Influence of wheat milling by-products on some physical and chemical properties of filled and unfilled fresh pasta

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Abstract The effects of wheat bran (WB) and wheat germ (WG) (5, 10, 15 and 20%) on physical, chemical and sensory properties of filled (with cheese) and unfilled fresh pasta were investigated. Pasta formulations with increased WB and WG ratio resulted in higher water uptake, volume increase, cooking loss, and lower firmness values. Filling material usage and the addition of WB or WG significantly ($p < 0.05$) affected the color parameters (L^* , a^* and b^*) of the fresh pasta samples. WG supplemented samples had higher protein, fat, Mg, P, Zn content and antioxidant activity, as well as lower cellulose, Ca, Fe, K and phytic acid content than those of containing WB. Filled fresh pasta samples presented superior chemical properties (excluding cellulose and Fe content) compared to unfilled ones. Increasing amount of WB and WG enhanced all the chemical properties of fresh pasta. Sensory analyses results demonstrated a decrease in the overall acceptability of fresh pasta formulations prepared with over 10% of WB and 15% of WG.

Keywords Wheat bran · Wheat germ · Fresh pasta · Filled fresh pasta

Introduction

Pasta is a cereal product that has been consumed extensively for centuries. Pasta is classified into two major classes as fresh and dried (Tazart et al. 2016). Moisture content of fresh pasta is generally above 24%, and water activity varies in the range of 0.92 and 0.97 (Pagani et al. 2007). Fresh pasta can be produced as unfilled or filled forms. Filled fresh pasta has gained a significant economic importance as it has been widely consumed throughout the world. This product is obtained by combining two fresh layers of dough with a suitable filling material (usually prepared with a mixture of minced meat, cheese and vegetables). The main feature of filled fresh pasta is the flavor that comes out during cooking. The high water content of the filling material evaporates during cooking with temperature and the steam is trapped in the dough layer surrounding it which gives the end-product a special taste (de Cindio et al. 2001). The high water activity of both pasta and filling material of packed fresh pasta limits its shelf life (Sanguinetti et al. 2011). Thermal heat treatment with steam and/or modified atmosphere packaging (MAP) can be used to extend the shelf life of products.

Wheat which is the oldest crop known to scientist is generally processed into refined white flour for human consumption. A wheat grain mainly consists of wheat bran (WB), wheat germ (WG) and endosperm. Inner part of grain, endosperm, is the main source of commercial refined white flour. Outer parts, WB and WG are considered as by-products of wheat milling and mainly used for animal feeding, as well as in food formulations to a much lesser extent (Apprich et al. 2014; Onipe et al. 2015). WB approximately consists of 14–19% of the weight of a wheat grain (Javed et al. 2012). In 2001, 52 products containing WB were introduced to the market only, however this

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number has increased up to 800 in 2011 (Onipe et al. 2015; Prückler et al. 2014). WB is composed of pericarp, testa and aleurone layers from the outermost layer to the inner, respectively. It contains approximately 53% of dietary fibers (xylans, lignin, cellulose, galactan and fructans) as well as some other components such as vitamins, minerals and bioactive components (ferulic acid, lignans, flavonoids and sterols) (Onipe et al. 2015).

About 2.5–3.8% of the wheat grain is composed of WG (Brandolini and Hidalgo 2012). WG has a high protein content (> 20%) which consists of mainly albumin and globulins (Gomez et al. 2012). The biological value of the WG proteins is close to the proteins of animal origin. Besides high protein content, WG is a good source of lipids, sugars, minerals, tocopherols, B group vitamins, carotenoids, flavonoids and phytosterols. As WG is a potentially nutritious food supplement, it is an excellent raw material for the preparation of cereal products such as bread, cookies and muffins (Brandolini and Hidalgo 2012).

A scan of reviews shows that WB and WG have many functional properties. For instance, therapeutic potentials of WB components such as reduced risk of cardiovascular disease, prostate cancer, colon cancer and type II diabetes have been summarized by Onipe et al. (2015). Moreover, WG and its derivatives have also been investigated in terms of their activity to lower plasma and liver cholesterol, reduce cholesterol absorption, inhibit platelet aggregation, improve physical endurance and fertility, and retard aging (Brandolini and Hidalgo 2012).

