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EFFECT OF THERMAL STABILIZATION ON PHYSICO-CHEMICAL PARAMETERS AND FUNCTIONAL PROPERTIES OF WHEAT BRAN

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ABSTRACT

The food industry also focuses on the use of by-products from food processing. Wheat bran is a valuable by-product of the wheat milling process, which is rich in dietary fiber. In addition to nutritional value, dietary fiber has a functional potential in the production of novel foods. Pre-treatment of the dietary fiber using different methods can change its functional properties. The objective of this study was to evaluate the effect of stabilization process on physico-chemical parameters and functional properties of wheat bran. Wheat bran from two wheat variety was treated using microwave and hot air heating. It was observed that wheat bran included more than 45% of total dietary fiber. Results suggested that treatment of bran using both method increased total dietary fiber content. Thermal treatment process decreased the anti-nutritional agent in bran samples. Phytic acid content diminishing of 44% and 49% was observed in microwave treated bran samples. Moreover, treatment of bran using a hot air heating improved the hydration properties (water holding, water retention and swelling capacity), while oil holding capacity was not significantly altered. Treatment decreased the antioxidant activity of treated bran samples. It was observed that thermal treatment modified the color parameters of bran (lightness, yellowness and hue angle decreased and redness and Chroma increased).

Keywords: wheat bran; thermal treatment; functional property, phytic acid; retention capacity

INTRODUCTION

With growing interest in health-promoting functional foods, the demand for natural bioactive additives has increased and the exploration for new sources is ongoing. The food processing industry in most countries generates large quantities of byproducts every year, which are frequently abandoned as wastes. However, many of these byproducts are dietary, functional, and potentially novel sources of nutrition. Of the many materials obtained, dietary fibers are particularly promising ingredients that has attracted considerable interest over the past few decades. The reason for this is their significant availability in most food byproducts, low costs, and positive effects for the prevention and treatment of a diverse range of diseases **(Han et al., 2017)**.

Dietary fiber is the edible part of plants or analogous carbohydrates; it consists of polysaccharides that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Total dietary fiber (TDF) is the sum of insoluble (IDF) and soluble dietary fiber (SDF) **(Lebesi and Tzia, 2011)**. The soluble and insoluble nature of dietary fibres involves differences in their technological functionality and physiological effects. SDFs are characterised by their capacity to increase viscosity, and to reduce the glycemic response and plasma cholesterol. IDFs are characterised by their porosity, their low density and by their ability to increase faecal bulk and decrease intestinal transit **(Elleuch et al., 2011)**. Compared with the IDF, SDF has superior beneficial properties for human health. In the natural plant cell walls, IDF accounts for a large proportion, while the proportion of SDF is very low. Thus, finding the appropriate method to convert more IDFs into SDFs is extremely important **(Gan et al., 2020)**. Thermal steps like roasting, steaming, cooking under forced air or microwave radiation usually have little impact on the chemical composition, but some effects on the processing properties could be observed **(Prückler et al., 2014)**.

There are various sources of dietary fiber. The most common source in bakery products is cereal bran, especially wheat bran **(Almeida, Chang and Steel, 2010)**. Thus, using wheat bran with high TDF content, fiber enrichment objectives can be achieved by means of small amounts of bran. The incorporation of lower levels of bran means a less negative impact on the finished product quality **(Ellouze-Ghorbel et al., 2010)**. Nutritionally, bran fractions produced by milling are rich in fibre, minerals, vitamin B6, thiamine, folate and vitamin E and some phytochemicals, in particular antioxidants such as phenolic compounds. However, bioavailability is affected by the food matrix as well as processing conditions. Bran is used in the production of brown and wholemeal flours, hence retaining some of the valuable nutritional components that are depleted when these fractions are further removed in the refinement of white flour **(Stevenson et al., 2012)**. Wheat bran is therefore composed of pericarp, seed coats, and aleurone layer with some attached remnants of endosperm. Considerable amounts of wheat bran are produced annually that are mostly used in animal feeding. Due to the presence of the aleurone layer, wheat bran constitutes, however, a potential source of micronutrients that could be better valorized in human nutrition **(Antoine et al., 2003)**. The physiological effects of wheat bran can be split into nutritional effects (from the nutrients present), mechanical effects (mainly on the gastrointestinal tract, due to the fibre content) and antioxidant effects (arising from the phytonutrients present such as phenolic acid and alkylresorcinols) **(Stevenson et al., 2012)**.

