

Effects of dietary fibre and antioxidant-rich ingredients on some quality characteristics of fresh and dry pasta

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RESEARCH ARTICLE

Abstract

In this study, different sources of antioxidant (flaxseed, black cumin and pomegranate seed) and dietary fibre (wheat fibre, oat fibre and barley fibre) were used in fresh and dry pasta formulation to improve functional properties of pasta. Antioxidant (5%) and dietary fibre (15%) sources were replaced with wheat semolina in pasta formulation. These functional ingredients both individually and in combinations were used to create nine different pasta formulations. Control fresh and dry pasta were prepared using wheat semolina. The effect of different ingredients and drying process on some physical (colour values, cooking properties and firmness), chemical (ash, protein, fat, total dietary fibre, antioxidant activity, total phenolic, phytic acid and mineral matter contents) and sensory properties of pasta were determined. Antioxidant activity, total phenolic and phytic acid contents were also determined in the raw and cooked form of fresh and dry pasta. Colour values (L^* and b^*) and sensory properties of fresh pasta were found superior in comparison to dry pasta. Drying process did not affect the antioxidant activity and total phenolic contents of raw pasta, on the other hand phytic acid content decreased significantly ($P < 0.05$) with drying application. Fresh pasta containing oat fibre and pomegranate seed has the highest antioxidant activity and total phenolic content in both raw and cooked form. In fresh pasta, combination of dietary fibres and antioxidant sources resulted in the greatest increments with respect to Ca, Fe, K, Mg, P and Zn contents, followed by the sources of oat and barley fibres. Combinations of antioxidant and dietary fibre improved the chemical and nutritional properties of pasta samples whereas black cumin had the most negative effect on the sensory quality of pasta despite its high antioxidant capacity.

Keywords: antioxidant, dietary fibre, pasta, fresh pasta

1. Introduction

Pasta is a worldwide popular food stuff due to its long shelf life, diversity, easy preparation and low cost (Yeyinli, 2006). Basic conventional pasta production steps are mixing and kneading, shaping (extrusion or lamination) and drying (Elgün and Türker, 2005). As well as dry pasta which is undoubtedly the most consumed type of pasta, fresh pasta has also become very popular in recent years (Pagani *et al.*, 2007; Tazrart *et al.*, 2016). Fresh pasta production process is similar to classic pasta production, excluding the drying process (Carini *et al.*, 2009). Preferably, pasteurisation and modified atmosphere packaging can also be applied to

prolong the shelf life of fresh pasta. Fresh pasta may have some nutritional and sensory superiority in comparison to classic dry pasta. It should be noted that Maillard reaction which can result from the high temperature applied during the drying process may cause changes in pasta colour and taste (Maache-Rezzoug and Allaf, 2005). This reaction may alter the protein structure and amino acid content of the end product (Cubadda, 1994). Acquistucci (2000) reported a loss of total lysine content of pasta (up to 18.7%) due to Maillard reaction conditions. Various studies have been conducted to improve the nutritional properties of dry pasta (Aravind *et al.*, 2012; Brennan *et al.*, 2004; Chillo *et al.*, 2011; Jayasena and Nasar-Abbas, 2012; Khan *et al.*, 2013; Pınarlı

et al., 2004). There are only a few studies focused on the improvement of functional/nutritional properties of fresh pasta, whereas there is a number of studies revealing the effect of different pasteurisation applications and packaging methods on fresh pasta quality and shelf life (Alamprese *et al.*, 2008; Del Nobile *et al.*, 2009; Pagani *et al.*, 2007; Scioscia *et al.*, 2016).

