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Functional and Physicochemical Properties of Milled and Microfluidized Bulgur and Chickpea Brans

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ABSTRACT
Dietary fiber plays a crucial role in human diet due to their health-promoting effects. Cereal brans are widely used for fiber enrichment of bakery products; however, their high phytic acid content, mostly localized in the aleurone layer, lowers the nutritional value of the end-product. Therefore, the functional and physicochemical properties of two aleurone-free brans, bulgur and chickpea brans, were investigated as alternative fiber sources. Furthermore, effect of particle size reduction by means of milling and the microfluidization process on these properties were determined. The microfluidization reduced the particle sizes of bulgur and chickpea brans to 13.12 and 14.25 µm, respectively. The results indicated that the microfluidization significantly increased the soluble dietary fiber content of brans. Thus, the insoluble/ soluble dietary fiber ratios of bulgur and chickpea brans decreased to 8.42 and 6.13 from 19.20 and 15.33, respectively. The phytic acid contents ranged from 230.8 to 247.9 mg/100g for bulgur bran, and 112.1 to 113.1 mg/100g for chickpea bran. After the microfluidization, these contents decreased to 107.1 and 47.9 mg/100g for bulgur and chickpea brans, respectively. The milled samples did not show any differences in terms of phenolic contents and antioxidant activity, but the microfluidization increased the phenolic content of bulgur and chickpea brans as 73.80% and 59.62%, respectively. In addition, the antioxidant activity values increased 73.08% for bulgur bran, and 76.70% for chickpea bran with this process. Chickpea bran had higher swelling and water holding capacity than that of bulgur bran, but the oil holding capacities of both types of brans were close to each other. Conventional milling had no significant effect on these properties, whereas the microfluidization improved them. Therefore, it can be said that the applied microfluidization process enhanced physicochemical properties along with their functional properties, and it is possible to degrade phytic acid with microfluidization process.

Keywords: Bulgur bran, Leblebi, Antioxidant activity, Dietary fiber, Phytic acid

1. Introduction

Over the last decades, numerous studies have reported that consumption of an adequate amount of dietary fiber can help regulate blood glucose level, lower blood cholesterol, and reduce the risk of chronic diseases such as coronary heart disease, obesity, and colon cancer. Due to these striking health-promoting effects, once considered to be just a by-product of milling industry, cereal brans, now are regarded as significant food additives owing to their high dietary fiber content. These health benefits have also been attributed to their high phytochemical contents such as phenolic compounds that exhibit antioxidant activity including gallic, vanillic and ferulic acids (Adom & Liu 2002). However, these cereal brans are far from being ideal fiber sources. They all contain high levels of phytic acid, an antinutrient which has a strong affinity to form insoluble complexes with amino acids, and mineral cations including iron, magnesium, zinc, and calcium, thereby impairing the bioavailability of these micronutrients. Phytic acid is mostly localized in the aleurone layer of cereal grains, thus remain in the bran after the milling process (Stevenson et al. 2012). Therefore, these brans reduce the nutritional value significantly when they are incorporated into food products. In order to overcome these drawbacks regarding the use of cereal brans as functional ingredients, it is essential to find new alternative fiber sources without any limitations caused by the aleurone layer.

This paper presents two aleurone-free fiber sources; bulgur and chickpea brans. Bulgur is a traditional whole grain semi ready-to-eat product, preferably produced from durum wheat by cleaning, cooking in water, followed by drying, partially dehulling and grounding. Bulgur bran is the part disposed during partial dehulling stage in bulgur process. Roasted chickpea or simply leblebi, is a traditional snack, has been widely consumed in Turkey and the Middle East Region. The leblebi process includes cleaning and grading of chickpea, soaking, tempering, boiling, resting, roasting, and dehulling (Deshpande & Damodaran 1990). During this dehulling stage, chickpea bran is removed and disposed as the same manner as bulgur bran. These undervalued by-products may have great potential use as a functional ingredient since they do not contain the aleurone layer and consequently, should have considerably low phytic acid content compared to other cereal brans.

