Acta Alimentaria 50 (2021) 4, 548–556
DOI: 10.1556/066.2021.00107

AKADÉMIAI KIADÓ

Effects of shorts, by-product of milling, on the chemical composition and quality properties of pasta

K. Aktaş[1], H. Levent[2], S. Yeşil[3] and E. Adıgüzel[2*]

[1] Department of Gastronomy and Culinary Arts, School of Applied Sciences, Karamanoğlu Mehmetbey University, 70200, Karaman, Turkey

[2] Department of Nutrition and Dietetics, Faculty of Health Sciences, Karamanoğlu Mehmetbey University, 70200, Karaman, Turkey

[3] Department of Food Engineering, Faculty of Engineering, Karamanoğlu Mehmetbey University, 70200, Karaman, Turkey

ORIGINAL RESEARCH PAPER

Received: May 2, 2021 • Accepted: July 30, 2021
Published online: October 18, 2021

ABSTRACT

The aim of this study was to investigate the effects of wheat shorts, a milling by-product, on some properties of pasta. For this purpose, wheat semolina was replaced with wheat shorts at 15, 30, and 45% levels in pasta formulation. Some physical, chemical, and sensory properties of pasta samples were evaluated and compared with control samples prepared with durum wheat semolina. As the concentrations of shorts increased in the pasta formulation, the brightness values decreased and the redness values increased. The ash, fat, total dietary fibre, total phenolic content, antioxidant activity, and mineral content increased with the use of shorts. The highest solid loss value (10.28%) was found in pasta samples containing 45% shorts. The addition of shorts up to 30% presented similar overall acceptability scores to control pasta samples. As a result, it was observed that as the shorts content of the samples increase, the nutritional value and the levels of some components that affect health positively, increase as well. So, the samples containing 30% shorts appear to be at forefront due to health effects and overall acceptability scores.

* Corresponding author. Tel.: +90 338 226 2000/4345. E-mail: adiguzlemre@gmail.com

KEYWORDS

milling by-product, pasta, wheat, shorts

1. INTRODUCTION

Wheat as one of the staple foods has been cultivated for more than 10,000 years, and today the estimated wheat production is 774 million tons around the world (FAO, 2021). Therefore, the wheat milling industry that continues to develop each passing day produces a large amount of different by-products during separating the endosperm. The obtained by-products from the milling industry can be called as germ, red-dog flour, bran, and shorts (Serna-Saldivar, 2010). Wheat bran involves pericarp, testa, and aleurone layers and it approximately consists of 14–19% of the weight of a wheat grain. Wheat bran is a unique source of highly concentrated dietary fibres, minerals, B-group vitamins, and some bioactive compounds (Onipe et al., 2015). Cankurtaran and Bilgiçli (2019) reported that wheat bran has 13.63% protein, 4.16% ash, 4.99% fat, 7.25% cellulose, and 1.35 mg GAE/g total phenolic content. On the other hand, the milling by-product shorts include small pieces of pericarp, germ, aleurone, and even low grade flours. Therefore, this by-product is well-balanced in terms of fibre, protein, and even carbohydrates (starch). The shorts are especially rich in B-group vitamins associated with the aleurone layer. Also this fraction has a high oil and phytochemical content. The crude fibre, crude protein, fat, Ca, P, thiamine, and riboflavin contents of wheat shorts were reported as 6.8%, 16.5%, 4.6% 0.09%, 0.81%, 19.1, and 4.2 mg kg^{-1}, respectively. Most of shorts are blended with bran and the blend is widely used for animal feeding (Serna-Saldivar, 2010).