Recently, the use of by-products of wheat milling in food formulations has widely enhanced due to the increased awareness of their nutritional value. This study, therefore aims to improve the functional and nutritional properties of filled/unfilled fresh pasta with WB and WG.

Materials and methods

Materials

Wheat flour, WB and WG were supplied from a flour mill in Konya, Turkey. WB and WG were milled by a hammer mill equipped with 0.5 mm sieve (Perten, LM 3100, Perten Instruments AB, Huddinge, Sweden). Chicken egg was purchased from a local market and used as a whole in pasta production. Lor cheese (whey cheese) (with 16.1% protein and 15.6% fat), cream cheese (with 13.3% protein and 18.2% fat) and sunflower oil (with 91% fat and 56% polyunsaturated fatty acid) were obtained from the local markets in Konya, Turkey.

Preparation of filling material

To prepare filling material, whey cheese (1000 g), cream cheese (250 g), sunflower oil (25 ml) and wheat flour (30 g) were mixed to obtain a homogeneous mixture by using a Hobart mixer (Hobart N50, Canada Inc., North York, Ontario, Canada) for 5 min at the lowest speed.

Preparation of filled and unfilled fresh pasta

Wheat flour (1000 g), egg (100 g) and water (230 g) were mixed via the kneader part of pilot ravioli machine (La Monferrina, Italy) for 15 min to produce filled control fresh pasta under laboratory conditions. After mixing, the dough was thinned by a cylinder roll, and then passed through ravioli mold (48 × 48 mm). This was followed by shaping the dough with filling material (30% of filling material) using the same ravioli machine. Filled pasta formulations of this study were obtained by replacing wheat flour with WB or WG in a ratio-dependent manner (5, 10, 15 and 20%) (Table 1). The amount of water used in the formulations varied in the range of 235 and 300 g. Same procedure was also followed in the production of unfilled fresh pasta. Thermal treatment was applied to all products by injecting steam at 91 °C for 9 min through a closed line (Pama Machine, PS150, Italy). Immediately after the thermal treatment, the pasta was cooled down to room

Table 1 Experimental design for fresh pasta production

Additive type	Filling material	Additive ratio (%)
Wheat bran	Unfilled	0
		5
		10
		15
		20
	Filled	0
		5
		10
		15
Wheat germ	Unfilled	20
		0
		5
		10
		15
		20
	Filled	0
		5
		10
		15
		20

temperature using the same machine (Sanguinetti et al. 2011). Samples were packaged under modified atmosphere conditions with a 50–50% CO₂–N₂ gas mixture by a MAP machine (Apack-MAP25, Apack, Turkey). 210 × 315 mm plate-shaped packing material was used in order to protect the product against deformation during the MAP application. End-products were stored in the refrigerator at + 4 °C.

Color measurement

Colors readings for the raw materials, filled and unfilled fresh pasta samples were recorded using Hunter Lab Chroma Meter (Minolta CR-400, Osaka, Japan). The instrument was calibrated by a white reference tile before the measurements. Color readings were expressed by Hunter values as L^* , a^* and b^* . The hue angle (hue), which describes the relative amount of redness and yellowness in a pasta sample ($0^\circ/360^\circ$ is defined for red/magenta, 90° for yellow, 180° for green and 270° for blue or purple) was calculated using a^* and b^* values as $\arctan [b^*/a^*]$. Saturation index (SI) describes the color saturation or intensity. SI values of the pasta samples were calculated as $[a^{*2} + b^{*2}]^{1/2}$ (Ayala-Silva et al. 2005; Pedisic et al. 2009).

Cooking properties and firmness

Water uptake (WU), volume increase (VI), and cooking loss (CL) values of pasta samples were determined as cooking properties. Weighed fresh pasta samples (20 g) were cooked in 250 ml of boiling water for 18 min. After cooking, samples were allowed to drain for 2 min and analyzed with regard to WU and VI values according to the method described by Oh et al. (1983). WU was calculated by taking the weight difference of dry (before cooking) and cooked (after draining) pasta. For the VI determination, dry and cooked pasta samples were put into the water-full graduated cylinders. The VI was determined by the volume differences of water overflow. CL was determined, as the weight of total solids that remained after evaporating the pasta cooking water in an oven. Firmness of the cooked pasta samples was measured by a texture analyzer instrument (TA-XT plus, Stable Microsystems, UK).