Particle size distribution of bran also plays a vital role regarding end-products properties. Novel micronization techniques such as microfluidization alters the properties of bran, enhance some micronutrients and impair others. Brewer et al. (2014) showed that the phenolic acid content of whole wheat bran increased as the particle size decreased, while Rosa et al. (2013) reported that the increase in antioxidant capacity of wheat bran is well correlated with the decrease of the particle size. Ultrafine grinding slightly decreased phytic acid content of wheat bran from 7060 mg/100g to 6750 mg/100g (Hemery et al. 2011). Several studies showed that microfluidization improves antioxidant activity by loosening the microstructure of fiber-matrix (Chen et al. 2013; Wang et al. 2013; Wang et al. 2014) and alters the ratio between insoluble and soluble fiber by increasing the soluble fiber content (Chen et al. 2013). Furthermore, the microfluidization process can enhance the hydration properties of fiber as well as their oil holding capacity (Wang et al. 2012; Wang et al. 2013). These physicochemical properties are of importance due to their ability to modify viscosity, texture and health-promoting effects of the end-products.

Hence, the main objectives of this study are as follows: (a) to investigate the functional and physicochemical properties of two possible fiber sources with low phytic acid content, bulgur bran and chickpea bran and to reveal their potentials, (b) to determine if the particle size distribution obtained by conventional milling and microfluidization process affects these properties. To best to our knowledge, there has been no study regarding the functional and physicochemical properties of bulgur and chickpea brans. Moreover, the effects of milling and microfluidization on these properties are expected to be different considering the composition of these brans is quite different from wheat and cereal brans since they do not contain aleurone layer which is rich in some micronutrients including vitamins, minerals, and enzymes.

2. Material and Methods

2.1. Materials

Bulgur bran (11.3% moisture, 11.58% protein, 2.12% ash) and chickpea bran (9.80 % moisture, 6.55% protein, 4.78% ash) were purchased from local suppliers. Bran samples were ground by a laboratory mill (Laboratory Mill 120, Perten, Germany), and subsequently separated into 3 different particle sizes (100 µm; 200 µm; 350 µm) using a Retsch AS 200 tap sieve shaker (Retsch GmbH, Haan, Germany) and stored at 4 °C until used. All reagents were analytical grade and were purchased from Merck (Dermasdat, Germany).

2.2. Microfluidization of bran

Microfluidization process was performed with a Microfluidizer M-110P (Microfluidics, Newton, MA, USA). Bulgur and chickpea brans with a particle size of 100 µm were chosen for the microfluidization process to prevent the obstruction of the interaction chambers. Brans with a particle size of 100 µm were prepared as mentioned above, dispersed in distilled water in a ratio of 1:20 (w/w) separately. The bran suspensions subsequently processed through the Microfluidizer with a Z type interaction chamber with a diameter of 100 µm (IC 100) for five passes at 30000 psi as pre-trials showed the further passes did not decrease the particle size of the brans. The interaction chamber was cooled down with icy water to keep the temperature of processed material at about 30 °C. Microfluidized bran suspensions were collected after designated passes and were freeze-dried to the moisture content of a maximum of 4%. The dried samples were stored at 4 °C until used.

2.3. Particle size distribution

The particle size distribution of microfluidized samples was measured by laser scattering method using Microtrac Bluewave particle size analyzer (Microtrac, Montgomeryville, PA, USA) (Wang et al. 2012). D90, D50, and D10 were the selected D-values which respectively represent the diameter of the particle that 90%, 50% and 10% of the sample's volume is smaller than the indicated diameter. All measurements were conducted in triplicate.

2.4. Chemical analysis

The moisture, protein and ash contents of bran fractions were determined by AACCI approved method 44-01.01, 08-01.01and 46-12.01, respectively (AACCI 2010). Phytic acid and phytate phosphorus contents were measured according to the colorimetric method described by Haug & Lantzsch (1983). The insoluble (IDF), soluble (SDF) and total dietary fiber (TDF) contents were determined by AOAC method 991.43 (AOAC 2012). The extraction of phenolic compounds of samples was performed according to Adom and Liu (2002) with slight modifications as described in our previous report (Özkaya et al. 2017a). After the extraction, phenolic content was determined by the Folin-Ciocalteu spectrophotometric method whereas antioxidant activity was measured using 2.2-di-phenyl-2-picryl-hydrazyl (DPPH) according to Yu et al. (2002).

2.5. Physicochemical analysis

The physicochemical properties of brans including swelling capacity (SC), water holding capacity (WHC) as well as oil holding (OHC) capacity was measured according to Wang et al. (2012). SC is defined as the settled bed volume occupied by a sample immersed in excess water. Accurately weighted dry samples (0.5+0.001 g) immersed in water (20 mL) and left

undisturbed overnight in a volumetric cylinder for complete hydration. The volume attained by bran was recorded and the swelling capacity was expressed in mL/ g dry sample.

