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Effect of Wheat Bran Particle Size on the Quality of Whole Wheat Based Instant Fried Noodles

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Abstract This research investigated the effects of wheat bran (WB) particle size on the dough and final productions of instant fried noodles. With the decrease of particle size (from 487.9 to 148.5μm), the pasting properties gradually increased and the solvent retention capacities (SRC) of the dry mix were improved and the values of elasticity modulus (G') and viscous modulus (G'') of the noodle dough increased significantly. The SEM micrographs of noodle dough showed the more uniform starch granule structure could be formed with smaller WB particle. Moreover, the reduction of particle size gave the fried noodles a slightly darker surface, harder texture and weaker adhesiveness. Most importantly, the oil content of fried noodles decreased from 26.50% to 19.77% with the decrease of particle size. All the results indicated that the decreasing WB particle size reduce the negative effects of WB on the properties of dough and the qualities of noodles.

Keywords: *Instant fried noodles, Wheat bran size, Quality, Oil content*

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1. Introduction

As one of the traditional staple foods in the world, Asian noodles originated from the Han dynasty of China more than two thousand years ago [1]. For the low cost, easy cooking and convenient storage, instant noodles developed quickly and were wildly enjoyed in the global market. Based on the dehydration process, instant noodles can be classified into instant fried noodles and instant non-fried noodles. Instant fried noodles were dehydrated through a deep frying process, which resulted in the distinctive flavor and texture, as well as high level oil content [2]. To fulfill consumers' demand for healthy diet, researchers focused on improving the quality of the instant fried noodles and reducing the oil content to lower the subsequent potential health risks [3,4].

Wheat bran (WB), a major source of dietary fiber, vitamins, and other bioactive materials as compared to refined white flour (RWF), is widely used in the food industry. Since long-term intake of a diet high in dietary fiber and bioactive substances provides beneficial effects on the reduction of cholesterol levels and the risk of type 2 diabetes, chronic diseases and other types of cancer, the importance of wheat bran and germ has increasingly been recognized in recent years [5]. Several studies have focused on the effect of WB and germ addition on the quality of cereal products, such as bread, biscuit, and noodles [6]. In our previous study, we found the whole wheat flour (WWF) incorporation lowered peroxide values of the instant fried noodles during storage, while it led to higher oil content [7]. Except for the higher nutrition values and rapid digestibility, WWF would lead to the rough mouth feel and coarse texture, which limited the application of WWF in wheat-based foods. WB had been reported to have significant negative effects on the quality of dough and final productions [8]. Earlier studies showed that WB affected both physical and bio-chemical qualities of dough and final products [9,10]. Big bran particles may have physical interference effect on the gluten matrix of dough. The study of Penella et al. had shown that coarse bran had a negative effect on the qualities of bread dough and final production due to its interruption in the formation of gluten network [11]. However, some studies suggested that reduction of mill feed particle sizes before reconstituting WWF could provide beneficial effect on the quality improvement of wheat based production [12].

Considering the natural content of WB in wheat (about 12%), RWF were replaced by 12% of WB with different particle size to investigate the effects of WB particle size on the qualities of instant fried noodles. Before conducting this research, we determined the sensory evaluation of fried noodles containing 12% of different particle size WB. Preliminary descriptive sensory evaluation confirmed that suitable concentration (12%) of WB did not affect cooked noodle acceptability in terms of texture for consumers.

These results suggested that WB could be added into noodle fry mix as a useful and functional ingredient. In this research, the physicochemical properties and oil content were measured for studying the effects of different WB particle size on the fried noodles.

2. Materials and Methods

2.1. Materials and Chemicals

RWF and wheat bran (WB) were purchased from China Oil and Foodstuffs (Beijing, China). Palm oil was purchased from Eastocean Oils and Grains (Zhangjiagang, Jiangsu, China). Alkaline salt including potassium carbonate and sodium carbonate was purchased from Zhongxing Food Co., Ltd. (Guangzhou, Guangdong, China). Salt was purchased from the local supermarket.