Chemical analyses

Moisture, ash, protein, fat and cellulose content of raw materials and fresh pasta formulations were analyzed according to the standard methods of AACC (1990). Phytic acid was measured by a colorimetric method according to the method conducted by Haug and Lantzsch (1983). Phytic acid in the sample was extracted with a solution of

HCl (0.2 N) and precipitated with a solution of Fe III (ammonium iron). The amount of iron remaining in the extract was determined spectrophotometrically and the amount of phytic acid was calculated from the results obtained. Colorimetric analysis was conducted based on Folin–Ciocalteu method to determine the total phenolic content (TPC) of the samples. Results were expressed as mg of gallic acid equivalents (GAE) per g of sample on dry matter basis (Beta et al. 2005; Gao et al. 2002). Antioxidant activity (AA) measurements of the samples were carried out according to the DPPH (2,2-Diphenyl-2-picrylhydrazyl) method (Beta et al. 2005; Gyamfi et al. 1999). This method is based on the elimination of free radicals, through DPPH, by the antioxidant substances present in the sample. The mineral (Ca, Fe, K, Mg, P and Zn) content of samples was determined by inductively coupled plasma atomic emission spectrometer (ICP-AES) (Varian, Vista Model, Zug, Switzerland) (Skujins 1998).

Sensory analyses

Sensory analysis of the cooked fresh pasta samples was performed by 25 panellists (25–55 years) in terms of color, appearance, chewiness, taste, odor and overall acceptability, using the scale 1–7 (1: dislike extremely, 7: liked extremely).

Statistical analysis

For the statistical analysis, the JMP statistical program, version 10.0 (SAS Institute Inc., Cary, NC, USA) was used. The average of the main variation sources were compared at $p < 0.05$ level.

Results and discussion

Raw material properties

Chemical compositions and color values of wheat flour, WB and WG are shown in Table 2. Moisture content of raw materials ranged from 6.88 to 12.57%, with the highest value observed in wheat flour. Protein (21.44%) and fat (8.81%) content of WG were significantly ($p < 0.05$) higher than that of other raw materials. WG fraction is the richest source of protein and fat in wheat kernel. Compared to wheat flour, WB and WG have 6.0 and 5.3 fold much more ash and 17.7 and 10.8 fold much more cellulose content, respectively. The chemical composition results of this work generally are in agreement with the previous studies reported by Bilgiçli et al. (2006), Pınarlı et al. (2004). Please note that some results can show slight differences depending on the cultivar of the wheat, extraction

Table 2 Chemical properties and color values of raw materials

	Wheat flour	Wheat bran	Wheat germ
Moisture (%)	12.57 ± 0.12 ^a	8.51 ± 0.10 ^b	6.88 ± 0.03 ^c
Ash (%)	0.69 ± 0.00 ^c	4.16 ± 0.04 ^a	3.65 ± 0.04 ^b
Protein (%)	10.36 ± 0.04 ^c	13.63 ± 0.09 ^b	21.44 ± 0.08 ^a
Fat (%)	0.82 ± 0.03 ^c	4.99 ± 0.05 ^b	8.81 ± 0.01 ^a
Cellulose (%)	0.41 ± 0.02 ^c	7.25 ± 0.06 ^a	4.41 ± 0.03 ^b
Phytic acid (mg/100 g)	133.77 ± 1.86 ^c	2986.32 ± 3.09 ^a	2484.23 ± 4.95 ^b
TPC (mg GAE/g)	0.54 ± 0.62 ^b	1.35 ± 0.86 ^a	1.52 ± 0.94 ^a
AA (%)	15.83 ± 0.62 ^c	77.29 ± 0.86 ^b	91.03 ± 0.94 ^a
Minerals (mg/100 g)			
Ca	23.87 ± 0.11 ^c	70.89 ± 0.45 ^a	61.80 ± 0.37 ^b
Fe	1.39 ± 0.03 ^c	7.31 ± 0.05 ^a	6.55 ± 0.05 ^b
K	165.31 ± 0.83 ^c	931.62 ± 1.33 ^a	886.71 ± 1.21 ^b
Mg	35.00 ± 0.23 ^c	249.00 ± 0.33 ^b	271.00 ± 0.89 ^a
P	169.42 ± 0.54 ^c	660.14 ± 1.09 ^b	864.52 ± 1.60 ^a
Zn	0.74 ± 0.02 ^c	5.10 ± 0.12 ^b	8.90 ± 0.25 ^a
Color values			
<i>L</i> *	91.51 ± 0.03 ^a	72.70 ± 0.01 ^b	70.52 ± 0.05 ^c
<i>a</i> *	0.77 ± 0.03 ^c	4.70 ± 0.00 ^a	3.88 ± 0.01 ^b
<i>b</i> *	10.41 ± 0.03 ^b	20.52 ± 0.02 ^a	21.11 ± 0.05 ^a
SI	10.44 ± 0.02 ^b	21.06 ± 0.02 ^a	21.46 ± 0.04 ^a
Hue	85.77 ± 0.15 ^a	77.11 ± 0.01 ^c	79.60 ± 0.05 ^b