WHC and OHC is the quantity of water and oil retained by a known amount of sample under the conditions used. WHC and OHC are measured by mixing the accurately weighted dry samples (0.5+0.001 g) with 20 mL water for 24 h and with 20 mL vegetable oil 30 min, respectively. After the centrifugation at 2000 g for 10 min, the supernatant was carefully removed. The WHC and OHC were expressed as g water/ g dry sample and g oil/ g dry sample, respectively.

2.6. Statistical analysis

All analyses were conducted in triplicate and data presented as the mean of measurements. The data were analyzed with SPSS software (V.22.0 for Windows, SPSS Inc., Chicago, IL) using one-way analysis of variance (ANOVA), followed by Duncan's post-hoc test to verify any significant differences among means. Significance of differences was defined as $P<0.05$.

3. Results and Discussion

3.1. The particle size distribution of microfluidized bulgur and chickpea brans

Table 1 shows the particle size distribution of 100 µm bran samples before and after the microfluidization treatment. After the microfluidization, the particle size of bulgur and chickpea bran decreased to 13 µm and 14 µm from 94 µm, respectively. It shows that the microfluidization process dramatically reduced D50 values (<2 µm) and narrowed the particle size distribution of brans.

Table 1- The particle size distribution of 100 µm and microfluidized bulgur and chickpea brans

Bran samples	*Particle size (µm)*	*Particle size distribution (µm)*		
		D90	D50	D10
Bulgur bran	100	93.45±2.15	5.40±0.08	2.81±0.05
	MF(<15)	13.12±0.13	1.89±0.04	0.97±0.03
Chickpea bran	100	94.36±2.83	6.22±0.07	3.12±0.04
	MF(<15)	14.25±0.08	1.92±0.03	0.98±0.01

MF: Microfluidized; D90: 90% of the volume that is smaller than the size indicated; D50: 50% of the volume that is smaller than the size indicated; D10: 10% of the volume that is smaller than the size indicated; Values are means ± standard deviations

3.2. The dietary fiber content of bulgur and chickpea brans

An adequate amount of dietary fiber intake provides many health benefits, however soluble and insoluble fibers play different roles in human health and soluble fiber provides more essential health benefits than insoluble ones in many aspects (Galisteo et al. 2008). Cereal brans typically have low soluble fiber (2-4%) and high insoluble fiber (25-48%) content and it is possible to redistribute these fiber fractions using novel milling techniques and microfluidization process. Table 2 indicates that both bulgur and chickpea brans are rich in dietary fiber, mainly in IDF similar to the other cereal brans. The IDF, SDF, and TDF contents of 350 µm bulgur bran were 65.22%, 3.39% and 68.61%, respectively. Saka et al. (2020) also reported that TDF contents of 200 µm, 400 µm and 850 µm bulgur bran quite high as 72.67%, 77.00% and 83.04%, respectively. Bulgur bran has considerably high TDF compared to wheat bran (36.5%-54.2% TDF) probably due to being aleurone-free. Aleurone is the very outside layer of endosperm, which contains low dietary fiber content compared to the other bran layers (Esposito et al. 2005).

IDF, SDF, and TDF contents of 350 µm chickpea bran were 64.34%, 4.97% and 69.32%, respectively. For the sake of comparison values of the dietary fiber content of chickpea bran are not available in the literature. However, some studies reported that the total fiber contents of whole grain were found between 16.1% and 21.6% (Rincón et al. 1998). It would be reasonable to assume that dietary fiber is also mainly localized outer layer of the grain; therefore, chickpea bran has higher fiber content than the whole grain.

Fiber contents of bulgur and chickpea brans decreased with decreasing particle size from 350 µm to 100 µm; however; these decreases were found to be significant for only SDF content of chickpea bran ($P<0.05$). It is probable that the part which has lower fiber content was more easily broken down to smaller particles. Saka et al. (2020) reported similar results that TDF content of 850 µm bulgur bran decreased to 72.67% from 83.04% when it was milled to 200 µm.