2.2. Measurement of Wheat Bran Particle Size

WB was ground by the laboratory grinder (Weililiang Food Machinery Co., LTD, mode HB-08B, China) until passed through different meshes (40, 60, 80, 100 meshes). The distribution of WB particle size was measured by the Laser particle size analyzer (Microtrac, mode S3500, USA), and the values of mean particle size (MZ) passing through 40, 60, 80, 100 meshes were 487.9μm, 336.1μm, 260.8μm and 148.5μm, respectively (Figure 1).

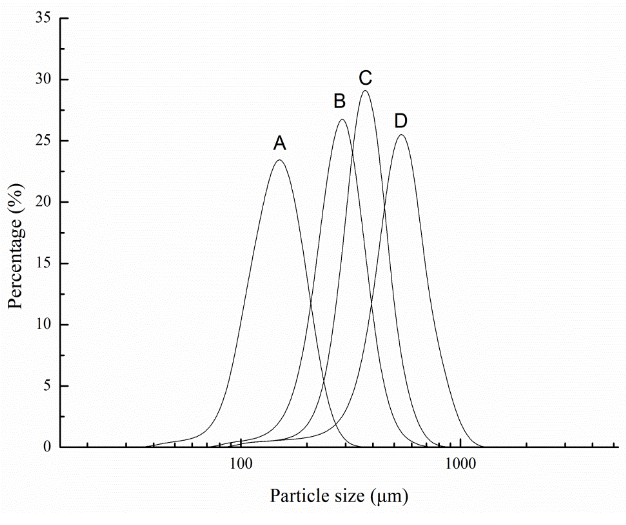

Figure 1. The particle size distribution curves of wheat bran and wheat flour (A: wheat bran passing through100 meshes; B: wheat bran passing through 80 meshes; C: wheat bran passing through 60 meshes; D: wheat bran passing through 40 meshes.)

2.3. Preparation of Instant Fried Noodles

Instant fried noodles were made according to the procedure described by Wang et al. with slightly modification [13]. Briefly, salt (1.5%) and alkaline salt (0.2%, potassium and sodium carbonate, 1:1) were dissolved in distilled water (35%), which was then mixed with flour (300 g) in a mixer (Kenwood, model KM510, UK) at a low speed (at speed minimum) for 2 min, followed by scraping down and an additional 4 min mixing process at a high speed (at speed 1). The prepared dough was placed in a plastic bag and rested for 30 min, after which the dough was sheeted through six pairs of rollers on a noodle machine (Marcato Atlasmotor, Wellness 150, Italy). Then, the noodle sheet was slit into 1.5 mm × 1.5 mm (thickness × width) strands with a slitter and steamed for 4 min at 100 ºC. The steamed noodle strands were fried at 160 ºC in a fryer (Yuda Household Electrical Appliances Co. Ltd., Guangdong, China) for 75 s. The fried noodle strands were drained the excess oil and cooled for subsequent analysis.

2.4. Measurement of Pasting Properties of Noodle Dry Mix

The pasting properties of the flour samples were determined by a Rapid Visco Analyser (RVA, Model Super-3, Newport Scientific, Australia) using the AACC Method [14].

2.5. Measurement of Solvent Retention Capacity of Noodle Dry Mix

Solvent retention capacity (SRC) tests including lactic acid SRC (LA-SRC), sodium carbonate SRC (SC-SRC), and sucrose SRC (Suc-SRC) of the flour blends were measured according to the AACC method [14]. Three measurements were performed for each sample.

2.6. Measurement of Dynamic Viscoelastic Properties of Noodle Dough

The dynamic viscoelastic properties of noodle dough were measured by a controlled-stress rheometer (TA Instruments, mode AR-G2, USA) using a 20-mm parallel plate as previous report [15]. Test settings: Frequency range: from 0.1 to 10 Hz; Temperature: 25°C; Gap: 2 mm; Strain: 0.1%.

2.7. Analysis of Scanning Electron Micrographs of Noodle Dough

The structure morphology of noodle dough was investigated according to Heo et al. [16], by a scanning electron microscope (SEM) (TM-3030, Hitachi, Tokyo, Japan) at 5 kv. The micrographs were taken using 800 × magnification.