Means followed by the same letter within a row are not significantly different ($p < 0.05$). Chemical properties except moisture are based on dry matter

TPC Total phenolic content, AA Antioxidant activity

ratio and purification of milling by-products. Phytic acid content in wheat flour, WB and WG was found as 133.77 mg/100 g, 2986.32 mg/100 g and 2484.23 mg/100 g, respectively. The outer layer of the kernel were rich in both nutritional-functional components such as ash, protein, fat, cellulose, mineral, and phytic acid content which is considered as an anti-nutrient agent due to its negative effect on mineral bioavailability. Similar phytic acid results of wheat flour (337 mg/100 g), WB (3116 mg/100 g), and WG (2478 mg/100 g) were also reported by Bilgiçli et al. (2006). WG (91.03%) presented the highest antioxidant activity (AA), followed by WB (77.29%) and wheat flour (15.83%). Although WG has a descriptively higher total phenolic content (TPC) than WB, this difference is not statistically significant. Outer layer of the kernel (bran/germ) accounts for approximately 83% of the TPC of the whole meal flour. Both TPC and AA gradually decrease from the aleurone towards the inner layer (Adom et al. 2005; Laddomada et al. 2015). WB and WG were rich in minerals as obtained from the outer layer of the kernel. On the other hand, refined wheat flour has a considerably low amount of mineral compared to WB and WG. Ca, Fe and K content of WB were higher than WG, whereas Mg, P and Zn content were higher in WG. Similar results regarding

the mineral content of wheat flour, WB and WG have been reported by Bilgiçli et al. (2006). Refined wheat flour presented lower yellowish and reddish color compared to WB and WG due to the removal of the fractions containing colored pigments. Numerous studies in the related literature also indicate that wheat flour has lower yellowness and redness values than milling by-products (Aktaş et al. 2015; Bilgiçli et al. 2006; Ertaş 2016).

Color values of fresh pasta samples

Color values of filled and unfilled fresh pasta samples prepared with WB and WG are given in Table 3. Pasta samples containing WB demonstrated lighter and reddish color than that of containing WG. Usage of filling material in fresh pasta preparation decreased the lightness and redness in comparison to unfilled one. Generally, an increase in the WB and WG level in fresh pasta formulation resulted in a decrease in the lightness and Hue values. This can be related to the presence of dark pigments in WB and WG which becomes more visible when used at higher levels (Majzoobi et al. 2012). Fresh pasta samples formulated with WB and WG were more reddish and yellowish unlike the pasta samples prepared without WB and WG.

Table 3 Color values and cooking properties of filled and unfilled fresh pasta samples