Scientific hypothesis

This work evaluated the effect of different treatment process (hot air heating and microwave heating) on the physico-chemical parameters and functional properties of treated wheat bran.

MATERIAL AND METHODOLOGY

Material

Wheat bran from the variety PS Bertold (BB) and PS 215 (WB) were observed from Research and Breeding Station, Vígľaš Pstruša, Slovakia and Research Institute of Plant Production Piešťany, Slovakia. Wheat bran samples were treated using hot-air and microwave heating acording to method described by **Lauková et al. (2019)**.

Chemical composition

Chemical composition of wheat bran included determination of: moisture (AACC Method 44-19.01), ash (AACC Method 08-01.01), protein (AACC Method 46-13.01) and crude fat (AACC Method 30-25.01) **(AACC, 2000)**.

TDF, IDF and SDF content was determined by enzymatic-gravimetric method **(AOAC, 2003)**.

Phytic acid content was measured using colorimetric method according to **McKie and McCleary (2016)**.

Antioxidant activity of wheat bran was determined according to the method of **Cai et al. (2014)** by measuring free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging capacity. Wheat bran (0.1 g) was extracted with 1 cm^3 of pure methanol at 25 °C for 2 h with continuous shaking under a dark environment and centrifuged at 1,200 × g for 10 min. The extract (0.05 cm^3) was reacted with 1 cm^3 of 0.1 mM DPPH solution at 25 °C for 30 min, and absorbance was measured at 517 nm. Antioxidant activity was calculated as percent discoloration of DPPH = $[1 - (A_1/A_0)] \times 100$, where A_1 is the absorbance of wheat bran extract at the end of the reaction (t = 30 min) and A_0 is the absorbance of the pure methanol control at the beginning of the reaction (t = 0). The data were reported as percentage of discoloration.

Functional properties

Swelling capacity, water absorption and water retention capacity were determined according to method described by **Lauková et al. (2018)**. Oil holding capacity was evaluated using method presented by **Mora et al. (2013)**.

Solvent retention capacity (SRC) tests were performed according to the method from authors **Xiao et al. (2006)** using 5% lactic acid, 5% sodium carbonate, 50% sucrose, and distilled water. Sample (5g) was added into a 50 cm^3 centrifuge tube with a screw cap. Then 25.0 cm^3 of an appropriate solvent was added and the mixture was vortexed vigorously to suspend the flour for 5 sec. The mixture was allowed to set and swell for 20 min and was vortexed for 5 s each at 5, 10, 15, and 20 min. After centrifugation at 1,000 x g for 15 min (not including time to achieve speed), the supernatant was decanted and the tube was drained at a 90° angle for 10 min on a paper towel. Finally, SRC value (14% mb) was calculated for each solvent as:

$$SRC\ (\%) = \left(\frac{gel\ weight - flour\ weight}{flour\ weight}\right) \times 100$$

Color of wheat bran

The color parameters *L* (lightness), *a* (redness/greenness), and *b* (yellowness/blueness) of the samples were measured by spectrophotometer Cary 300 UV-Vis (Agilent Technologies, Santa Clara, USA) with DRA-CA-30I sphere accessory. The spectrophotometer was calibrated with a white calibration tile. The Cary WinUV software with "Color" application was used for recalculation the Chroma (*C*) and hue angle (*H*). Color coordinates were determined five times per bran sample.

Statistical analysis

All determinations were carried out in triplicate unless otherwise state. The results were expressed as mean ± standard deviation. The significant differences between mean values of raw and treated bran were establish using a Student`s test at p <0.05. The XLSTAT statistic software was used for data evaluation.