2.8. Measurement of Fried Noodle Color

According to Choy et al. [17], approximate 15 g of fried noodle was ground with a mortar and pestle and packed into a small sealing plastic bag that was transparent to measure the color of samples by a Chroma Meter (Konica Minolta, Osaka, Japan). Three measurements were performed for each sample.

2.9. Measurement of Texture Properties of Cooked Noodle

According to the methods described by Wang et al. [18], the textural profile analysis (TPA) of cooked noodles was investigated by a TA-XT2i Texture Analyser (Stable Micro-Systems, London, England). TPA settings: Probe:

HDP/PFS; Load cell: 5 kg; Mode: TPA; Trigger type: Auto-10 g; Pre-test speed: 4 mm/s; Test speed: 1 mm/s; Post-test speed: 1 mm/s; Strain: 70%. Each sample was performed 10 replicates and the values of hardness, adhesiveness, gumminess and resilience were recorded.

2.10. Measurement of Oil Content and Moisture Content of Fried Noodle

The oil content of instant fried noodles was estimated using the Soxhlet extraction method [19] and the moisture content was measured by the AACC method [14]. Three measurements were performed for each sample.

2.11. Statistical Analysis

Results were expressed as mean ± standard deviation (SD). Data were analyzed by one-way analysis of variance (ANOVA) with Student–Newman–Keuls post hoc test. Statistical significance was set at 5%.

3. Results and Discussion

3.1. Effect of WB Particle Size on Pasting Properties of the Dry Mix

The values for the pasting properties of the wheat flour with different particle size of WB are shown in Table 1. The all values of control group (100% RWF) were significantly different to those of the group with WB, which indicated that the WB had a significant effect on the pasting properties of dry mix ($p<0.05$). Although the values of peak viscosity and final viscosity, and setback gradually increased as the reduction of the particle size of WB from 487.9 to 148.5μm in the dry mix, the values of these indexes didn't show a significant difference ($p>0.05$). It was reported that peak viscosity was one of the main quality parameters of cooked dry Chinese noodles, which was positively related with stickiness, appearance, smoothness, and total score [20]. In addition, the decrease of final viscosity and setback values with the adding of WB was a delaying indicative of the retrogradation tendency of amylose, which might be beneficial for the noodle qualities [21]. However, the decreasing of values on pasting properties as compared to control indicated that the available starch for gelatinization was reduced and the forces maintaining the network of the granules were weakened, which was due to the WB particles that obstructing the weak linkages in the starch granule and withholding water from the starch granules [22].

3.2. Effect of Wheat Bran Particle Size on the Dynamic Viscoelastic Properties of Noodle Dough

The effect of WB particle size on the dynamic viscoelastic properties of noodle dough was shown in Figure 2. The values of elasticity modulus (G′) and viscous modulus (G″) that generally refer to the gluten strength and processing property of the dough were provided [16]. In Figure 2, both G′ and G″ values increased with increasing frequency for all samples, and the G′ values were higher than G″ values at all the frequency, implying that elastic properties were dominant in noodle dough [15]. The two values decreased when WB were added into the noodle formulation, indicating that WB had a negative influence on the gluten network forming. It has been reported that the addition of WB or oat bran interrupted the gluten matrix, and then weakened the overall structure of noodle dough [23]. However, both G′ and G″ values increased with the MZ of WB decreased from 487.9 to 148.5μm, which meant that the decrease of WB particle size weakened the interruption caused by the WB.

Table 1. Effect of wheat bran particle size on pasting properties of the dry mix

Wheat bran mean particle size (μm)	Peak viscosity (mPa•s)	Trough (mPa•s)	Breakdown (mPa•s)	Final viscosity (mPa•s)	Setback (mPa•s)
487.9	1635.00±35.36^{b}	973.33±11.31^{c}	662.00±6.67^{NS}	2105.00±32.23^{b}	1112.00±35.54^{b}
336.1	1654.33±17.48^{b}	992.67±8.49^{c}	622.67±25.96	2114.33±13.54^{b}	1126.00±12.02^{b}
260.8	1699.67±40.10^{b}	1082.33±14.95^{b}	615.00±9.75	2220.67±47.88^{b}	1142.00±32.53^{b}
148.5	1709.00±27.07^{b}	1094.00±35.36^{b}	626.33±12.12	2263.33±17.78^{b}	1181.00±22.83^{ab}
Control group	2417.33±13.34^{a}	1783.00±30.20^{a}	633.33±13.13	3010.00±24.75^{a}	1316.50±44.55^{a}

Data are expressed as mean ± SD (n = 10). Values in the same column with different superscript letters are significantly different ($p<0.05$). NS means not significant.The letter 'a' denotes the highest value.

