higher and it is essential to determine the best quality wheat flour for bread cooking by examining the particle size of the flour. To obtain and measure the flour particle size sieving system was utilized. Sieves were first weighed and placed on a flour vibrating sieve shaker (model 161, Ryan Shamsi Co., Iran), in the order of 475µm on the upper level to 125µm on the lowest. These apparatus have four mesh sizes with No.475, No.180, No.125, and <125µm fraction. All mesh sizes have been chosen according to the Iranian flatbread standard No.103 [17]. A 100 g of flour was weighed and transferred to an upper sieve (475µm) and screened for 5 minutes. The sieves were weighed and the particle size of the flour was calculated as a percentage (%) based on the weight difference with empty sieves [18].A schematic representation of wheat flour sample preparation and related analysis are shown in Fig. 1.

Chemical analysis

Whole Four (WF), the control, was sieved and flour samples with different particle sizes were subjected to chemical analysis in three replicates. Chemical tests including ash, wet gluten, Zeleny (sedimentation) number, and falling number, were carried out on WF (control) following the national and international standard methods.

Measurement of ash content

An electric furnace (F47 model, Shimifan-Iran) was used to measure the ash content. According to ISIRI-2706 standard, 3-5 g of samples were placed in crucibles and transferred to the furnace at a temperature of 500-550℃ [19, 20].

Measurement of wet gluten content

Gluten Washer 6100 (Bastak Model, Turkey) was used for wet gluten estimation. According to Method 9639-2, 10 g of the sample was weighed in a special container followed by the addition of 5 ml of 2% saline. The dough washing was continued until the removal of clear saline water from the rinse area. The resulting gluten in this stage was centrifuged for 2 minutes [21]. The wet gluten content was calculated as follows, where m_1 is the weight of wet gluten in grams:

Formula (1): $G_{wt} = m_1 \times 10\%$

Measurement of Zeleny number

According to the ISIRI standard method-3681 to measure the sedimentation number, 3.2 g of the homogeneous samples with a moisture content of about 14% were weighed. The sedimentation number test was performed using bromophenol blue, 2-hydroxypropanoic, and isopropanol solutions, using a stirrer 2100 (Bastak model, Turkey). The recorded volume in ml of sedimentation represented the amount of sediment [22].

Measurement of Falling number

According to ISIRI standard method- 4175, 7 g of homogeneous flour were weighed and the falling number was measured using the falling number device (1500-FN model, PERTEN Co., Sweden-Germany) [23, 24].

Rheological properties

Similar to chemical analysis, rheological attributes of control (whole flour) and samples in particle sizes of 125µm, 125-150µm, and 150-180µm were subjected to Farinograph and Extensograph analysis.

Farinograph test

The Farinograph characteristics of tested flour samples were examined according to the International Standard ICC-115.1 using a 300-gram Farinograph mixer [25]. The test examined water absorption percentage, development time, stability, softening degree, and Farinograph quality number of dough.

Extensograph test

The method of working with an Extensograph device was in accordance with the International Standard ICC-114.1 [25]. Parameters obtained from the analysis of dough samples with Extensograph in three different dough Resting Times (RT) including 45, 90, and 135 min, were extension energy (required to stretch and tear dough), extensibility (extension-to-rupture length), maximum resistance extension (R_{max}), resistance to extension (height of the curve in terms of Brabender), and the ratio of maximum resistance-to-extension to extensibility.

Statistical analysis

Data were analyzed by SPSS version 25 software using one-way ANOVA and Tukey's post-hoc test. Analysis of variances and comparison of the means were performed on the results from the experiments of flour samples with different particle sizes and at a significance level of 0.05.

RESULTS AND DISCUSSION

Distribution of wheat flour particle size

The distribution percentage of particle size of wheat flour samples is shown in Table 1. According to the results, the whole flour samples were apparently considered as coarse flour. The flour samples with a particle size of 180-475µm were excluded from the testing process due to the partial percentage.

Results of chemical analysis

The results of the chemical tests are shown in Table 2. Statistical analysis exhibited a significant difference in the wet gluten content, Zeleny number, and falling number ($P<0.05$) of samples while there was no significant difference between ash content of flours with different particle sizes ($P>0.05$).