Factor	n	L*	a*	b*	Hue	SI	Water uptake (%)	Volume increase (%)	Cooking loss (%)	Firmness (g)
Additive type										
Wheat bran	20	72.01 ± 3.85 ^a	3.60 ± 1.84 ^a	25.75 ± 1.13 ^b	82.08 ± 4.04 ^b	26.06 ± 1.16 ^b	102.74 ± 9.02 ^a	79.89 ± 14.52 ^a	4.37 ± 0.57 ^a	416.53 ± 36.46 ^b
Wheat germ	20	70.34 ± 4.40 ^b	3.30 ± 1.68 ^b	26.06 ± 1.20 ^a	82.82 ± 3.67 ^a	26.32 ± 1.22 ^a	99.78 ± 7.99 ^b	78.91 ± 6.26 ^a	4.04 ± 0.38 ^b	463.15 ± 8.48 ^a
Filling										
Unfilled	20	72.02 ± 4.52 ^a	3.71 ± 1.68 ^a	25.40 ± 0.83 ^b	81.61 ± 3.94 ^b	25.73 ± 0.60 ^b	97.83 ± 7.46 ^b	78.51 ± 13.28 ^b	4.19 ± 0.55 ^a	–
Filled	20	70.33 ± 3.70 ^b	3.19 ± 1.82 ^b	26.40 ± 1.25 ^a	83.30 ± 3.62 ^a	26.64 ± 1.44 ^a	104.69 ± 8.38 ^a	80.29 ± 8.51 ^a	4.22 ± 0.47 ^a	–
Additive ratio (%)										
0	8	77.41 ± 1.77 ^a	0.85 ± 0.40 ^e	25.58 ± 1.09 ^c	88.13 ± 0.82 ^a	25.59 ± 1.10 ^d	90.98 ± 2.97 ^e	65.70 ± 7.09 ^e	3.65 ± 0.04 ^e	474.53 ± 7.13 ^a
5	8	73.80 ± 1.33 ^b	2.40 ± 0.24 ^d	25.72 ± 0.28 ^c	84.67 ± 0.54 ^b	25.83 ± 0.28 ^c	95.70 ± 3.62 ^d	74.44 ± 2.27 ^d	3.83 ± 0.15 ^d	448.27 ± 17.49 ^b
10	8	70.16 ± 1.34 ^c	3.52 ± 0.36 ^c	26.01 ± 0.62 ^b	82.28 ± 0.95 ^c	26.25 ± 0.57 ^b	100.93 ± 4.55 ^c	78.08 ± 2.43 ^c	4.11 ± 0.23 ^c	438.06 ± 25.88 ^c
15	8	68.18 ± 1.33 ^d	4.61 ± 0.40 ^b	25.99 ± 1.20 ^b	79.89 ± 1.25 ^d	26.40 ± 1.13 ^b	106.69 ± 4.96 ^b	84.69 ± 2.37 ^b	4.49 ± 0.20 ^b	428.61 ± 30.37 ^d
20	8	66.31 ± 1.02 ^e	5.87 ± 0.26 ^a	26.22 ± 1.88 ^a	77.31 ± 1.24 ^e	26.87 ± 1.80 ^a	112.01 ± 4.96 ^a	94.09 ± 10.38 ^a	4.94 ± 0.35 ^a	409.75 ± 44.29 ^e

Means followed by the same letter within a column are not significantly different ($p < 0.05$). Firmness values were determined only in the unfilled pasta samples (n values for additive type factor were 10:10, for additive ratio factor were 4:4:4:4, respectively)

These effects observed might be related to color properties of the raw materials (Table 2). Moreover, the red color component might be the result of non-enzymatic browning related to the Maillard or carbonyl-amino reactions (Pinarlı et al. 2004). Heat treatment applied with the steam at 91 °C for 9 min can induce Maillard reaction especially in pasta samples containing WB and WG due to their high protein content. Similar findings have been reported for pasta samples by Wojtowicz and Moscicki (2011), macaroni samples by Pinarlı et al. (2004), noodle samples by Aktaş et al. (2015), and flat bread samples by Ertaş (2016).