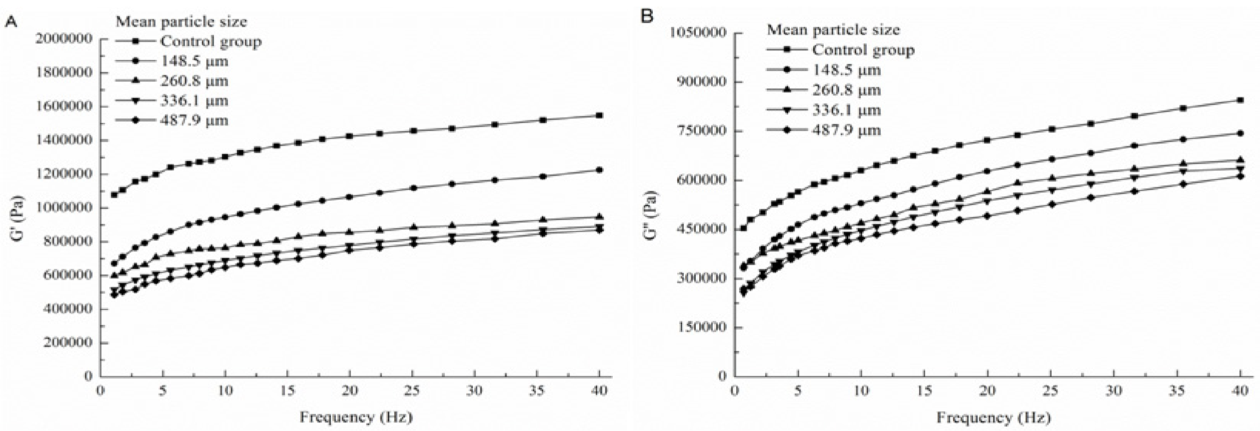

Figure 2. Effect of wheat bran particle size on the dynamic viscoelastic properties of noodle dough (A: Elasticity modulus (G′); B: Viscous modulus (G″))

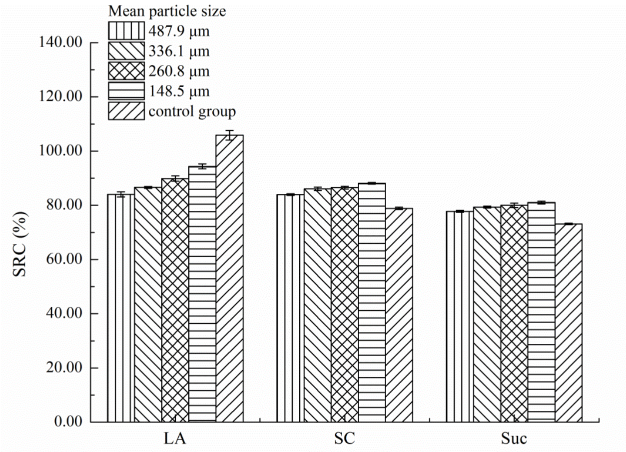

Figure 3. Effect of wheat bran particle size on the solvent retention capacity of dry mix (n=3). LA: lactic acid, SC: sodium carbonate, Suc: sucrose

3.3. Effect of Wheat Bran Particle Size on Solvent Retention Capacity

Previous studies reported that the lactic acid SRC (LA-SRC) value, sodium carbonate SRC (SC-SRC) value and sucrose SRC (Suc-SRC) value were related the solvent compatibility of gluten, damaged starch and pentosans, respectively [24]. Effect of WB particle size on the SRC values was shown in Figure 3. Groups added with WB had higher SC-SRC values and Suc-SRC values compared with the control group (RWF), which may be caused by the higher amount of damaged starch and pentosans in the WB [25]. The lower LA-SRC values of groups added with WB indicated that WB had negative effect on the swelling behavior of gluten, which was consistent with the study of Li et al. [26]. On the other hand, with the particle size of WB decreased, the values of SC-SRC, Suc-SRC and LA-SRC had an increasing trend. It has been reported that the reduction of the WB particle size would lead to an increase of damaged starch and pentosans release, which may be beneficial for strengthening swelling behavior of gluten [27]. Meanwhile, the increase of water absorbility caused by the decrease of WB particle size might also be helpful for the swelling behavior of gluten [28].