In recent years, flaxseed (*Linum usitatissimum* L.) has attracted attention because of its potential health effects. Flaxseed is one of the richest omega-3 sources, and also rich in soluble and insoluble fibre, lignin, protein and antioxidant components. Antioxidant, antimicrobial and anticarcinogenic effects of flaxseed are originated from phenolic acids (İşleroğlu *et al.*, 2005). Flaxseed can be used easily for improvement of various cereal-based food formulations. Various studies have been conducted on utilisation of flaxseed in bread (Hussain *et al.*, 2008), muffin (Chetana *et al.*, 2010), noodle (Bhise *et al.*, 2015) and pasta (Manthey *et al.*, 2008; Sinha and Manthey, 2008) formulations. Black cumin (*Nigella sativa* L.) is an aromatic plant and used generally as a seasoning. It is a great source of potassium, phosphorus, iron, zinc, calcium, magnesium, manganese and copper (Al-Jassir, 1992). It has anticarcinogenic, antidiabetic, antimicrobial and anti-inflammatory effects. The medicinal benefits of black cumin are attributed to phenolic compounds (Salvador *et al.*, 2001). Both black cumin seed and black cumin oil are rich in unsaturated fatty acids such as oleic acid, linoleic acid and linolenic acid (Atta, 2003). Pomegranate seed (*Punica granatum* L.) is a by-product formed during the production of pomegranate juice. It possesses antiviral, antifungal, anticarcinogenic, anti-inflammatory and antibacterial effects. These effects of pomegranate seed are associated with ellagitannins, anthocyanins and other phenolic compounds (Martos *et al.*, 2010). In spite of the positive health effects of black cumin and pomegranate seed, studies focused on the food formulations with black cumin and pomegranate seed are limited.

Dietary fibre is not digested in the human small intestine and is partially or completely fermented in the colon (Trowel and Burkitt, 1986). Many studies suggest a relationship between a high consumption of dietary fibres in diet and reduced risk of various chronic diseases such as colon cancer, obesity and diabetes. Wheat fibre has a high water holding capacity, neutral taste and light colour, and it can easily use in the bakery products without causing any sensory problem (Özavar, 2004). Moreover, oat fibre which also offers therapeutic potentials can be used in the production of many foods like bakery products, yoghurt and desserts. Barley fibre is obtained as a by-product of barley processing, and functional properties of food can be improved by barley fibre addition.

This study investigates the effects of several antioxidant sources (flaxseed, black cumin and pomegranate seed) and dietary fibres (wheat fibre, oat fibre and barley fibre) to enhance the functional properties of both dry and fresh pasta. In future studies, the effect of different pasteurisation and packaging methods on functional-fresh pasta properties will be investigated.

2. Material and methods

Materials

Semolina was obtained from Selva Food A.Ş. (Konya, Turkey). Antioxidant sources (flaxseed, black cumin and pomegranate seed) were procured from a local market, and their particle size was reduced down to 500 µm by a grinder (Sinbo, SCM 2934, Istanbul, Turkey) immediately prior to pasta production. Wheat fibre was acquired from Creafill Fibers Corp. (Maryland, MA, USA), while oat and barley fibres were purchased from Shaanxi Ciyuan Biotech Co. (Shaanxi, China).

Preparation of pasta samples

Control pasta sample was prepared using approximately 100:30 semolina:water ratio (1,500 g semolina + 500 ml water) according to the method described by Brennan and Tudorica (2008), whereas preliminary tests have been conducted to determine the amount of water used in nine different pasta formulations. A pilot type of pasta machine (Dolly, La Monferrina, Moncalieri, Italy) equipped with short cut dough mould (penne) was used to produce pasta samples. After extrusion of pasta dough, samples were dried by a pilot scale dryer (EC25, La Monferrina, Moncalieri, Italy). Drying process was not applied to fresh pasta samples after extrusion process. Dry samples were stored in room temperature, whereas fresh pasta samples were kept in the refrigerator prior to analysis.

Pasta formulations were prepared using three different antioxidant sources (flaxseed, black cumin and pomegranate seed) and three dietary fibres (wheat fibre, oat fibre and barley fibre). The appropriate contents of antioxidant (5%) and dietary fibre (15%) to replace wheat semolina in pasta formulations were determined by preliminary tests. These functional ingredients both individually and in combinations were used to create nine different pasta formulations. Antioxidant (5%) and dietary fibre (15%) were used together as 20% ratio to prepare combined samples. Black cumin has not been preferred for the combined pasta formulations due to its adverse effects on sensory properties. Also, wheat fibre also caused some difficulty in dough processing, and hence not included in the combinations. Consequently, the final combinations are as follow:

- Combination 1: 5% flaxseed + 15% oat fibre,

- Combination 2: 5% flaxseed + 15% barley fibre,
- Combination 3: 5% pomegranate seed + 15% oat fibre.