Cooking quality of fresh pasta samples

Cooking quality is the most important quality attribute for pasta, including optimal WU, VI and minimum CL. These attributes of pasta are related to the gelatinization rates of starch and chemical composition of the raw material used. Table 3 shows the cooking properties of fresh pasta samples. WU, VI and CL values of the pasta samples changed between 90.98 and 112.01%; 65.70 and 94.09%; 3.65 and 4.94%, respectively. The utilization of WG in pasta formulations resulted in lower WU and CL values in comparison to WB. Higher cellulose content of WB (7.25%) than WG (4.41%) may have been effective on obtaining this result. The use of filling material did not change CL significantly. An increase in the amount of milling by-products in pasta formulations also caused an increase in all the cooking parameters, such as WU, VI and CL. Pinarlı et al. (2004) stated that the increasing water absorption may be caused by the higher water retention capacity of WB and WG due to their high cellulose content. Disruptions in the protein matrix by bran particles would promote water absorption and facilitate starch granule swelling (Kaur et al. 2012). Maximum VI (94.09%) values of pasta was observed in 20% addition level of milling by-products. Similarly, increase in volume expansion values of pasta enriched with different cereal bran have been reported by Kuar et al. (2012). Increasing amount of WB and WG in pasta formulation increased CL value significantly ($p < 0.05$). This increase in CL could be due to a disruption of the protein–starch matrix by WB and WG particles along with the presence of water-soluble components within the bran and aleurone layers. This led to greater CL in cooked fresh pasta (Kaur et al. 2012). Similarly, CL values of noodles prepared using different ratios of WG increased from 5.8% up to 7.3% (Aktaş et al. 2015).

Firmness values of cooked-unfilled fresh pasta samples are also shown in Table 3. Filled pasta samples were not subjected to firmness measurements due to the lack of homogeneous appearance and structure. Results obtained in this study show that textural characteristics of the pasta may be affected by the type and rate of milling by-

products. The addition of both WB and WG reduced the firmness values of cooked-pasta samples, e.g. the firmness value recorded with milling by-product (20%) was 409.75 g whereas the control value was recorded as 474.53 g. The reduction in pasta firmness may be associated with the role of fiber which disrupt the protein–starch matrix within the pasta microstructure. Also these results are agreement with the findings obtained by Tudorica et al. (2002), who reported that fortification of pasta with some fiber resulted in moderate reduction in pasta firmness. Pasta firmness can be also associated to the hydration of the starch granules during the cooking process and the subsequent embedding of gelatinized starch granules in a matrix of partially denatured protein. As such, the decrease in firmness may be related with a reduction in starch gelatinisation in the pasta (Brennan et al. 2004). Moreover, Kordonowy and Youngs (1985) reported that the firmness values of samples decreased with increasing amount of WB usage in spaghetti formulations. This decrease is attributed to the diluting effect of WB on gluten cohesiveness. Also Pinarlı et al. (2004) and Rayas-Duarte et al. (1996) reported similar results with the usage of WG in macaroni samples and dark buckwheat-amaranth in spaghetti formulations, respectively.

Chemical characteristics of fresh pasta samples

The results of chemical properties of fresh pasta samples are presented in Table 4. Since WG is richer in protein, fat, and AA (see Table 2) compared to WB, fresh pasta prepared using WG resulted in higher protein, fat and AA content. Table 4 shows that the cellulose and phytic acid content of fresh pasta are higher in the presence of WB. Most fibers are located in the outer layers of the grain (pericarp and seed coat) and are generally called WB. Similarly, phytic acid mainly concentrated in the outer layers of the kernel i.e. pericarp and aleurone, as well as, in the WG with a partially lower ratio (Stevenson et al. 2012). The positive effects of dietary fiber intake on reducing certain diseases risks such as cardiovascular disease, diabetes and cancer have been reported in literature (Onipe et al. 2015). Phytic acid is an anti-nutritional component that reduces the bioavailability of minerals such as Ca, Fe, Zn, Mg and Cu (Rickard and Thompson 1997). In contrast to the anti-nutritional properties of phytic acid, studies have suggested that it might possess an anticarcinogenic effect (Stevenson et al. 2012). The use of filling material resulted in an increase in the moisture, ash, protein, fat content and AA of the samples. The reduced phytic acid content in the filled fresh pasta samples compared to unfilled ones was due to the low level of phytic acid content in the filling material. An increment in the ratio of WB or WG in fresh pasta formulations significantly ($p < 0.05$)