Ash content

In flour, ash is mainly a mineral material, which is affected primarily by the wheat type and flour milling extraction diagram [26, 27]. The results of the experiment showed that the ash content was elevated with the increasing particle size of the flour (Fig. 2). The particle sizes of <125µm had the lowest ash content which can be legitimatized given that this particle size is extracted from the endosperm of the grain during the early stages of the mill [28]. The content of ash in flour with particle sizes of 125-150µm was similar to whole flour. The particle sizes of 150-180µm contained the highest ash content. Increasing ash content seems logical by approaching the outermost layers of the grain and the presence of salts and minerals in the bran and aleurone layer. However, no significant difference was found between the flour samples with different particle sizes ($P>0.05$). The results of this study were consistent with the research carried out by *Wang* and *Flores* [29]. They have indicated that the >75µm fraction of hard red winter and soft red winter wheat flour had higher ash content, 0.43%, and 0.57% respectively, while the 38–53µm fraction of hard red winter wheat flour had higher ash content (0.43%) [27].

Wet gluten content

Wet gluten content provides a quantitative measure of the gluten-forming proteins in wheat flour that are mainly accountable for its dough mixing and baking properties [30]. As shown in Fig. 2, the wet gluten content

Table 1: Distribution percentage of whole wheat flour samples particle size.

Flour Particle Size	<125μm	125-150μm	150-180μm	180-475μm
Distribution Percentage	32.84%	29.03%	37.51%	0.62%

Table 2: Results of chemical experiments based on the particle size of flour samples.

Flour Sample	Ash (% dry matter)	Wet gluten (%)	Zeleny number (ml)	Falling number (sec)
WF	$0.546{\pm}0.01^{c}$	$25.33{\pm}0.02^{a}$	$28.35{\pm}1.43^{abc}$	$423{\pm}1.8^{ab}$
150-180μm	$0.585{\pm}0.02^{a}$	$21.90{\pm}0.02^{a}$	$24.50{\pm}0.3^{ad}$	$389{\pm}2.9^{acd}$
125-150μm	$0.546{\pm}0.03^{b}$	$23.10{\pm}0.03^{a}$	$26.45{\pm}0.3^{be}$	$422{\pm}2.6^{ce}$
<125μm	$0.536{\pm}0.02^{d}$	$26.82{\pm}0.04^{a}$	$33.15{\pm}0.4^{cde}$	$453{\pm}4.9^{bde}$

Values are means ± standard deviation (n = 3). Means with similar superscripts in the columns are significantly different (p<0.05).

was decreased with increasing particle size, due to the reduction of gluten content in the outermost layers [31]. A comparison of the results showed that there was a significant difference between wet gluten content of the flours with different particle sizes (*P*<0.05). The highest content of gluten was obtained for the particle size <125μm (the same with whole flour) and the lowest content of gluten for the particle size 150-180μm in agreement with *Fistes* and *Tanovic* [7]. They have reported a rise in protein content in parallel with a decrease in size fractions of wheat. They have shown that wheat flour with >2.8, 2.5–2.8, and <2.5mm size fractions have 15.3, 14.7, and 14.5% protein content, respectively.

Zeleny number

The Zeleny value (as sedimentation value) describes the degree of sedimentation of flour suspended in a lactic acid solution during a standard time interval and this is taken as a determination of the baking characters. Superior gluten quality and higher gluten content give rise to slower sedimentation and higher Zeleny number values [32]. Zeleny sedimentation rate was decreased in samples by increasing the particle size of the flour (Fig. 2). These results are justifiable with regard to the direct relationship between wet gluten/protein content and Zeleny number. Although there is a potential for increased protein content by approaching the outermost layers of the grain, the quality of the gluten is reduced. The maximum Zeleny number was obtained for the particle size of <125μm and the minimum value for the particle size of 150-180μm. The result has shown that the Zeleny number of flours with particle sizes of 125-150μm was significantly different from whole flour in values (*P*<0.05). A study by *Shahedi et al*, who investigated the flour quality indices and dough rheological properties of wheat flour for the production of flat Tafton bread demonstrated that with increasing flour particle sizes, sedimentation values were decreased. The flour with 154μm particle sizes exhibited 30mm Zeleny values compared with flour with 173μm particle sizes which had 20/33mm Zeleny values [33].