Recently, there has been a growing interest in consuming whole grains as a number of health benefits have been discovered. Epidemiological studies have reported that regular consumption of whole grains and whole grain products is related to reduced risk of different types of chronic diseases, such as cardiovascular disease, type 2 diabetes and some cancer types. Furthermore, the researches have shown that these beneficial effects come from phytochemicals and antioxidant components in whole grains (Liu, 2007). As a result of the awareness of consuming whole grain, a great number of whole grain added functional food formulations have been introduced. Although the number of enriched food products with wheat bran in market was only 52 in 2001, this number has approximately gone up to 800 by 2011 (Onipe et al., 2015). In this context, pasta is one of the most studied food products owing to its simple ingredients and preparation, long shelf life, and low cost. Especially, researchers have endeavoured to enhance the nutritional composition of pasta after the authorisation of Food and Drug Administration of the United States (FDA) about enrichment of pasta with vitamins and iron in 1949 (Brennan, 2013).

This study focused on utilisation of wheat shorts rather than wheat bran in pasta production. For this purpose, some chemical and quality properties of wheat shorts added pasta samples were investigated.

2. MATERIALS AND METHODS

2.1. Materials

The basic ingredient, semolina, was obtained from Golda Gıda San. A.Ş. in Karaman, Turkey, and the milling by-product, shorts was supplied by a local milling factory in Karaman, Turkey.

2.2. Preparation of pasta

The four pasta samples were prepared by modifying the method specified by Ajila et al. (2010), using a durum wheat semolina/water ratio of approximately 100:30. Semolina in pasta formulation was replaced by 15, 30, and 45% shorts. An additional sample without shorts was also prepared as a control. Semolina (1,500 g) with warm (40 ± 2 °C) distilled water (~500 ml) were premixed in a mixer (Kitchen aid, USA) at low speed for 5 min to ensure an even distribution of water. The premixed dough was then transferred to a laboratory-type pasta machine (La Monferrina, Dolly, Italy) and mixed for another 10 min. The moisture content of the shorts-containing pasta samples was adjusted during manufacture taking into account the water absorption levels of the shorts to produce a visually optimal dough prior to extrusion. Then the mixture was extruded and cut using a penne mold. The dried samples were stored in polyethylene bags until further analysis.

2.3. Chemical composition

Chemical analyses were conducted on dry matter basis. The moisture, ash, protein, and fat contents were estimated by the methods of AACC 44-19, 08-01, 46-12, and 30-25, respectively (AACC, 1990). The proximate carbohydrate content and the energy value were calculated according to Desai et al. (2018). The total fat, protein, ash, and moisture contents were used for carbohydrate content calculation, and the energy value was calculated with the equation Eq. (1).

$$\text{Energy value}\left(\text{kcal kg}^{-1}\right) = (4\times\text{protein}(\%)) + (9\times\text{lipid}(\%)) + (4\times\text{carbohydrate}(\%)) \tag{1}$$

Total dietary fibre analysis was performed by an enzymatic method according to AACC 32-07 (AACC, 1990). The conducted analyses for the total phenolic content (TPC) and antioxidant activity determination were performed according to method of Wronkowska et al. (2010). The TPC of extracts were determined colorimetrically using Folin–Ciocalteu phenol reagent, and the results were expressed in mg of gallic acid equivalent (GAE) per kg dry-weight basis. The antioxidant activity of the sample extracts was measured using 2,2 diphenyl-1-picrylhydrazyl (DPPH) radical, and the results were calculated with the equation Eq. (2).

$$\text{Antioxidant activity} = \left[1 - \left(\text{Abs sample}_{t=20}/\text{Abs control}_{t=0}\right)\right]\times 100 \tag{2}$$

A colorimetric method was used for the determination of phytic acid. For spectrophotometrical measurement of phytic acid, remaining iron was determined after the extraction with HCl and precipitation with Fe (III) solution. Besides, the phytate phosphorus value was calculated with factor 3.546 (Haug and Lantzsch, 1983). The Ca, Mg, Cu, Fe, and Zn contents of the samples were measured by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) Agilent 720 (Agilent Technologies, USA). Nitric acid and perchloric acid were used for concentration of dry samples (Levent et al., 2020).