Table 2- Insoluble, soluble, and total dietary fiber contents of bulgur and chickpea brans with different particle sizes

Bran samples	*Particle size (μm)*	*IDF* (%)*	*SDF* (%)*	*TDF* (%)*	*IDF/SDF*
Bulgur bran	350	65.22± 2.40[a]	3.39±0.16 [a]	68.61±2.56 [a]	19.24
	200	63.42±1.56 [a]	3.29±0.24 [a]	66.71±1.80 [a]	19.28
	100	61.43± 1.27[a]	3.20±0.17 [a]	64.63±1.10 [a]	19.20
	<15**	60.94±1.98[a]	7.24± 0.21[b]	68.18± 2.19 [a]	8.42
Chickpea bran	350	64.35±2.55 [a]	4.97±0.13 [b]	69.32± 2.42 [a]	12.95
	200	62.73±2.12 [a]	4.45±0.23 [ab]	67.18±2.35 [a]	14.10
	100	62.38±1.13 [a]	4.07± 0.18[a]	66.45± 0.95[a]	15.33
	<15**	60.29± 1.84[a]	9.83± 0.28 [c]	70.12±1.56 [a]	6.13

IDF: Insoluble dietary fiber; SDF: Soluble dietary fiber; TDF: Total dietary fiber; * On a dry basis; ** Microfluidized; Values are means ± standard deviations; The lower-case letters 'a-c' in the same column indicate differences between the averages of the same bran samples with the different particle sizes are statistically significant (P<0.05)

Microfluidization process significantly increased SDF contents of bulgur and chickpea brans up to 7.24% and 9.83%, respectively while decreased IDF mildly and consequently increased TDF. However, these changes in IDF and TDF contents were not found to be statistically significant (P<0.05). It is reasonable to assume that this process changed the soluble and insoluble fiber ratio by causing a redistribution of fiber fractions. This result is parallel to the finding of Zhu et al. (2010) who stated that ultrafine grinding decreased insoluble fiber of wheat bran while it increased SDF content significantly. Chau et al. (2007) also reported a similar trend of IDF/ SDF ratio change for carrot dietary fiber with high-pressure micro-size grinding at 11600 psi. This ratio change is probably due to degrading of hemicellulose, cellulose and lignin to smaller particles (Zhu et al. 2010).

3.3. The phytic acid content of bulgur and chickpea brans

The high amount of phytic acid content of cereal bran is regarded as one of the attributes limiting their use as a fiber source for enrichment of the food products. Therefore, the aim was to investigate novel fiber sources with low phytic acid content as an alternative for cereal brans. Table 3 shows that milled bulgur brans have extremely low phytic acid content ranged from 230.8 to 247.9 mg/100g considering phytic acid content of wheat bran changing between 2500 to 6000 mg/100g (Özkaya et al. 2017a). The findings are similar to those of Saka et al. (2020) who reported phytic acid content of 200 μm, 450 μm and 800 μm bulgur brans are 228.6 mg/100g, 215.4 mg/100g and 215.7 mg/100g, respectively. The phytic acid contents of bulgur brans are considerably low probably due to removing phytic acid-rich aleurone layer from bran during bulgur process. In addition, phytic acid may be degraded during the bulgur process due to the exposure to the high temperature in the cooking stage. Although phytic acid is heat-stable, it may be easily degraded while heating in aqueous media (Cheryan & Rackis 1980).

Table 3- Phytic acid, phytate phosphorus and total phosphorus contents of bulgur and chickpea brans with different particle sizes

Bran samples	*Particle size (μm)*	*Phytic acid* (mg/100g)*	*Phytate phosphorus* (mg/100g)*	*Total phosphorus* (mg/100g)*
Bulgur bran	350	230.8±5.5 [b]	65.1±1.6 [b]	119.0±1.0 [a]
	200	231.6±7.0 [b]	65.3±2.0 [b]	118.9±1.8 [a]
	100	247.9±8.1 [b]	69.9±2.3 [b]	121.2±1.7 [a]
	<15**	107.1±4.0 [a]	30.2±1.1 [a]	122.6±1.1 [a]
Chickpea bran	350	112.1±4.0 [b]	31.6±1.1 [b]	242.6±2.0 [a]
	200	112.6±5.5 [b]	31.8±1.6 [b]	243.4± 2.1[a]
	100	113.1±3.5 [b]	31.9±1.0 [b]	242.7±2.5 [a]
	<15**	47.9 ±6.5 [a]	13.5±1.8 [a]	243.2±3.0 [a]

*: On a dry basis; **: Microfluidized; Values are means ± standard deviations; The lower-case letters 'a-b' in the same column indicate differences between the averages of the same bran samples with the different particle sizes are statistically significant (P<0.05)

Chickpea bran, which had even less phytic acid than bulgur bran, has its content ranged from 112.1 to 113.1 mg/100g. Similar to bulgur bran, phytic acid of chickpea bran is probably degraded during the leblebi process; boiling stage and additionally resting stage considering phytic acid content of whole grain chickpea is between 121 and 403 mg/100 g (Hussain et al. 1989; Zia-Ul-Haq et al. 2007). These results are consistent with Hussain et al. (1989) who reported that phytic acid and phytate phosphorus contents of unprocessed whole chickpea decreased of 40% and 38%, respectively, after the autoclave process in an aqueous media.