Falling number

The Falling Number (also referred to as the Hagberg Number) refers to a test for increased enzyme activity (alpha-amylase), which can significantly reduce grain and flour quality when is present [34]. The results revealed that the falling number was elevated by decreasing the particle size of the wheat flour (Fig. 2). The maximum falling number was obtained for the particle size of <125μm and the lowest value for the particle size of 150-180μm. The falling number values of whole wheat flour were the same as flours with particle sizes of 125-150μm (*P*>0.05). The results showed that there was a significant difference in falling numbers due to the particle size of the wheat flour (*P*<0.05). Reducing alpha-amylase activity levels in the outermost layers can be justified due to the presence of the bran and aleurone layer [35]. The results of this study were in line with the results of *Sakhare et al* [9]. They have indicated that falling number values can be increased with a decrease in particle size indicating lower alpha-amylase activity in finer fractions. According to their results, wheat flour fractions of 180–150, 150–118, 118–75, and <75μm have 463±2.02, 553±3.03, 558±1.51, and 563±2.00 falling numbers, respectively.

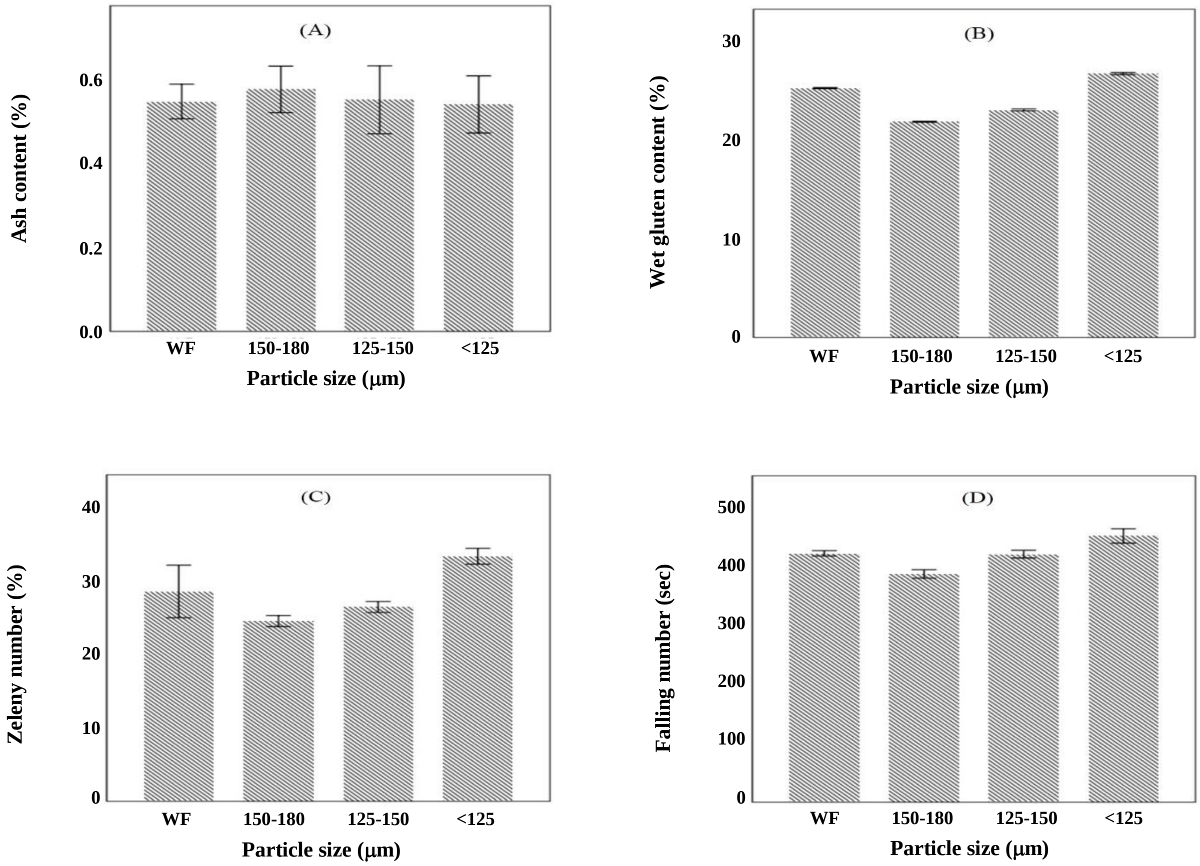

Fig. 2: The relation between flours with deferent particle size and ash content (A), wet gluten content (B), Zeleny number (C), and falling number (D).

Results of the rheological experiment

The Farinograph tests (including water absorption, development time, stability, softening degree, Farinograph quality number of the dough) and Extensograph tests (including energy, extension, resistance to extension, and the ratio of maximum resistance to an extension to extensibility) were performed on whole flour samples with the particle sizes of <125μm, 125-150μm, and 150-180μm in three replicates.

Results of the Farinograph experiment

In this experiment, the effect of flour particle size was investigated on the Farinograph properties. According to Table 3, the comparison of results from Farinograph tests showed that the flour samples with different particle sizes had a significant difference in the levels of water absorption, dough development time, dough stability, degree of softening, and Farinograph quality number (P<0.05).

Water absorption