Chemical analyses

AACC methods were followed to determine ash (AACC 08-01), protein (AACC 46-12), fat (AACC 30-25) and total dietary fibre content (AACC 32-07) of raw materials and pasta samples (AACC, 1990). Antioxidant activities, total phenolic content and phytic acid of both fresh and dry pasta were determined in the raw and cooked form of pasta samples. Antioxidant activity was determined by 2-2-Diphenyl-2-picrylhydrazyl (DPPH) method (Beta *et al.*, 2005; Gyamfi *et al.*, 1999). Absorbances were measured at 517 nm and the inhibition percentage was calculated according to Equation 1.

$$\% \text{ Inhibition} = \frac{\text{Abs}_{\text{control}} - \text{Abs}_{\text{sample}}}{\text{Abs}_{\text{control}}} \times 100 \quad (1)$$

Colourimetric analysis based on Folin Ciocalteu method was conducted to determine the total phenolic contents of the samples. Absorbance was measured at 760 nm using a spectrophotometer (Hitachi-U1800, Japan) and results were expressed as mg Gallic acid equivalent (Gamez-Meza *et al.*, 1999; Slinkard and Singelton, 1977). Phytic acid analysis was carried out using the colourimetric method as described by Haugh 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 (III) sulphate-12 H₂O). Finally, the amount of iron remaining in the serum fraction was determined via a spectrophotometer. The mineral (Ca, Cu, Fe, K, Mg, Mn, P and Zn) contents of raw materials and pasta samples were determined by inductively coupled plasma spectroscopy, ICP-AES (Vista series, Varian International AG, Switzerland) described by Bubert and Hagenah (1987).

Physical analyses

Colour values of both raw materials and pasta samples were measured using Minolta CR-400 (Minolta Camera, Osaka, Japan). The numerical values of the colours were expressed by the lightness (L^* , light-dark), redness (a^* , \pm red-green) and yellowness (b^* , \pm yellow-blue). Saturation index [$(a^{*2} + b^{*2})^{1/2}$] and Hue angle (if $a^* > 0$ and $b^* > 0$, $\arctan(b^*/a^*)$; if $a^* < 0$ and $b^* > 0$, $\arctan(b^*/a^*) + 180^\circ$) values were calculated using a^* and b^* parameters (Francis, 1998). Firmness properties of pasta samples were determined by TAXT Plus Texture Analyser (Stable Microsystems, Surrey, UK) using A/LKB-F blade probe (Yeyinli, 2006).

Cooking properties

Weight increase (WI) and volume increase values (VI) of pasta samples were determined according to the method described by Oh *et al.* (1985) and Özkaya and Kahveci (1990). Twenty-gram of pasta sample was cooked in 250 ml distilled water and weight differences between raw and cooked samples were determined (Equation 2). For VI analysis raw/cooked pasta samples were put into measuring cylinder with distilled water, and VI were measured with regard to Equation 3. Following cooking of pasta, cooking water of the pasta was dried in an oven at 135 °C to determine the cooking loss (CL) value (Kahveci and Özkaya, 1989).

$$\text{WI (\%)} = \frac{\text{the weight of cooked pasta} - \text{the weight of raw pasta}}{\text{the weight of raw pasta}} \times 100 \quad (2)$$

$$\text{VI (\%)} = \frac{\text{the volume of cooked pasta} - \text{the volume of raw pasta}}{\text{the volume of raw pasta}} \times 100 \quad (3)$$

Sensory analyses

Sensory properties of both fresh and dry pasta were evaluated by 22 panellists from Food Engineering Department of Necmettin Erbakan University. Colour, appearance, hardness, stickiness, taste, odour and overall acceptance characteristics of cooked pasta samples were rated using a 7 point scale; 1: dislike extremely, 7: like extremely (Epler *et al.*, 1998).

Statistics analyses

Statistics analyses were performed using a statistical software JMP 10 (SAS Institute Inc., Cary, NC, USA). Means were compared at 5% confidence interval (Lehman *et al.*, 2013).