Table 4 Chemical properties of the filled and unfilled fresh pasta samples

Factor	n	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Cellulose (%)	Phytic acid (mg/100 g)	TPC (mg GAE/g)	AA (%)
Additive type									
Wheat bran	20	36.84 ± 6.02 ^b	1.75 ± 0.67 ^a	13.13 ± 0.96 ^b	3.69 ± 1.93 ^b	0.89 ± 0.42 ^a	389.44 ± 186.19 ^a	0.63 ± 0.08 ^a	24.91 ± 5.83 ^b
Wheat germ	20	37.76 ± 5.82 ^a	1.72 ± 0.66 ^a	14.02 ± 1.61 ^a	4.04 ± 2.03 ^a	0.53 ± 0.21 ^b	354.11 ± 163.38 ^b	0.65 ± 0.09 ^a	27.88 ± 8.08 ^a
Filling									
Unfilled	20	31.63 ± 1.98 ^b	1.10 ± 0.23 ^b	12.56 ± 0.87 ^b	1.93 ± 0.41 ^b	0.80 ± 0.41 ^a	376.04 ± 175.99 ^a	0.63 ± 0.08 ^a	25.77 ± 7.29 ^b
Filled	20	42.98 ± 1.49 ^a	2.37 ± 0.20 ^a	14.59 ± 1.05 ^a	5.81 ± 0.44 ^a	0.61 ± 0.32 ^b	367.51 ± 176.00 ^b	0.66 ± 0.09 ^a	27.01 ± 7.05 ^a
Additive ratio (%)									
0	8	34.77 ± 0.621 ^e	1.43 ± 0.65 ^e	12.52 ± 1.10 ^e	3.34 ± 1.93 ^e	0.30 ± 0.05 ^e	125.64 ± 5.14 ^e	0.54 ± 0.04 ^d	17.12 ± 1.04 ^e
5	8	36.43 ± 5.64 ^d	1.59 ± 0.65 ^d	13.08 ± 1.23 ^b	3.62 ± 1.94 ^b	0.48 ± 0.14 ^d	251.35 ± 10.74 ^d	0.60 ± 0.05 ^{cd}	21.47 ± 0.81 ^d
10	8	37.42 ± 5.69 ^c	1.74 ± 0.64 ^c	13.55 ± 1.25 ^c	3.89 ± 1.97 ^c	0.71 ± 0.21 ^c	370.89 ± 22.72 ^c	0.64 ± 0.05 ^{bc}	25.69 ± 1.20 ^c
15	8	38.41 ± 5.61 ^b	1.89 ± 0.62 ^b	14.04 ± 1.16 ^b	4.13 ± 1.96 ^b	0.93 ± 0.31 ^b	484.84 ± 22.48 ^b	0.69 ± 0.05 ^{ab}	31.04 ± 2.86 ^b
20	8	39.50 ± 5.38 ^a	2.03 ± 0.61 ^a	14.69 ± 1.16 ^a	4.36 ± 1.96 ^a	1.20 ± 0.35 ^a	626.15 ± 34.96 ^a	0.74 ± 0.05 ^a	36.66 ± 3.19 ^a

Means followed by the same letter within a column are not significantly different ($p < 0.05$). Chemical properties except moisture are based on dry matter

TPC Total phenolic content, AA Antioxidant activity

increased ash, protein, fat, cellulose, phytic acid, TPC content and AA. These findings are in agreement with an increase observed in ash, protein and fat content of macaroni with the addition of WG (Pınarlı et al. 2004), ash, protein, fat and phytic acid content of cake enriched with WG (Bilgiçli and Levent 2013).

Mineral content of fresh pasta samples are illustrated in Table 5. The substitution of WB and WG into fresh pasta formulations caused the highest increment in the Ca, Fe, and K content; and Mg, P and Zn content, respectively. Filling material increased the K, Mg, and especially Ca and P content of the fresh pasta samples. The amount of Ca in the filling material was determined as 926.74 mg/100 g, which resulted in a significant increase in the Ca content of the final product. Compared to fresh pasta without WB and WG, the highest ratio of milling by-products (20%) increased the mean values of Ca, Fe, K, Mg, P and Zn of the fresh pasta samples about 1.09-, 1.44-, 1.77-, 3.24-, 1.37- and 2.16-fold, respectively. Similarly, the mineral content of noodle (Aktaş et al. 2015), cake (Bilgiçli and Levent 2013), tarhana (Bilgiçli et al. 2006) and flat breads (Ertaş 2016) increased upon addition of WB or WG due to their rich mineral content.