The presence of water absorption in wheat flour is related to protein quantity and quality, damaged starch, and wheat polysaccharides such as β-glucans and pentosans and it is also important for the process of precise bread making [36]. The results of the Farinograph test showed that the particle size had a significant effect on the water absorption level of dough (P<0.05). As shown in Fig. 3, in addition to the whole flour, the flour particle size of 150-180μm had the highest water absorption level due to the presence of high fiber content in the outer layers of wheat as well as pentosans [37]. As well as, there was a significant difference level between flours with 150-180μm and 125-150μm particle sizes (P<0.05). Other researchers have reported similar results in the textural properties of flour Tortillas [29]. They have shown that the soft red winter wheat flours with particle sizes of 75μm had more water absorption compared to other flours with smaller particle sizes (58.3%).

Table 3: Results of Farinograph tests.

Sample Flour	Water absorption	Dough development time (min)	Dough stability (min)	Dough softening degree (FU)	Farinograph quality number
WF	61.2 ± 0.3^{ab}	2.1 ± 0.1	5 ± 0.05^{abc}	74 ± 4.6^{ab}	38.8 ± 2.4^{a}
150-180µm	60.7 ± 0.3^{c}	1.7 ± 0.1^{a}	3.4 ± 0.1^{ade}	83 ± 1.6^{acd}	30.5 ± 1.9^{ab}
125-150µm	59.2 ± 0.4^{ac}	2 ± 0.1	4.5 ± 0.2^{bdf}	71 ± 1.2^{c}	36.5 ± 1.6^{c}
<125µm	59.7 ± 0.1^{b}	2.2 ± 0.3^{a}	6.08 ± 0.2^{cef}	66.2 ± 1.15^{bd}	41.5 ± 1.8^{bc}

Values are means ± standard deviation (n = 3). Means with common superscripts in the columns are significantly different (p< 0.05).

Dough development time

The wheat dough development time depends on the formation of the gluten network and it can directly influence the quality of bread. Subsequently, monitoring the gluten network development could improve bread processing and formulation [38]. The highest and lowest dough development times were obtained for the particle sizes of <125µm and 150-180µm, respectively (Fig. 3). These results are reasonable based on the results of chemical tests and the higher content and quality of the gluten of <125µm particle size. The results showed a significant difference in dough development times between flours with <125µm and 150-180µm particle sizes (P<0.05). Moreover, the whole flour had the lowest dough development time compared to flours with <125µm particle sizes (P>0.05). These results were consistent with the results of the study by *Sakhare et al* [9]. They have suggested that dough development time increased from 1.8 min to 6.0 min with a decrease in particle size. The finest fractions of flour with <75µm particle sizes showed higher dough development time.