2.4. Colour measurements

The colour measurements were implemented with L^* (white; black), a^* (red; green), and b^* (yellow; blue) values using a Hunter Lab Colour QUEST II Minolta CR-400 (Minolta Camera, Co., Ltd., Osaka, Japan) instrument. All measurements were obtained from three different points. The total colour difference (ΔE^*) was calculated with the equation Eq. (3).

$$\Delta E = \left((L_c - L_i)^2 + (a_c - a_i)^2 + (b_c - b_i)^2\right)^{1/2} \quad (3)$$

The L_c, a_c, and b_c references are colour parameters of the control sample, on the other hand, L_i, a_i, and b_i references are colour parameters of the enriched pasta samples. ΔE is usually classified as a trace level (0–0.5), slight (0.5–1.5), noticeable (1.5–3.0), appreciable (3.0–6.0), large (6.0–12.0), and obvious difference (>12.0) (Zarzycki et al., 2020).

The whiteness index (WI) of the pasta sample was also calculated according to the equation Eq. (4) (Zarzycki et al., 2020).

$$\mathrm{WI} = 100 - \left((100 - L)^2 + a^2 + b^2\right)^{1/2} \quad (4)$$

2.5. Cooking properties

Water absorbtion and volume expansion values were determined according to Kaur et al. (2012). The solid loss was determined according to the AACC-approved method 66-50 (AACC, 1990). The weighed four pasta samples (10 g) were cooked in 250 ml boiling water for 10 min with occasional stirring. The water absorption and volume expansion ratios were calculated from the increase in weight and volume during the cooking of pasta. The amount of solid loss was calculated by the evaporation of cooking water in the beaker.

2.6. Sensory evaluation

The four pasta samples were cooked in boiling water for 10 min and used in sensory analysis after being drained. The sensory properties of pasta samples were evaluated with 15 panellists (untrained) in the age group of 26–48. The pasta samples were coded with different letters and served to the panellists in a random order to avoid any bias. Before testing new samples, the panellists were asked to clean their mouths with purified drinking water. Different sensory attributes (colour, appearance, hardness, cohesiveness, taste-odour, and overall acceptability) were evaluated using a five point hedonic scaling system (like very much [5]; dislike very much [1]).

2.7. Statistical analysis

The assessment of the differences obtained from the results was performed by One Way Analysis of Variance (ANOVA) using Statistical Package for the Social Sciences software (SPSS Inc., Chicago, IL, USA). Duncan's Multiple Range Test was conducted for comparing of the means that were statistically different from each other.

3. RESULTS AND DISCUSSION

3.1. Chemical composition of raw materials and pasta samples

The chemical composition of raw materials and pasta samples are presented in Table 1. Compared to durum wheat semolina, wheat shorts have 4.6, 1.2, 6.1, and 6.9 fold more ash, protein, fat, and total dietary fibre contents, respectively. The phytic acid contents of durum

Table 1. Chemical composition of raw materials and pasta samples with 0–45% wheat shorts contents