3.4. Effect of wheat bran particle size on the microstructure of noodle dough

The cross-section microstructures of WB and control noodle dough are shown in Figure 4. Control noodle dough showed uniform smoother starch granules and a more compact structure than WB groups, which was mainly due to less WB in RWF, and less likelihood to disturb the formation of protein network in the noodle structure [29]. There was less continuous gluten network and more severely damaged starch observed in the graph of group 487.9 and 336.1μm compared to that of group 260.8 and 148.5μm. However, the fragments of bran and starch granules that were not covered by the gluten network could easily be identified in the microscopic graph of group 148.5μm. The open and porous structure may be attributed to the introduction of wheat bran, which obstructed the interaction between the starch granules and protein bodies. The results demonstrated that the smaller WB particle could improve the structure characteristics of noodle dough by adding WB.

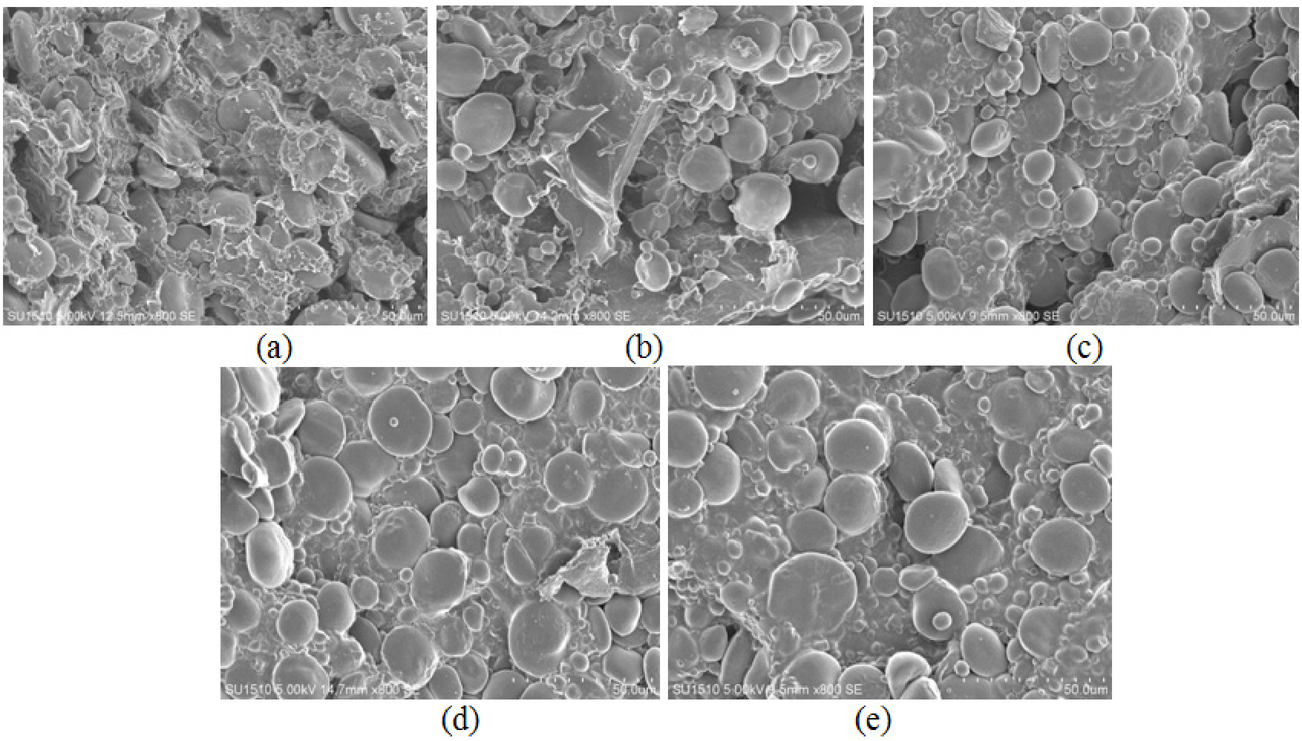

Figure 4. Effect of wheat bran particle size on the microstructure of noodle dough, (a) 487.9μm, (b) 336.1μm, (c) 260.8μm, (d) 148.5μm, (e) control group

3.5. Effect of Wheat Bran Particle Size on the Color of Instant Fried Noodles

As one of the most important evaluation indicators of the instant fried noodles, color directly affects the first impression of consumers and their judgment for the instant noodles quality [2]. The color measurement results of instant fried noodles were shown in Table 2. It was shown that the L* values decreased significantly with the addition of WB, while the a* values had a reversed tendency. This phenomenon was consistent with the study of Chen et al [6], who reported that coarse bran gave wet and dry dough sheet a darker and redder color than the control group due to the pigment in the bran.

Moreover, L* values decreased slightly from 60.18 to 59.52 when the WB MZ decreased from 487.9 to 148.5μm, while the ΔE values increased from 20.63 to 21.60 (Table 2). Both a* and b* values were slightly changed, which indicated that the WB particle size didn't have significant effect on the redness and yellowness of instant fried noodles. Niu et al. had found that coarse WWF had higher L* values than the fine-grinding WWF, and they believed that the reduction of the particle size leading to a darker color of the WWF, which might be one of the reasons for the darker appearance of noodles with smaller particle size [21]. On the other hand, the oxidation reactions and Maillard reaction that related to compounds providing color and flavor might also be responsible for decrease of the L* values of instant fried noodles with smaller particle size [30]. Early studies showed that color of Chinese alkaline noodles was affected by compounds in the nature flour that were related to the oxidation reactions such as polyphenol oxidases [18]. It has been reported that the reduction of WB particle size led to an increase of polyphenol oxidases release, which would cause a stronger enzymatic-oxidative browning during the noodle making process and give the noodles darker appearance [28].