No significant differences were noted between phytic acid, phytate phosphorus and total phosphorus contents of 350 μm, 200 μm and 100 μm (P>0.05). However, even though total phosphorus content remained constant, a striking decrease occurred

in phytic acid contents of both bran samples with the microfluidization process. This dramatic decrease probably occurred due to degrading of phytic acid with the high pressure in the aqueous media during microfluidization process. Our previous work has shown that thermal degradation of phytic acid occurs under low pH and high-pressure conditions (Özkaya et al. 2017a). In this present work, pH was not lowered; however; the pressure used in the microfluidization process was quite high up to 30000 psi and probably resulted in degradation of phytic acid under low-temperature conditions.

3.4. Phenolic compounds content of bulgur and chickpea brans

Cereal brans have attracted much attention over the last decades not only because of their high dietary fiber content but also because of their high phenolic compounds content. Phenolic compounds are secondary metabolism products of plants and have plenty of reported health-promoting effects. As seen in Table 4, the total phenolics content of milled bulgur bran fractions ranged between 3675.68 and 3720.55 µg GAE/g. These results are approximately 30% lower than those reported for wheat bran (Özkaya et al. 2017a), indicating that the bulgur process might have decreased the phenolics content due to the high temperature during the cooking stage of bulgur process. The lower phenolic compound could also be attributed to the differences between wheat cultivars and the fact that bulgur bran does not contain micronutrients-rich aleurone layer. However, bulgur bran has still a high amount of phenolics ranged between the phenolic compound contents of rice bran (4209.8 µg GAE/g) and oat bran (2892.8 µg GAE/g) (Özkaya et al. 2017a; 2017b). As seen from Table 4, chickpea bran is also a good source of phenolic compounds with the total phenolic contents of 1727.48-1756.11 µg GAE/g. It is likely that phenolics are located mostly in the outer layer of chickpeas similar to the cereal grains considering total phenolic compounds of raw whole grain chickpea is ranged between 980 and 1800 µg GAE/g (Xu & Chang 2007, 2008). Xu & Chang (2008) stated that approximately 40–50% of phenolics decreased in chickpea by leaching into soaking and cooking water. Therefore, it would be reasonable to assume that phenolic compounds content of chickpea bran decreased during the process (leblebi) in the same manner as those of bulgur bran.

Table 4- Free, bound and total phenolic compounds contents and antioxidant activity of bulgur and chickpea brans with different particle sizes

Bran samples	*Particle Size (µm)*	*Phenolic compounds* (µg GAE/g)*			*Antioxidant activity* (µmol TE/100 g)*		
		Free	*Bound*	*Total*	*Free*	*Bound*	*Total*
Bulgur bran	350	725.0±8.8^{ab}	2950.7±22.1^{a}	3675.7±30.9^{a}	145.0±6.6^{a}	274.3±7.4^{a}	419.2±0.8^{a}
	200	705.2±11.6^{a}	2974.9±26.0^{a}	3680.2±37.6^{a}	148.3±6.0^{a}	280.1±5.9^{a}	428.0±11.9^{a}
	100	755.7±10.1^{b}	2964.9±32.3^{a}	3720.6±22.2^{a}	149.6±4.5^{a}	284.5±6.4^{a}	433.1±10.9^{a}
	<15**	1723.8±21.8^{c}	4743.8±27.4^{b}	6467.5±49.2^{b}	323.2±8.7^{b}	426.1±9.7^{b}	749.6±1.0^{b}
Chickpea bran	350	353.2±5.9^{a}	1374.3±16.2^{a}	1727.5±22.2^{a}	175.2±4.9^{a}	91.2±3.5^{a}	266.3±1.4^{a}
	200	383.1±7.4^{b}	1360.2±19.2^{a}	1743.3±11.8^{a}	183.8±5.6^{a}	89.7±3.9^{a}	272± 9.5^{a}
	100	399.4±7.3^{b}	1356.7±20.1^{a}	1756.1±27.4^{a}	189.4±5.4^{a}	86.1±4.2^{a}	275.1± 9.6^{a}
	<15**	918.6±14.0^{c}	1884.4±17.6^{b}	2803.0±31.6^{b}	348.1±8.4^{b}	138.2±4.5^{b}	486.1±12.9^{b}