Sensory properties of fresh pasta samples

Sensory analysis results of fresh pasta samples are presented in Fig. 1. High utilization ratios of WB or WG in filled/unfilled pasta formulation reduced the color values, with a more pronounced reduction when WB was used. Appearance and chewiness values of all pasta samples were also adversely affected at high ratios of WB or WG. Generally, taste and odor values of filled/unfilled pasta

samples prepared using WG were more appreciated by the panelist in comparison to samples containing WB. Moreover, WG usage (except 20% level) in pasta formulations presented a higher/closer taste and odor score to control filled/unfilled pasta samples. On the other hand, WB usage above 10% resulted in a decrease on the taste and odor scores of filled/unfilled pasta samples. High ratios (15–20%) of WB or WG reduced the overall acceptability of all pasta samples. It can be concluded that WB and WG can be used in fresh pasta production up to 10% and 15%, respectively. Majzoobi et al. (2012) stated that WG substituted (particularly 15%) flat bread affected taste and general acceptability of the bread positively. Moreover, incorporation of WB (25%) into pasta formulation resulted in the best odor and taste (Amel et al. 2015).

Conclusion

This study investigated some quality properties of filled/unfilled fresh pasta prepared with wheat milling by-products. Utilization of WB and WG in fresh pasta enhanced the chemical and nutritional properties. Moreover, using filling material provided a significant increase in ash, protein, fat and more specifically Ca and P content. On the other hand, phytic acid content increased up to fivefold in the presence of wheat milling by-products. The results of this study showed that the highest level of WB and WG revealed a maximum improvement on the nutritional properties of fresh pasta. However, high ratios of WB and WG had an adverse effect on the sensory quality, cooking loss and color values of pasta formulations. When all nutritional, physical and sensory properties of fresh pasta

Table 5 Mineral content (mg/100 g) of filled and unfilled fresh pasta samples

Factor	n	Ca	Fe	K	Mg	P	Zn
Additive type							
Wheat bran	10	126.20 ± 91.13 ^a	2.52 ± 0.37 ^a	271.75 ± 55.38 ^a	49.76 ± 20.26 ^b	336.77 ± 74.71 ^b	1.35 ± 0.29 ^b
Wheat germ	10	123.30 ± 89.49 ^b	2.48 ± 0.29 ^b	267.20 ± 53.16 ^b	51.51 ± 20.79 ^a	355.29 ± 79.13 ^a	1.71 ± 0.53 ^a
Filling							
Unfilled	20	34.53 ± 4.19 ^b	2.55 ± 0.35 ^a	260.57 ± 56.56 ^b	43.34 ± 20.77 ^b	279.55 ± 41.52 ^b	1.55 ± 0.50 ^a
Filled	20	214.97 ± 4.54 ^a	2.45 ± 0.31 ^b	278.37 ± 50.45 ^a	57.93 ± 17.50 ^a	412.52 ± 38.09 ^a	1.52 ± 0.43 ^a
Additive ratio (%)							
0	4	119.06 ± 89.99 ^c	2.04 ± 0.06 ^c	193.95 ± 15.21 ^e	24.07 ± 9.73 ^c	292.59 ± 68.45 ^c	0.97 ± 0.07 ^c
5	4	122.14 ± 90.76 ^d	2.27 ± 0.06 ^d	232.59 ± 9.79 ^d	37.58 ± 8.30 ^d	319.00 ± 68.18 ^d	1.23 ± 0.07 ^d
10	4	124.66 ± 90.24 ^c	2.50 ± 0.03 ^c	267.57 ± 8.29 ^c	49.18 ± 7.61 ^c	345.44 ± 65.16 ^c	1.55 ± 0.18 ^c
15	4	127.34 ± 90.39 ^b	2.73 ± 0.09 ^b	308.79 ± 9.52 ^b	64.24 ± 6.81 ^b	373.41 ± 68.09 ^b	1.82 ± 0.29 ^b
20	4	130.56 ± 89.81 ^a	2.95 ± 0.13 ^a	344.48 ± 5.74 ^a	78.10 ± 4.92 ^a	399.72 ± 67.86 ^a	2.10 ± 0.36 ^a

Means followed by the same letter within a column are not significantly different ($p < 0.05$). Mineral content are based on dry matter

Fig. 1 Effect of additive type and filling materials on sensory attributes of unfilled (a, b) and filled (c, d) fresh pasta

were taken into account, it can be safely said that WB and WG can be used in pasta preparation up to 10% and 15%, respectively.

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