Dough stability

Dough stability demonstrates the time (min) when the dough retains maximum consistency and is a good indication of dough strength [39]. The results showed that the highest dough stability was achieved for the particle size of <125µm, which is defensible due to the high quality and gluten content in this particle size that resists mixing and rupture of dough (Fig. 3). Comparison of results revealed a significant difference between dough stability of flours with different particle sizes (P<0.05). According to the findings, flours with <125µm particle sizes had more dough stability compared to whole flour. These results were consistent with the findings of *Sakhare et al* [9]. They have reported that dough stability increased from 3.2 to 8 min with a decrease in particle size. The finest fraction of flour with <75µm particle sizes showed the highest dough stability compared to other greater fractions, which could be due to the higher protein content present in the finest fraction.

Dough softening degree

The degree of softening of the dough (index of tolerance to kneading) is the gluten quality, which illustrates the viscoelastic properties of the formed gluten network, and the increased softening degree is especially an important index of proteolytic degradation of gluten [40]. The dough softening obtained by Farinograph revealed a significant relationship between the flour particle size and the dough softening degree. The lowest softening degree was found for the particle size of <125µm whereas in comparison the highest softening degree was obtained for the particle size of 150-180µm (Fig. 3). This attribute can be explained by the high quality and content of gluten and also high dough stability with a reverse relationship with the dough softens. The results revealed a significant difference between dough softening degrees of flours with different particle sizes (P<0.05).

Farinograph Quality Number (FQN)

FQN indicates the overall quality of the flour. In fact, instead of calculating a number of different indicators in the Farinograph curve, flour quality can be reported by a number as FQN. In this regard, the weak flours have a low FQN number and the high FQN number shows strong flours [41]. FQN number provides a general quality description of the flour based on other Farinograph parameters such as water absorption, dough development time, dough stability, and softening degree. According to the entire results, there was a significant difference in the Farinograph quality number of wheat flour based on the size distribution (P<0.05). The highest and lowest values were determined for the particle sizes <125µm and 150-180µm, respectively. This result is expectable due to the compositional properties and high content and quality of the gluten in particle sizes <125µm (Fig. 3).