3.6. Effect of Wheat Bran Particle Size on the Texture of Instant Fried Noodles

The effect of WB particle size on the textural characteristics of instant fried noodles was shown in Table 3. It was clear that the values of hardness and adhesiveness decreased when WB was added into the formula of instant fried noodles. Hardness values were related to the softness of instant fried noodles [31]. The decrease of the hardness and adhesiveness values indicated that instant fried noodles added with WB had a softer texture and smoother surface than the control sample after rehydration. On the other hand, when the MZ decreased from 487.9 to 148.5μm, the values of hardness and adhesiveness were both on a rise while the values of gumminess and resilience were barely waved. Chen et al. [32] found the analogous result that the smaller particle size of WB gave a softer texture to the cooked dry white Chinese noodles.

3.7. Effect of Wheat Bran Particle Size on the Oil Content and Moisture Contents of Instant Fried Noodles

The effects of WB particle size on the oil content and moisture contents of instant fried noodles were shown in Figure 5. As the MZ decreased from 487.9 to 148.5μm, there was no significant difference for the moisture content among all the groups, while the oil content of instant fried noodles decreased from 26.5 to 19.8%, which close to the similar level of control. It had been reported that oil content of instant fried noodles was highly related to the inner structure of noodles [33].

Protein and starch were two essential components for the formation of the gluten matrix of the dough. During the frying process, the water in the matrix evaporated rapidly along with the oil permeation, forming a porous structure of the instant fried noodles [34]. When the WB was added into the flour, the fiber of the bran would interrupt the gluten matrix formation, leading to a less compact texture of the noodle dough [35]. As products being fried, the exists of WB particles might cause big pores and less continued structure of instant fried noodles, which was likely to hold more oil [36]. The reduction of WB particle size weakened the disruption of the bran and therefore reduced the oil content increase caused by big bran particle. Bae et al. observed similar phenomenon that instant fried noodles made with WWF passing 100 meshes contained less oil content than the control group, they attributed the decrease of oil content to the compact inner structure of the instant fried noodles [37].