	Raw materials		*Pasta samples*			
	Durum wheat semolina	Wheat shorts	Control	15%	30%	45%
Moisture (%)	10.3 ± 0.7	8.1 ± 0.9	9.1 ± 0.7^{a}	8.8 ± 0.2^{a}	7.5 ± 0.4^{a}	8.1 ± 0.6^{a}
Ash (%)	0.9 ± 0.1	4.1 ± 0.1	0.1 ± 0.03^{c}	2.1 ± 0.1^{b}	2.3 ± 0.03^{ab}	2.3 ± 0.1^{a}
Protein (%)	11.0 ± 0.2	13.3 ± 0.1	11.8 ± 0.1^{a}	12.3 ± 0.5^{a}	12.7 ± 0.6^{a}	13.2 ± 0.9^{a}
Fat (%)	0.8 ± 0.1	4.9 ± 0.5	0.4 ± 0.1^{c}	1.6 ± 0.1^{b}	2.1 ± 0.2^{ab}	2.6 ± 0.3^{a}
Carbohydrate (%)	77.0 ± 1.1	69.6 ± 1.6	77.8 ± 1.3^{a}	75.2 ± 0.1^{ab}	75.3 ± 0.0^{ab}	73.8 ± 0.7^{b}
Total dietary fibre (mg kg^{-1})	44.0 ± 5.3	304.2 ± 24.8	42.4 ± 3.7^{c}	99.3 ± 15.2^{bc}	142.2 ± 9.2^{b}	183.3 ± 25.1^{a}
Energy (kcal kg^{-1})	3592.0 ± 27	3757.0 ± 15	3615.2 ± 61.7^{a}	3645.9 ± 13.1^{a}	3710.8 ± 39.6^{a}	3714.1 ± 35.9^{a}
Total phenolic content (mg GAE/kg)	581.4 ± 4.2	1512.0 ± 3.7	475.3 ± 8.9^{d}	702.6 ± 14.4^{c}	819.7 ± 10.2^{b}	902.6 ± 11.1^{a}
Antioxidant activity (%)	13.8 ± 1.0	57.8 ± 1.3	13.0 ± 3.4^{b}	23.0 ± 1.8^{a}	27.1 ± 0.4^{a}	30.0 ± 1.3^{a}
Phytic acid (g kg^{-1})	0.16 ± 0.0	5.01 ± 0.0	1.9 ± 0.0^{d}	2.4 ± 0.0^{c}	3.0 ± 0.0^{b}	3.5 ± 0.0^{a}
Phytate phosphorus (mg kg^{-1})	45.8 ± 0.69	1427.1 ± 13.6	550.4 ± 14.4^{d}	703.7 ± 3.3^{c}	852.3 ± 11.7^{b}	1004.1 ± 10.4^{a}
Ca (mg kg^{-1})	248.3 ± 5.6	722.3 ± 15.7	270.6 ± 2.2^{d}	396.2 ± 13.4^{c}	562.3 ± 37.9^{b}	713.8 ± 27.6^{a}
Mg (mg kg^{-1})	314.5 ± 13.7	2924.4 ± 30.9	269.2 ± 26.9^{d}	658.8 ± 23.3^{c}	977.2 ± 16.9^{b}	1246.1 ± 39.5^{a}
Cu (mg kg^{-1})	4.9 ± 0.7	13.1 ± 0.7	3.7 ± 0.8^{c}	4.9 ± 0.3^{bc}	5.8 ± 0.0^{ab}	7.4 ± 0.4^{a}
Fe (mg kg^{-1})	14.2 ± 3.6	68.3 ± 4.6	15.6 ± 1.2^{d}	22.4 ± 1.6^{c}	30.8 ± 2.2^{b}	39.3 ± 0.8^{a}
Zn (mg kg^{-1})	11.8 ± 0.5	55.5 ± 6.6	12.6 ± 0.3^{c}	19.0 ± 1.1^{b}	24.8 ± 0.4^{b}	33.4 ± 2.8^{a}

Mean values displayed with different letters in a row significantly differ by Duncan's multiple range test (P < 0.05).

wheat semolina and wheat shorts were 0.16 g kg^{-1} and 5.01 g kg^{-1}, respectively. Phytic acid is considered an anti-nutritional agent due to its negative effect on mineral bioavailability. It is reported that the phytate is concentrated in the aleuron layer of the wheat in mature grains (Kaur et al., 2012). The total phenolic content and antioxidant activity of the wheat semolina and wheat shorts were 581.4 and 1,512.0 mg GAE/kg and 13.8 and 57.8%, respectively. Despite the high amount of phytic acid, shorts have a much higher total phenolic content and antioxidant activity than wheat semolina. The bioactive phytochemicals, which are concentrated in the outer layers of wheat (bran and germ fractions), contain phenolic acids, tocopherols, carotenoids, alkylresorcinols, sterols, benzoxazinoids, steryl ferulates, and lignans. These compounds have high antioxidant activity and many health benefits (Luthria et al., 2015). When the mineral contents of raw materials were compared, it was determined that shorts contains 2.9, 9.3, 2.7, 4.8, and 4.7 times more Ca, Mg, Cu, Fe, and Zn than semolina. The ash, fat, and total dietary fibre contents of the pasta samples were significantly ($P < 0.05$) affected by shorts usage in the pasta formulation. The ash, fat, and total dietary fibre contents of the pasta samples prepared with shorts ranged between 2.1–2.3%, 1.6–2.6%, and 99.3–183.3 mg kg^{-1}, respectively. The lowest carbohydrate content (73.8%) was determined in samples containing 45% shorts. The pasta samples were not significantly different in terms of energy values. Similarly, Sobota et al. (2015) reported that the ash, protein, lipid, and total dietary fibre contents of pasta samples increased with the use of wheat bran in pasta formulation (20–40%). The total phenolic content and antioxidant activity of control samples significantly increased with the use of shorts ($P < 0.05$). Similar to our results, Pasqualone et al. (2017) reported that the bread samples with durum wheat milling by-products contained significantly higher total soluble phenolic compounds than the control samples (remilled semoline bread). They also stated that *in vitro* antioxidant activities of bread samples with wheat milling by-products were statistically significantly higher than the control samples.