GAE: Gallic acid equivalent; TE: Trolox equivalent; *: On a dry basis; **: Microfluidized; Values are means ± standard deviations; The lower-case letters 'a-c' in the same column indicate differences between the averages of the same bran samples with the different particle sizes are statistically significant (P<0.05)

No significant differences were noted between the phenolics contents of milled bran fractions apart from the free phenolics (P>0.05). However, a clear trend was not observed among free phenolics of bulgur bran fractions while a slight increase occurred for those of chickpea bran with decreasing particle size from 350 µm to 100 µm.

Microfluidization process dramatically enhanced phenolic compound contents of bulgur and chickpea bran, especially free phenolics (up to 56% and 57%) and consequently total phenolics (up to 42% and 37%). Several studies have also mentioned this enhanced phenolics content phenomenon with the microfluidization application (Wang et al. 2013; Wang et al. 2014) and stated that this process increases the extractability of phenolic compounds due to loosening structure of the dietary fiber. It is worth noting that advance dry milling technique like jet-milling might result in collapsing of dietary matrix, and hence decrease the extractability of phenolic compounds (Zhu et al. 2010), while microfluidization process causes a loosen matrix structure due to the rapid pressure release at the end (Wang et al. 2013).

3.5. Antioxidant activity of bulgur and chickpea brans

Free, bound and total antioxidant activity of bulgur bran ranged from 145-149 µmol TE/ 100 g, 274-284 µmol TE/ 100 g to 419-431 µmol TE/ 100 g, respectively (Table 4). The total antioxidant activity of bulgur bran is 54% lower than those of wheat bran (Özkaya et al. 2017a). Chickpea bran has a lower total antioxidant activity compared to wheat bran as expected due to their relatively low phenolic compound contents; however, despite their lower free phenolic compounds content, their free antioxidant activity was found slightly higher than those of bulgur bran as ranged from 175 to 189 µmol TE/ 100 g. There were not any significant differences noted among the different fractions of milled brans; however, microfluidization process again

strikingly enhanced the antioxidant activity of brans parallel to their phenolic compound contents. The applied microfluidization process increased their total antioxidant activity, approximately two-fold, indicating again the loosen structure of the dietary fiber. Due to this loosen structure, antioxidant functional groups might be more exposed to the surrounding environment (Wang et al. 2013).

3.6. Physicochemical properties of bulgur and chickpea brans

Physicochemical properties of fibers including SC, WHC, and OHC are important characteristics due to their ability to influence the end product quality and their health-promoting effects. SC and WHC of 350 µm bulgur bran were found as 6.96 and 6.62 g water/ g bran, respectively (Figure 1). Hydration properties of bulgur bran are higher than the findings of Wang et al. (2012) who reported that untreated wheat bran has SC of 5.96 mL water/ g bran and WHC of 4.02 g water/ g bran. These higher hydration properties probably originate from the higher dietary fiber content of bulgur bran. Chickpea bran has slightly higher SC and WHC as 7.21 mL water/ g bran and WHC of 7.69 g water/ g bran, respectively. Milling process did not affect the hydration properties of brans; however, microfluidization process significantly improves hydration properties, especially of chickpea bran (P<0.05). SC and WHC are strongly related to the chemical composition, porosity and particle size of fibers. As mentioned before, the microfluidization process may loosen the structure of the fiber matrix, even might cause cavities and pores inside the matrix. These structural changes may result in a more exposing surface to outside media and binding of more water, and consequently enhance hydration properties (Chau et al. 2006).