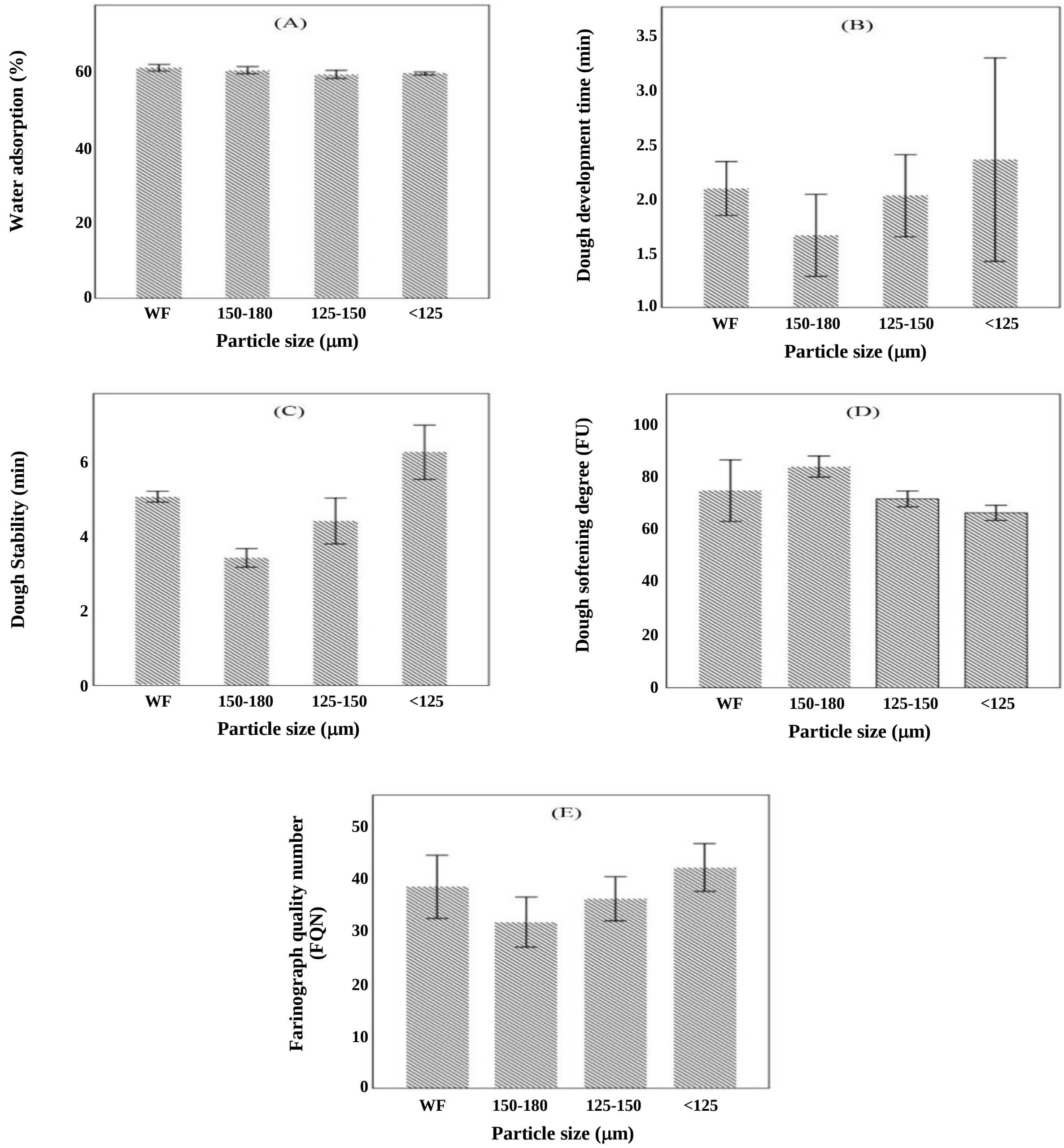

Fig. 3: Relation between flours with deferent particle size and water absorption (A), dough development time (B), dough stability (C), dough softening grade (D), and Farinograph quality number (E).

Results of Extensograph

The results of these tests, including energy, extension, resistance to extension, and a ratio of maximum resistance-to-extension to extensibility, were evaluated and analyzed at the Resting Times (RT) of 45, 90, and 135 min (Table 4). A comparison of significance level ($P<0.05$) was performed for each of the flour samples at given times.

Dough energy

Dough energy value expresses the resistance ability of dough against the deformation forces and correlates well with the gas retention capacity of dough, the volume of the end product after baking, and handling properties and it is also taken as a guideline parameter for flour blending operations at milling facilities [42]. Based on the results, the particle size of <125μm showed the highest energy

Table 4: Results of Extensograph tests.

RT (min)	Particle size	Energy (cm^2)	Extensibility (mm)	Resistance to extension (BU)	The ratio of resistance to extension to extensibility
45	WF	85.1±1.8^{ab}	154.3±3.8^{a}	305.8+10.9^{a}	2.1±0.2^{a}
	150-180µm	80.5±0.8^{acd}	153.5±1.4^{b}	346.3±6.4^{abc}	2.2±0.02^{b}
	125-150µm	88±0.6^{ce}	149.5±2.7^{c}	308±5.8^{b}	2.3±0.01^{c}
	<125µm	96±0.8^{bde}	170±3.8^{abc}	298.5±4.6^{c}	1.7±0.00^{abc}
90	WF	80.5±1.1^{abc}	135.5±5.7^{ab}	309.2±8.9^{abc}	2.3±0.02^{abc}
	150-180µm	91±0.9^{ad}	145.5±5.2^{ac}	390.5±4.4^{ade}	2.7±0.01^{ade}
	125-150µm	94±2.07^{be}	143.5±2.15^{d}	357.5±5.6^{bd}	2.5±0.01^{bdf}
	<125µm	101.5±2.3^{cde}	169.8±0.8^{bcd}	348.5±6.9^{ce}	2±0.1^{cef}
135	WF	67.8±1.2^{abc}	134.5±1.7^{ab}	363.2±7.8^{a}	2.7±0.02^{ab}
	150-180µm	87±1.5^{ade}	134.5±1.8^{cd}	410.5±9.4^{abc}	2.91±0.01^{acd}
	125-150µm	93±1.6^{bdf}	142.5± 2.7^{ace}	360.5±4.2^{b}	2.7±0.02^{ce}
	<125µm	105.5±2.4^{cef}	157±2.3^{bde}	358.5±6.3^{c}	2.2±0.02^{bde}