The phytic acid and phytate phosphorus contents of the control sample increased from 1.9 g kg^{-1} and 550.4 mg kg^{-1} to 3.5 g kg^{-1} and 1,004.1 mg kg^{-1} at 45% shorts, respectively. All investigated mineral (Ca, Mg, Cu, Fe, and Zn) contents increased with the use of shorts in pasta formulation. This increase in the amount of mineral contents was between 2.0 and 4.6 times compared to control at 45% shorts. The shorts, obtained from the outer layer of the grain, was a rich source of minerals. Our results are in accordance with the findings reported by Cankurtaran and Bilgiçli (2019).

3.2. Colour values

Wheat shorts presented a darker, more reddish, and more yellowish colour than durum wheat semolina (Table 2). An increase in the amount of shorts in pasta formulations decreased the lightness (L^*) value. The lowest L^* value was determined in pasta samples containing 45% shorts. The addition of shorts to the pasta formulation decreased the brightness and increased the redness values of pasta samples compared to the control. These results agree with the findings reported by Kaur et al. (2012), who observed that the usage of cereal brans in pasta formulation (0–25%) resulted in darker, more reddish, and less yellowish colour. WI values in pasta samples varied between 69.5 and 74.7 and decreased as the concentration of shorts increased in pasta formulation.

Table 2. Colour measurements of raw materials and pasta samples with 0–45% wheat shorts contents

	L^*	a^*	b^*	ΔE	WI
Raw materials					
Durum wheat semolina	88.6 ± 0.2	-1.1 ± 0.4	20.9 ± 0.1	-	-
Wheat shorts	70.9 ± 0.1	4.8 ± 0.1	21.6 ± 0.4	-	-
Pasta samples					
Control	86.0 ± 0.8^a	-1.2 ± 0.1^d	21.1 ± 0.1^a	-	74.7 ± 0.5^a
15%	80.8 ± 0.7^b	1.7 ± 0.1^c	18.8 ± 0.4^b	6.4 ± 1.1^a	73.1 ± 0.8^{ab}
30%	78.9 ± 0.8^{bc}	2.5 ± 0.2^b	18.7 ± 0.3^b	8.4 ± 1.3^a	71.7 ± 0.7^{bc}
45%	76.0 ± 0.5^c	3.1 ± 0.1^a	18.6 ± 0.1^b	11.2 ± 1.2^a	69.5 ± 0.4^c

Mean values displayed with different letters in a column are significantly different by Duncan's multiple range test ($P < 0.05$).

Table 3. Cooking properties of pasta samples with 0–45% wheat shorts contents

	Water absorption (%)	Volume expansion (mL g^{-1})	Solid loss (%)
Control	175.9 ± 9.3^a	1.7 ± 0.02^b	6.6 ± 0.6^b
15%	189.1 ± 3.1^a	1.8 ± 0.1^{ab}	7.6 ± 0.3^b
30%	193.3 ± 3.6^a	1.9 ± 0.01^a	8.8 ± 0.1^{ab}
45%	197.7 ± 5.3^a	1.9 ± 0.1^a	10.3 ± 1.1^a

Mean values displayed with different letters in a column are significantly different by Duncan's multiple range test ($P < 0.05$).