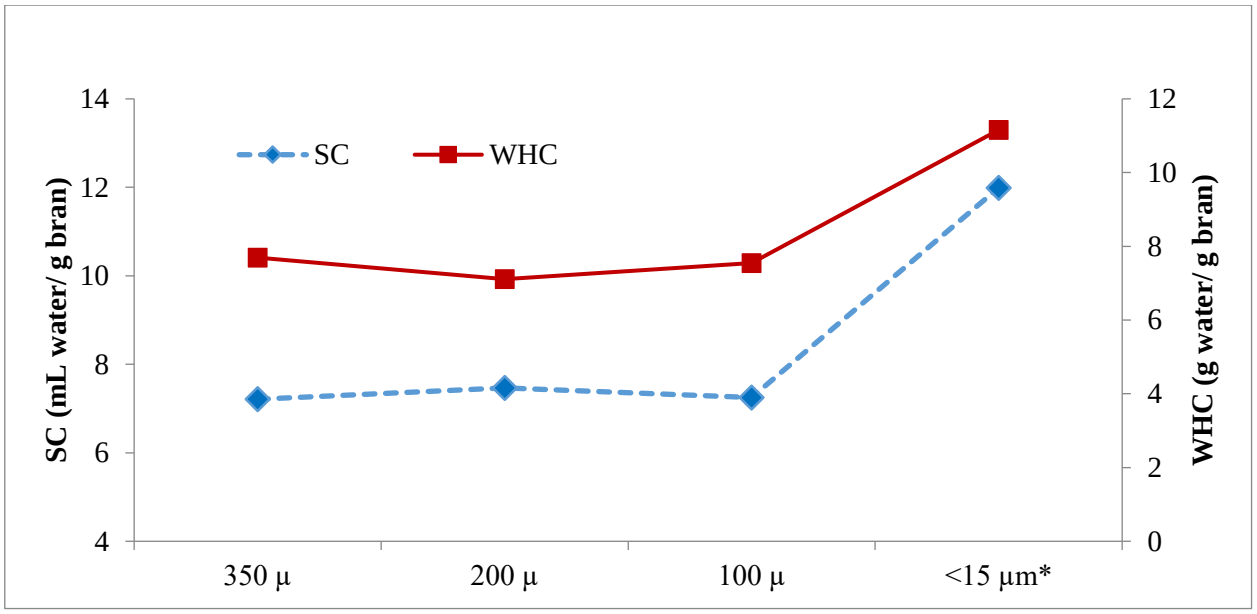

Figure 1- Swelling capacity (SC) and water holding capacity (WHC) of bulgur (A) and chickpea (B) brans with different particle sizes * *Microfluidized*

OHC of 350 µm bulgur and chickpea brans were found as 2.35 g oil/ g bran and 2.31 g oil/ g bran, respectively (Figure 2). As in hydration properties, grinding did not affect OHC of bulgur bran; however, it enhanced OHC of chickpea bran with no clear trend. Similar to hydration properties, microfluidization process again dramatically increased OHC probably due to the increased porosity, surface area and capillary attraction of fiber and lead to an increase of physical entrapment of oil (Chau & Huang 2003). These results suggest that these fiber sources might be a useful functional ingredient to modify viscosity and texture, avoid syneresis, stabilize of fat-food products and emulsions.