Values are means ± standard deviation (n = 3). In each column, according to the similar resting time among flour samples with different particle sizes, common superscripts indicate significantly different (p<0.05).

the level at all resting times which can be explained by the high quality and high content of gluten, and also the ability to keep gas due to a strong gluten network. Overall, the biggest particle size exhibits the lowest energy value at a similar resting time. According to the findings, there was a significant difference between the dough energy of flours with different particle sizes (P<0.05).

Dough extensibility

The length that the dough can tolerate the stretch imposed by Extensograph prior to its rupture is reported by millimeters. This parameter exhibits the consistency of the dough and the quality of a final baked good [43]. According to the results, at all times of rest, total flours with deferent particle sizes had the lowest extension value compared to the flours with <125µm particle sizes (P<0.05), which can be due to qualitative strong gluten network formation and thus its resistance to stretch followed by quick rupture. These results were similar to the reported findings by *Sakhare et al* [9]. They have indicated that the flours with the finest fractions (<75µm) showed better dough extensibility compared to other coarser fractions with higher dough development time and dough stability.

Dough resistance to extension

Resistance to Extension of dough is demonstrated by the maximum height of the curve and measured in Brabender Units (BU) after 5 minutes from the start. It can characterize the force counteracting stretching [43]. The results of treatments showed that the highest resistance to extension was for the flours with particle sizes of 150-180µm at the resting times of 45, 90, and 135 min, and the lowest values were related to the particle size of <125µm. This result is justifiable due to the optimal extension of the particle size of <125µm at different resting times and the inverse relationship between extension and resistance to extension (Fig. 4). The results of resistance to extension at the resting time of 45, 90 and 135 minutes between the flour samples with different particle sizes showed a significant difference (P<0.05). Similar results were reported by Šebečič and Šebečič [44]. They have shown that smaller granules (6.5–19.5µm in diameter) significantly decrease resistance to extension (r = 0.756, P<0.005).

The ratio of resistance to the extension to extensibility (R/E)

R/E Ratio indicates the ratio of resistance to extension (R) to extensibility (E) of the gluten protein, which the dough can stretch before breaking [45]. R is mainly imparted to gluten by the elastic proteins glutenins, while E is conferred by viscous protein fractions of gluten i.e., gliadins [30]. The results showed that the highest ratio was for the flour with particle sizes of 150-180µm at all resting times and the lowest ratio was for the particle sizes of <125µm