3.3. Cooking properties

The water absorption values in pasta samples varied between 175.9% and 197.7% (Table 3). Although the water absorption values tended to increase as the shorts ratio increased, the water absorption values of the pasta samples were not significantly different from each other. The use of shorts resulted in an increase in volume expansion and solid loss of the pasta samples. Petitot et al. (2010) stated that the non-gluten proteins and insoluble fibres, which weaken the overall structure of pasta, are the main factors that increase the solid loss in pasta. Sobota et al. (2015) also reported that dry matter losses during cooking increased with the increase in the high fibre component (wheat bran) content in the pasta samples.

3.4. Sensory evaluation

Sensory properties of pasta samples are shown in Fig. 1. The appearance, hardness, cohesiveness, and taste-odour were not affected significantly by shorts usage in pasta formulation, but the increase in the shorts ratio caused a decrease in the colour score. Inclusion of shorts in the formulation at 30% or more decreased colour scores of the pasta samples. Also, the overall acceptability scores of the pasta samples with 45% shorts were significantly lower than of the control samples. The sensory analysis results revealed that the use of up to 30% shorts resulted

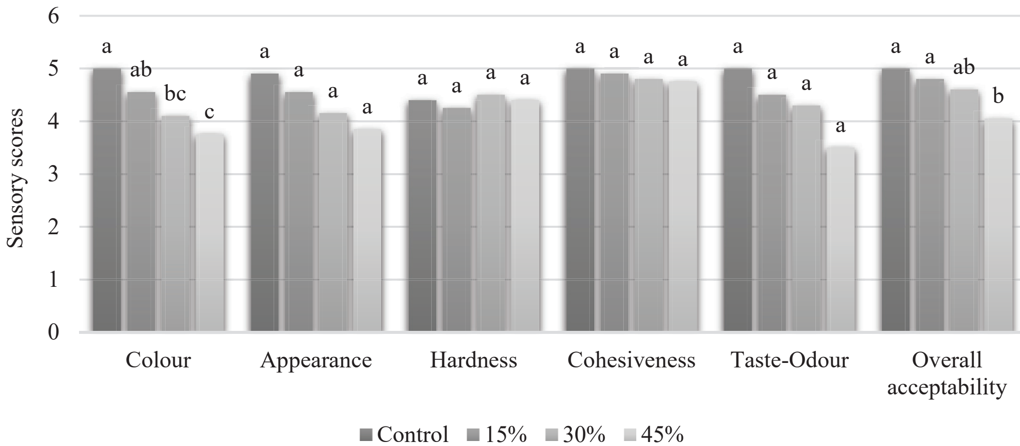

Fig. 1. Sensory evaluation of pasta samples with 0–45% wheat shorts contents
Mean values displayed with different letters are significantly different by Duncan's multiple range test ($P < 0.05$).

in acceptable pasta properties. In the study conducted by Kaur et al. (2012), the pasta samples were enriched with wheat, rice, barley, and oat brans (0–25%). It was reported that the cereal bran up to 15% can be used in the formulation for maximum acceptability score of enriched samples.

4. CONCLUSIONS

The use of wheat shorts increased the chemical properties (ash, fat, total dietary fibre, total phenolic content, and antioxidant activity) of pasta. As the shorts concentration increased in pasta formulation, volume expansion, Ca, Mg, Cu, Fe, and Zn contents increased. Shorts negatively affected solid loss, colour values, phytic acid and phytate phosphorus contents of pasta. Phytase enzymes can be used to reduce the phytic acid content of shorts reflected in pasta products, or some dephytinisation methods such as grinding, fermentation, soaking, or combinations of these methods can be applied. The total colour difference of pasta samples increased with increasing ratio of shorts. As a result of the sensory analyses, the pasta samples containing 30% shorts gained overall acceptability scores similar to the control. So, considering health effects, the samples containing 30% shorts seem to be generally acceptable for consumption.

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