RESULTS AND DISCUSSION

Chemical composition

Composition of wheat bran is purely based on the variety, cultivation conditions and the methods employed for its separation, which determines the amount of starch attached to the aleurone layer after the separation **(Babu et al., 2018)**. Chemical composition of treated and raw wheat bran is summarized in Table 1. Results presented that moisture content of bran decreased after thermal treatment, which was caused by loss of water as a result of heating **(Dong et al., 2019)**. Furthermore, it was observed that treatment of wheat bran using microwave and hot air heating had no significant effect on ash and fat content.

Wheat bran contains more than 15% high quality proteins, but most of them are enclosed within a matrix of cell wall polysaccharides and so they are poorly digested. Wheat bran proteins have also been explored as a source of amino acids and bioactive peptides or as inhibitors of enzymes of industrial interest **(Balandrán-Quintana, Mercado-Ruiz and Mendoza-Wilson, 2015)**. From the results concluded that protein content of raw bran varies from 15.46% (WB) to 15.92% (BB). These results were in agreement with those obtained by **Ferreira, Chang and Steel (2011)** (15.30%) and **Noort et al. (2010)** (15.90%). After microwave treatment, the protein content increased up to 16.56% (WB) and 17.20% (BB).

Wheat bran appears as an important dietary fiber source **(Ferreira, Chang and Steel, 2011)**. It was observed, that TDF content of raw bran samples were 46.35 and 45.99%, indicating bran as good source of dietary fiber. Similar TDF content in wheat bran was found by **Ma, Lee and Baik (2018)** (46.50%) and **Ferreira, Chang and Steel (2011)** (46.30%). Furthermore, IDF and SDF content of raw BB, 44.93% and 1.42%, respectively, were higher compared to raw WB (44.62 and 1.37%). Thermal treatments can change their physico-chemical properties of dietary fiber by altering the ratio between soluble and insoluble fiber (SDF/IDF), TDF content **(Ozyurt and Ötles, 2016)**. It can be concluded, that treatment of bran using both methods had significant effect on TDF and IDF. The results suggested that hot air treatment resulted in higher fiber content compared to microwave treated bran. Moreover, hot air treatment significantly increased the SDF content. In general, the changes in the dietary fiber composition during thermal processing may be partly attributed to the redistribution of the insoluble and soluble components of dietary fiber, and partly to the formation of resistant starch. An increased temperature breaks week bonds between polysaccharide chains and split glycosidic linkages in the polysaccharides **(Căpriţă, Căpriţă and Hărmănescu, 2012)**. Increase in total fiber can be also attributed to the formation of fiber-protein complexes that are resistant to heating and are quantified as dietary fiber **(Dhingra et al., 2012)**.

Bran also contains phytic acid which is the major phosphorus storage component and comprises 80% of total phosphorus in cereal grains **(Aktas-Akyildiz et al., 2017)**. The presence of phytate has been considered as an anti-nutrient in humans because of its effect on the bioavailability of iron, magnesium, zinc and calcium. While the mechanism is not entirely understood, it is suggested that phytic acid binds strongly with these mineral cations to form phytate-mineral complexes, changing their solubility, functionality absorption and digestibility. Consequently, the complex cannot be absorbed or easily hydrolysed by the human body and so there is an adverse effect on bioavailability of minerals **(Stevenson et al., 2012)**. The phytic acid content (Figure 1) in raw WB samples was higher (51.9 $mg.g^{-1}$) than in raw BB (40.4 $mg.g^{-1}$). These values are in agreement of those reported by **Noort et al. (2010)** (47.9 $mg.g^{-1}$) in wheat bran. It can be stated that thermal treatment significantly decreased phytic acid content in both bran variety. After microwave treatment, the phytic acid content was significantly reduced to 22.6 $mg.g^{-1}$ (BB) and 26.4 $mg.g^{-1}$ (WB). Recently, **Mosharraf, Kadivar and Shahedi (2009)**, and **Zhao, Guo and Zhu (2017)** also described a decrease in phytic acid content in treated wheat bran after steeping in acetate buffer and fermentation.