Table 2. Effect of wheat bran particle size on the color of instant fried noodles

Wheat bran mean particle size (μm)	L*	a*	b*	ΔE
487.9	60.18±0.13^{b}	6.99±0.02^{a}	21.33±0.53^{a}	20.63±0.14^{c}
336.1	59.86±0.07^{c}	7.00±0.05^{a}	21.52±0.31^{a}	20.94±0.08^{bc}
260.8	59.68±0.20^{cd}	6.92±0.10^{a}	21.50±0.27^{a}	21.18±0.27^{b}
148.5	59.52±0.11^{d}	6.96±0.23^{a}	20.99±0.72^{ab}	21.60±0.27^{a}
Control group	79.78±0.21^{a}	0.64±0.07^{b}	20.42±0.12^{b}	0.00±0.00^{f}

Data are expressed as mean ± SD (n = 3). Values in the same column with different superscript letters are significantly different ($p<0.05$). The letter 'a' denotes the highest value. L*: lightness-darkness; a*: redness-greenness; b*: yellowness-blueness. ΔE: total color difference.

Table 3. Effect of wheat bran particle size on the texture of instant fried noodles

Wheat bran mean particle size (μm)	Hardness (g)	Adhesiveness (g)	Gumminess (g)	Resilience (g)
487.9	4917.41±77.58^{d}	-43.02±3.33^{e}	3624.95±30.78^{NS}	0.36±0.01^{NS}
336.1	5065.26±12.52^{c}	-47.47±1.13^{d}	3649.14±37.29	0.36±0.01
260.8	5095.62±17.78^{c}	-52.00±1.00^{c}	3661.80±45.88	0.36±0.01
148.5	5187.27±41.40^{b}	-56.82±0.82^{b}	3674.03±32.39	0.37±0.01
Control group	5701.36±52.44^{a}	-75.09±4.10^{a}	3660.86±27.88	0.37±0.01

Data are expressed as mean ± SD (n = 10). Values in the same column with different superscript letters are significantly different ($p<0.05$). NS means not significant.The letter 'a' denotes the highest value.

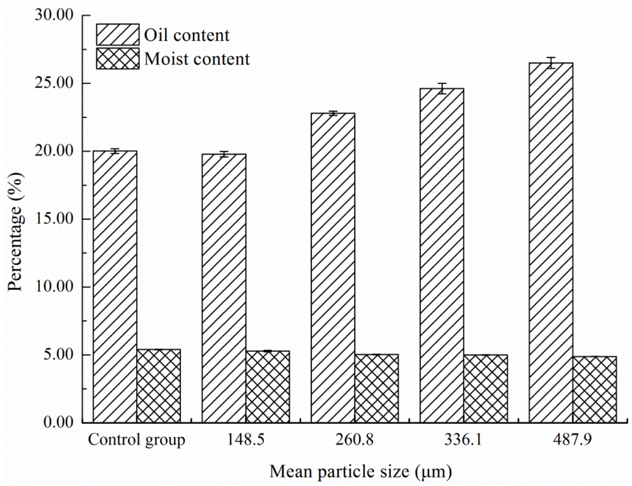

Figure 5. Effect of wheat bran particle size on moisture and total oil content of instant fried noodles (n=3)

4. Conclusion

In summary, with the decrease of the MZ, the values of peak viscosity, final viscosity and setback gradually increased, and the values of G' and G'' were both on a rise as well as the solvent retention capacity (SRC). The SEM micrographs of noodle dough showed the more uniform starch granule structure could be formed with smaller WB particle. The decrease of bran MZ also led to a slightly darker surface color of the instant fried noodles. The values of hardness and adhesiveness of the instant fried noodles were both on a rise, while the oil content decreased from 26.50 to 19.77% as the MZ decreased from 487.9 to 148.5μm. The results indicated that the decreasing WB particle size reduce the negative effects of WB on the properties of dough and the qualities of noodles.

Acknowledgments

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Conflicts of Interest

The authors state that they have no conflicts of interest.

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