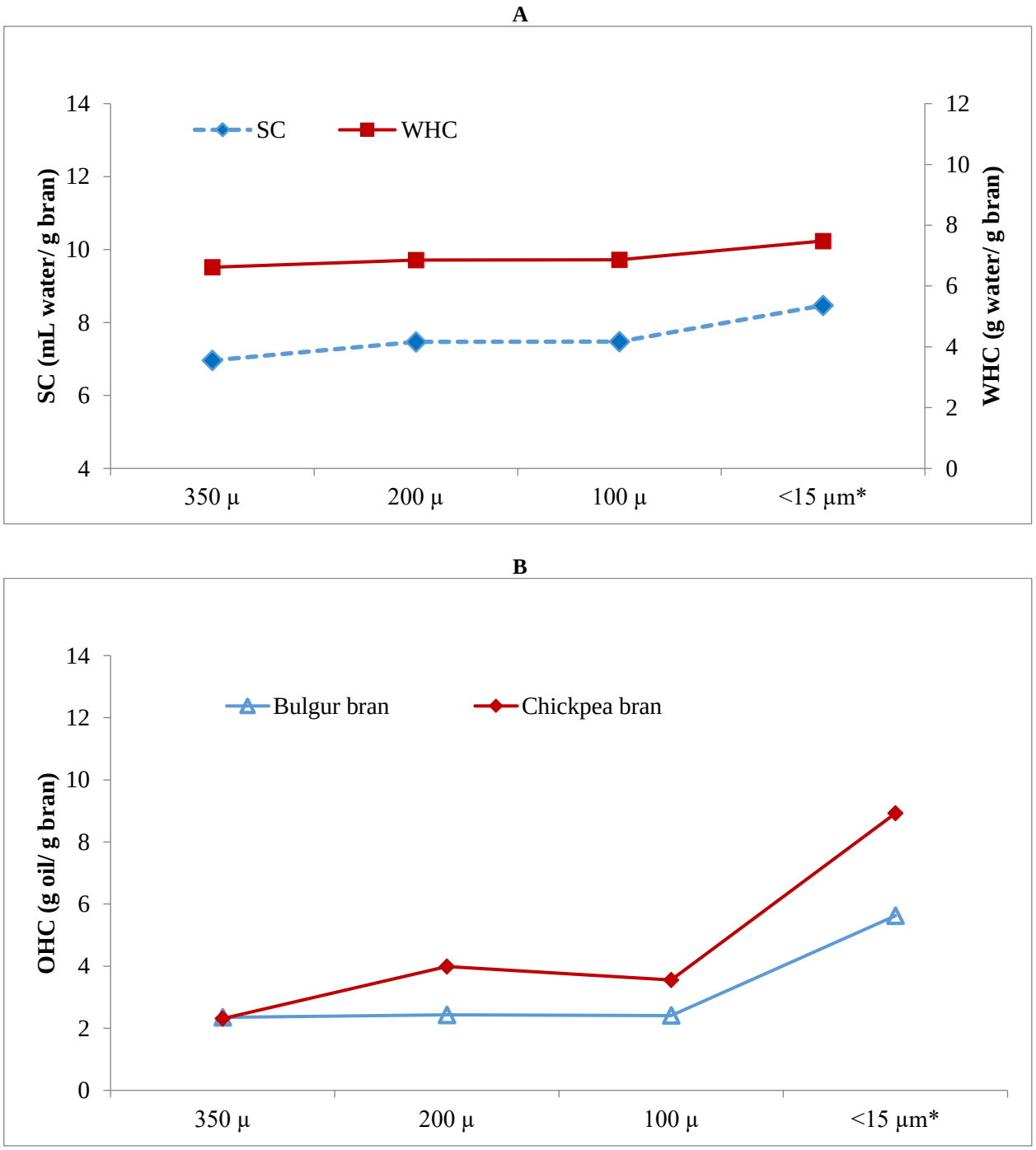

Figure 2- Oil holding capacity (OHC) of bulgur and chickpea brans with different particle sizes * *Microfluidized*

4. Conclusions

Cereal brans have been widely used to produce fiber enriched food products. Numerous studies conducted through the years reported their health-promoting effects as well as their adverse impacts on end-products. However, their severe effects on end-product are not the only limitation regarding their use in the food industry. Their dramatically high phytic acid content is an important issue considering phytic acid is an antinutrient and may cause nutritional problems when a large amount of fiber enriched products is consumed. Therefore, it is necessary to find new alternative dietary fiber sources with low phytic acid. Consequently, this study investigates the functional and physicochemical properties of bulgur and leblebi processes by-products, bulgur and chickpea brans as new dietary fiber sources. The results have shown that both brans contain a considerable amount of fiber as well as phenolic compounds along with a low amount of phytic acid. The milled bran fractions (350 µm; 200 µm; 100 µm) exhibited similar functional properties; however; further particle size reduction of brans with microfluidization process dramatically improved these functional properties. The microfludization process did not only increase phenolic compounds content and their antioxidant activity but also altered their insoluble/soluble dietary fiber ratio by increasing soluble fiber content and most importantly degraded phytic acid. In addition, the applied microfluidization process

enhanced the hydration properties along with the OHC. This study indicates that these brans, both milled and microfluidized, could be valuable functional ingredients for health-oriented food products considering their high dietary fiber content, physicochemical properties and low phytic acid contents and clearly should not be considered as disposable by-products. Furthermore, this process can be used successfully to alter functional and physicochemical properties of other fiber sources. Further studies should focus on the effects of bulgur and chickpea brans on end-products and investigate if the particle size has an impact on the quality, texture and functional properties of the products.

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Abbreviations

IDF	Insoluble dietary fiber
SDF	Soluble dietary fiber
TDF	Total dietary fiber
SC	Swelling capacity
WHC	Water holding capacity
OHC	Oil holding capacity
GAE	Gallic acid equivalent
TE	Trolox equivalent
DPPH	2.2-di-phenyl-2-picryl-hydrazyl

Conflict of interest

The authors have declared no conflict of interest.

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