The antioxidant activity of wheat bran measured using DPPH is illustrated in Figure 2. The results showed that antioxidant activity of raw wheat bran was 24.84% and 28.85% for BB and WB, respectively. Both values were higher than those reported by **Verma, Hucl and Chibbar (2008)** (12.5 – 20.1%) in bran from 51 wheat cultivars. On the other hand, **Cai et al. (2014)** observed higher antioxidant activity (29.2 – 53.6%) in bran from American and Korean wheat varieties. Microwave and hot air heating of bran decreased its antioxidant activity. The lowest antioxidant activity values were recorded after hot air heating of bran samples (23.11 and 23.64% for BB and WB).

Functional properties

The technological interest and physiological effects of dietary fibre are related to their functional properties. The hydration properties of dietary fibres determine their optimal usage levels in foods because a desirable texture should be retained **(Yaich et al., 2015).** Wheat bran is rich in polysaccharides which can bind water on a molecular level through formation of hydrogen bridges. These mechanisms contribute to water uptake by bran in the case of unconstrained hydration. Alternatively, when bran is exposed to an external stress, only the water strongly bound in nanopores or through hydrogen bonds will govern water retention **(Hemdane et al., 2016)**. Functional properties of untreated and treated wheat bran are summarized in Table 2.

WHC is related to the porous matrix structure formed by polysaccharide chains which can hold large amounts of water through hydrogen bonding **(Du, Zhu and Xu, 2014)**. The WHC of raw bran samples were 2.46 $g.g^{-1}$ (BB) and 2.57 $g.g^{-1}$ (WB), which was similar to those described by **Cai et al. (2014)** (2.04 – 2.51 $g.g^{-1}$). From the results concluded that thermal tretment of bran resulted in increased WHC values. Moreover, hot air treated bran had higher WHC than microwave treated bran. The high WHC of modified bran suggested that this material could be used as a functional ingredient to avoid syneresis and to modify the viscosity and texture of formulated products in addition to reducing calories by the total or partial substitution of high-energy ingredients **(Grigelmo-Miguel, Gorinstein and Martín-Belloso, 1999)**. **Yan, Ye and Chen (2015)** demonstrated higher WHC value of bran after extrusion.

WRC is one of the major key parameter which has been studied in functional food. Most significant changes that happen during baking i.e. gelatinization of starch, denaturation of protein, flavor and color formation are due to water contents **(Khan et al., 2018)**. WRC is related to the content of insoluble dietary fiber and the intact cell structure of bran **(Zhao, Guo and Zhu, 2017)**. Raw BB bran had lower WRC value (1.74 $g.g^{-1}$) compared to WRC value of raw WB bran (2.16 $g.g^{-1}$). This WRC values are in agreement with result (2.18 $g.g^{-1}$) presented by **Ma, Lee and Baik (2018)**. After hot air treatment the WRC significantly increased up to 2.38 and 2.63 $g.g^{-1}$ for BB and WB, respectively.

Table 1 Chemical composition of wheat bran.

	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	TDF (%)	SDF (%)	IDF (%)
				Raw bran			
BB	7.92 ±0.09	15.92 ±0.11	2.89 ±0.07	2.91 ±0.03	46.35 ±0.03	1.42 ±0.01	44.93 ±0.03
WB	8.37 ±0.06	15.46 ±0.09	2.90 ±0.03	2.39 ±0.02	45.99 ±0.08	1.37 ±0.06	44.62 ±0.03
				Hot air treated bran			
BB	3.18 ±0.06*	16.19 ±0.06*	3.30 ±0.01	2.10 ±0.02	49.74 ±0.05*	2.68 ±0.06*	47.06 ±0.02*
WB	2.84 ±0.06*	16.36 ±0.11*	2.84 ±0.11	2.19 ±0.03	47.80 ±0.06*	2.06 ±0.01*	45.74 ±0.05*
				Microwave treated bran			
BB	3.51 ±0.04*	17.20 ±0.12*	3.19 ±0.08	2.02 ±0.02	48.44 ±0.03*	1.56 ±0.01	46.88 ±0.02*
WB	4.50 ±0.10*	16.56 ±0.09*	3.01 ±0.03	2.99 ±0.07	46.52 ±0.10*	1.40 ±0.02	45.12 ±0.06*

Note: IDF – insoluble dietary fiber, SDF, soluble dietary fiber, TDF total dietary fiber, * denotes statistically significant difference at $p < 0.05$ level.