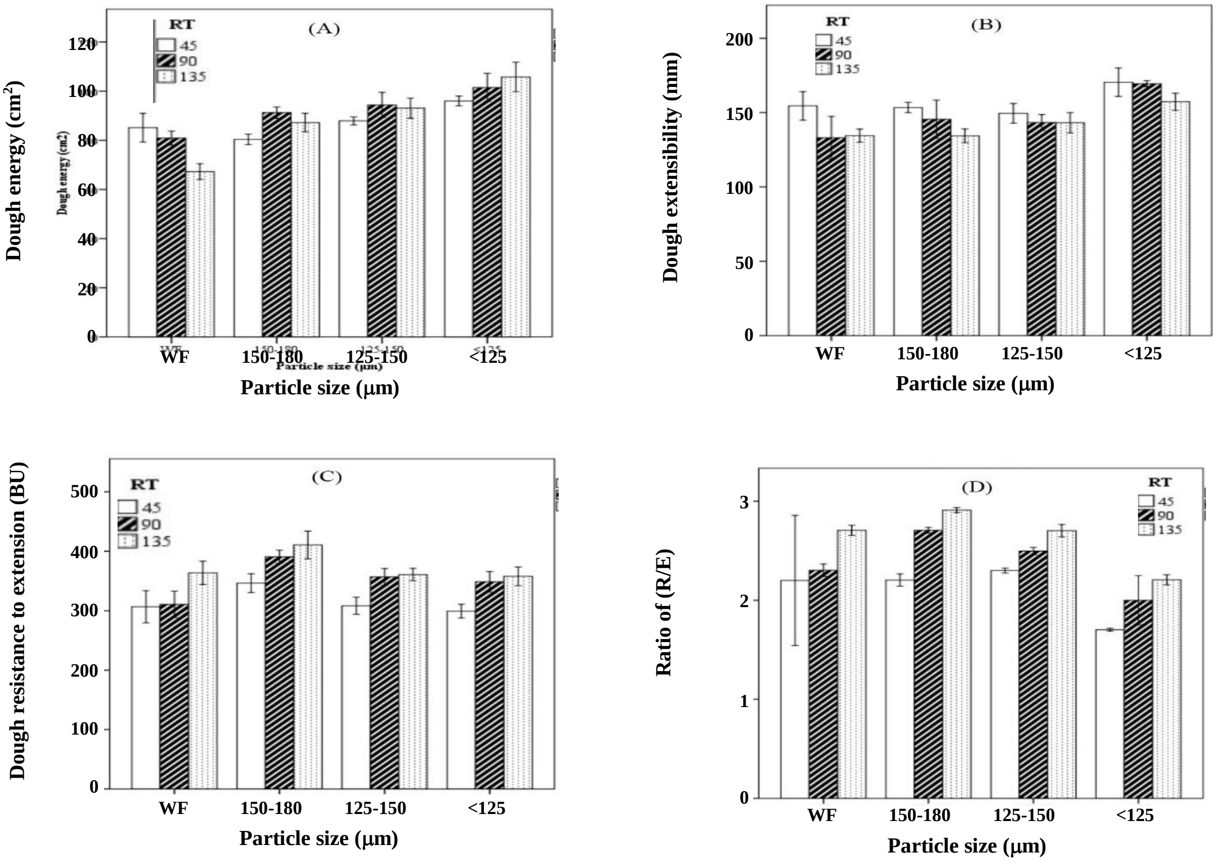

Fig. 4: The relation between flour particle size and dough energy in resting time (A), extensibility in resting time (B), resistance to extension in resting time (C), and the ratio of resistance to the extension to extensibility (R/E) in resting time (D).

. These results are an indictable reason due to the high extension of particle size <125µm and the least resistance to extension (Fig. 4). A comparison of the results of this ratio between flour samples with different particle sizes at different resting times showed a significant difference between flour samples with the particle sizes of 125-150µm at the resting time of 45 minutes (P<0.05).

CONCLUSIONS

The overall result of chemical and rheological tests showed that the particle size of <125µm had a suitable quality for baking flatbread (leading to an increase in the shelf life and reduced waste of bread), and an increase in particle size reduced some chemical and rheological properties. The particle size of <125µm had the largest extension due to the high quality and high gluten content and relatively strong gluten network, which prevents dough rupture, and increases the gas retention capacity in the resting stage. The presence of some bran plus flour in a larger particle size reduces some rheological properties such as dough extension and energy due to a decrease in gluten quality and weakness in the gluten network, which can be the cause of dough rupture; the dough stability is also noticeable against mixing. According to the results, the ash content could increase by raising the flour extraction rate. The quality and amount of gluten are reduced by increasing the size of the particles and approaching the outermost layers of the wheat grain. Moreover, the flour particle size increases with increasing flour extraction rate, which is due to the presence of fine particles of bran in the flours with a high extraction rate, resulting in a decrease in dough stability, increase in softening grade of dough, decrease in maximum resistance, also increase in water absorption caused by starch damage, accordingly high dough development time is observed. It should be noted that while the protein content increase by a high extraction rate, the decline of gluten stability and consistency is obtained, resulting in easy damage by mixing and other mechanical agents as well as debilitation of gas maintenance.

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