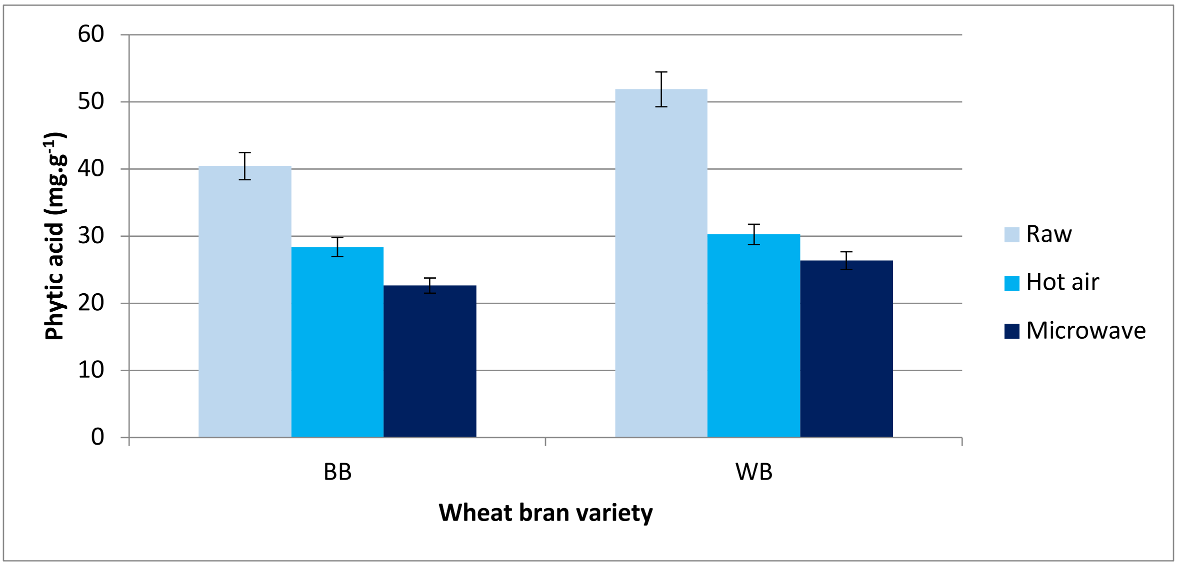

Figure 1 Phytic acid content in raw and treated wheat bran.

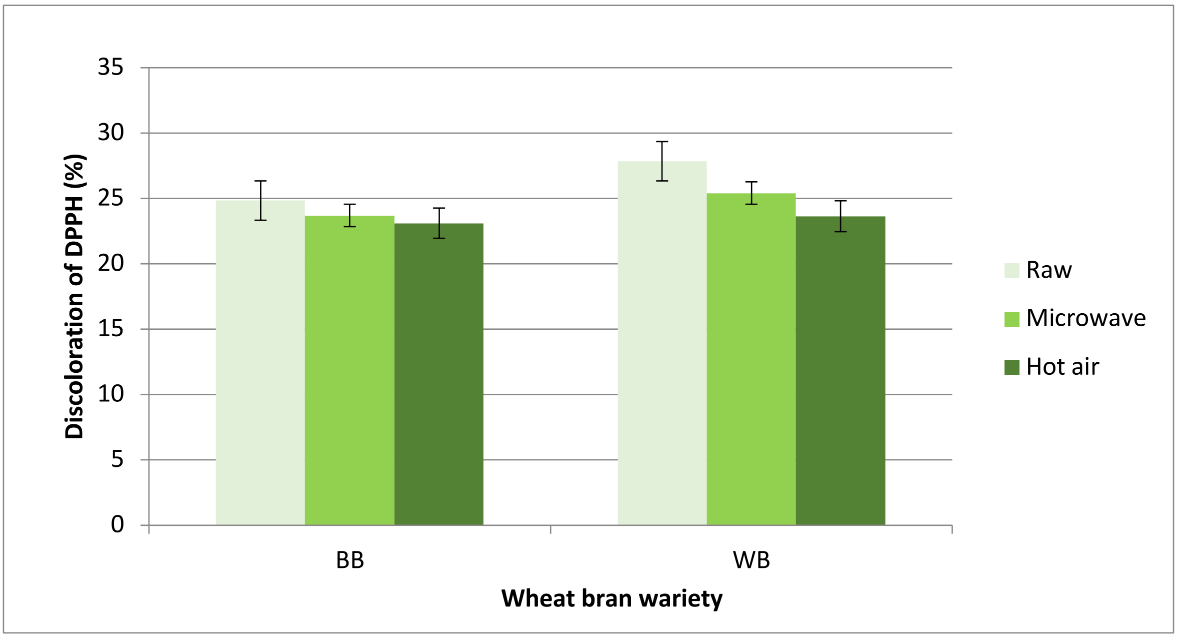

Figure 2 Discoloration of DPPH in raw and treated bran.

Table 2 Functional properties of wheat bran.

	WAC ($g.g^{-1}$)	WRC ($g.g^{-1}$)	SC ($cm^3.g^{-1}$)	OAC ($g.g^{-1}$)	LA-SRC (%)	SU-SRC (%)	Na-SRC (%)
Raw bran							
BB	2.46 ±0.03	1.74 ±0.01	4.21 ±0.03	1.49 ±0.02	141.98 ±4.21	183.50 ±1.65	182.41 ±3.15
WB	2.57 ±0.01	2.16 ±0.01	4.40 ±0.02	1.33 ±0.00	142.79 ±3.47	161.52 ±2.54	176.17 ±2.31
Hot air treated bran							
BB	2.99 ±0.00*	2.38 ±0.00*	5.22 ±0.06*	1.48 ±0.02	174.44 ±4.06*	199.74 ±3.02*	177.84 ±3.01*
WB	3.19 ±0.04*	2.63 ±0.01*	5.41 ±0.01*	1.39 ±0.01	198.11 ±1.86*	214.54 ±1.09*	163.54 ±2.65*
Microwave treated bran							
BB	2.54 ±0.01	1.97 ±0.00	5.66 ±0.03*	1.57 ±0.01	154.44 ±2.71*	195.70 ±2.57*	164.52 ±4.16*
WB	3.13 ±0.02*	2.34 ±0.01	5.75 ±0.02*	1.39 ±0.00	172.12 ±2.48*	224.56 ±3.63*	167.88 ±2.45*

Note: OAC – oil absorption capacity, SC – swelling capacity, LA-SRC – lactic acid retention capacity, Na-SRC – sodium carbonate retention capacity, SU-SRC – sucrose retention capacity, WAC – water absorption capacity, WRC – water retention capacity, * denotes statistically significant difference at p <0.05 level.

Table 3 Color parameters of wheat bran.

	L	*a*	*b*	*C*	*H*
Raw bran					
BB	63.33 ±0.62	8.57 ±0.14	13.50 ±0.22	14.58 ±0.26	57.59 ±0.06
WB	65.84 ±0.02	8.41 ±0.06	14.53 ±0.07	16.44 ±0.09	59.25 ±0.22
Hot air treated bran					
BB	59.87 ±0.04*	8.61 ±0.05	12.62 ±0.07*	14.95 ±0.45	55.68 ±0.05*
WB	58.60 ±0.62*	9.25 ±0.10*	14.16 ±0.30*	17.17 ±0.22*	57.38 ±0.21*
Microwave treated bran					
BB	61.79 ±0.76*	8.63 ±0.19	13.24 ±0.31	15.74 ±0.36	57.19 ±0.14*
WB	64.39 ±0.70	8.90 ±0.05*	14.46 ±0.21	17.40 ±0.28*	59.23 ±0.51

Note: * denotes statistically significant difference at p <0.05 level.

SC indicates how much the fiber matrix swells as water is absorbed, including loosely associated water. It is a consequence of the macromolecule relaxation during hydration, which leads to an increment in the occupied volume by the fiber product. The greater capacity to swell is the most desirable parameter for the physiological functionality of DF **(Lebesi and Tzia, 2012)**. The SC of raw bran was higher (4.21 and 4.40 $cm^3.g^{-1}$) than obtained **Mora et al. (2013)** (2.92 $cm^3.g^{-1}$) for wheat bran. From the results concluded that thermal treatment significantly increased the SC of wheat bran. The highest SC (5.66 and 5.75 $cm^3.g^{-1}$) was recorded after microwave treating of bran. The increase in SC might be attributed to a rise in the amount of short chains and the surface area of DF induced by thermal processing **(Dong et al., 2019)**.

OAC is the capability of dietary fiber to adsorb fat. During food processing, the reduction of cholesterol level in blood is linked with higher value of OAC **(Khan et al., 2018)**. Oil absorption of cereal derivatives, e.g., wheat bran, is related mainly to the surface properties of the bran particles but may also be related to the overall charge density and to the hydrophilic nature of the constituents **(Elleuch et al., 2011)**. It was observed that OAC of raw BB bran was higher (1.33 $g.g^{-1}$) than WB bran (1.49 $g.g^{-1}$). These values were lower compared to values observed by **Mora et al. (2013)** for wheat bran (2.18 $g.g^{-1}$). Authors **Ma and Mu (2016)** describe that low OAC values might be due to the absence or limited presence of lignin. The results showed that treatment of bran using both methods had no significant effect on OAC values.

The SRC method has been conceived to produce a combined pattern of the four SRC values to establish a practical flour quality/functionality profile. It is clear that fibre functionality in food formulations derived from its interaction and spatial arrangement within the biopolymers system **(Rosell, Santos and Collar, 2009)**. Wheat bran is increasingly added to mostly cereal-based food products (bread, cookies, breakfast cereals, pasta, snacks, cakes, and more) **(Hemdane et al., 2016)**. For this reason the selected SRC of wheat bran samples and the effect of bran treatment were also evaluated. The SRC values are summarized in Table 2. Generally, lactic acid SRC is associated with glutenin characteristics, sodium carbonate SRC is related to levels of damaged starch, and sucrose SRC with pentosan characteristics **(Rosell, Santos and Collar, 2009)**. The results showed that thermal treated bran had significantly higher lactic acid and sucrose SRC compared to raw bran. The highest values of lactic acid SRC were observed after hot air heating (174.44 and 198.11% for BB and WB, respectively). Furthermore, the results revealed that microwave treated WB bran had the highest sucrose SRC (224.56%). On the other hand, the sodium carbonate SRC decreased after thermal treatment process up to 163.25% (hot air heated WB).

Color parameters

Color is an important visual quality (attribute) of food products **(Ferreira, Chang and Steel, 2011)**. The color attributes of raw and treated bran are summarized in Table 3. The lightness values of raw bran (63.33 and 65.84 for BB and WB, respectively) were similar to results described by **Onipe, Beswa and Jideani (2017)**. Results showed that thermal treatment of bran samples decreased the lightness value of bran. Moreover, the lowest lightness values (58.60 and 59.87 for WB and BB, respectively) were recorded after hot air heating. It was also observed that after treatment of bran using both methods the redness of bran increased, while yellowness of bran decreased. Chroma (*C*), considered the quantitative attribute of colorfulness, is used to determine the degree of difference of a hue in comparison to a grey color with the same lightness **(Minarovičová et al., 2019)**. The results suggested that treated bran using both methods had higher *C* value compared to raw bran samples. The higher the *C* value, the higher is the color intensity of samples perceived by humans **(Minarovičová et al., 2019)**.

CONCLUSION

Wheat bran is the main source of dietary fiber in bakery products. The results showed that microwave and hot air heating altered the soluble and insoluble dietary fiber content. Hot air treatment significantly increased the total dietary fiber content up to 49.74%. The loss of phytic acid content was more than 44 % after microwave heating. The thermal treatment modified the functional properties of wheat bran, which are important in food processing. Wheat bran treated using hot air had higher water absorption and water retention capacity compared to wheat bran treated using microwave heating. Hot air heating significantly altered the color parameters of treated bran. From this study resulted that treatment of wheat bran using hot air heating significantly improved the wheat bran functional and physico-chemical properties.

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