3. Results and discussion

Raw material properties

Chemical properties and colour values of semolina, antioxidant and dietary fibre sources are presented in Table 1. Ash, protein, fat, total dietary fibre, antioxidant activity, total phenolic and phytic acid contents of both antioxidant and dietary fibre sources (except wheat fibre) were found higher than semolina. Oat fibre was found as a great source of ash and phytic acid. Black cumin presented the highest protein and fat content, followed by flaxseed and barley fibre, respectively. Cheikh-Rouhou *et al.* (2007) and Hussain *et al.* (2008) reported similar results regarding the chemical

properties of flaxseed and black cumin. Wheat fibre has the richest total dietary fibre content (95.04%), followed by oat fibre (54.40%) and barley fibre (51.95%). On the other hand, flaxseed presented remarkably high amount of dietary fibre content (47.37%) among antioxidant sources. Phytic acid content of the raw materials ranged from 141.0 mg/100 g to 3,503.9 mg/100 g, and dietary fibre sources except wheat fibre presented high phytic acid content. Among the antioxidant sources, flaxseed has 1.5 and 2.5 times as much more phytic acid as compared to black cumin and pomegranate seed, respectively. Similar phytic acid content for flaxseed has been reported by Oomah *et al.* (1996). Pomegranate seed was determined as the richest antioxidant and total phenolic source in all raw materials. Wheat fibre and semolina was poor in minerals while oat fibre has the highest K, Mg, Mn, P and Zn content. L^* values of raw materials varied in the range of 36.39 (black cumin) and 96.07 (wheat fibre). Pomegranate seed and semolina presented more reddish and yellowish colour, respectively in comparison to other raw materials.

Physical properties of pasta samples

Colour values and cooking properties of pasta samples are given in Table 2. Significant differences ($P<0.05$) were observed on colour values of pasta samples including different functional ingredients (dietary fibre and/or antioxidant sources). The lowest L^* value was obtained with sample containing black cumin, whereas wheat fibre usage gave the highest L^* value on pasta colour. Utilisation of pomegranate seed in pasta formulation presented more reddish colour in comparison to other samples. Dilution of semolina content with functional ingredients up to 20% level in pasta formulation decreased the b^* values. The colour properties of the final pasta samples may be reflected the colour of the raw materials that were made of. Drying process significantly ($P<0.05$) decreased the L^* , b^* , SI and Hue values of the pasta samples. The reason behind such decrease may arise from the Maillard reaction that occurs during the drying process. Our results are in agreement with Petitot *et al.* (2010). Acquistucci (2000) also reported a decrease in L^* and b^* values of pasta due to Maillard reaction.

Table 1. Chemical properties and colour values of semolina, antioxidant and dietary fibre sources.^{1,2}

	Semolina	Flaxseed	Black cumin	Pomegranate seed	Wheat fibre	Barley fibre	Oat fibre
Ash (%)	0.80±0.02 ^e	3.62±0.06 ^c	4.16±0.10 ^b	1.50±0.05 ^d	0.25±0.01 ^f	4.96±0.15 ^a	5.34±0.17 ^a
Protein (%)	10.65±0.11 ^e	16.31±0.07 ^b	18.23±0.14 ^a	12.13±0.06 ^d	2.68±0.03 ^g	14.33±0.04 ^c	10.24±0.07 ^f
Fat (%)	0.59±0.11 ^c	29.85±2.46 ^a	33.98±3.44 ^a	5.00±0.27 ^{bc}	0.21±0.04 ^c	9.55±0.48 ^b	8.81±0.41 ^b
TDF (g/100 g)	5.49±0.10 ^e	47.37±0.72 ^c	38.30±0.41 ^d	35.74±0.78 ^d	95.04±1.57 ^a	51.95±0.86 ^b	54.40±0.91 ^b
Antioxidant activity (%)	13.18±0.49 ^e	55.47±0.92 ^d	64.53±0.69 ^c	81.67±1.15 ^a	15.57±0.62 ^e	54.90±0.74 ^d	67.74±1.03 ^b
TPC (mgGAE/g)	0.47±0.08 ^{de}	1.46±0.06 ^c	2.19±0.11 ^b	2.94±0.14 ^a	0.21±0.03 ^e	0.66±0.11 ^d	0.83±0.83 ^d
Phytic acid (mg/100 g)	220.6±5.69 ^f	2,157.3±22.05 ^c	1,457.1±19.02 ^d	848.5±11.58 ^e	141.0±4.50 ^g	3,151.2±26.43 ^b	3,503.9±29.98 ^a
Minerals (mg/100 g)							
Ca	26.43±0.72 ^e	162.15±2.63 ^c	429.03±4.43 ^a	117.44±2.50 ^d	19.30±0.40 ^e	161.46±2.53 ^c	200.22±2.91 ^b
Cu	0.33±0.03 ^e	1.85±0.06 ^a	1.50±0.04 ^{bc}	1.36±0.06 ^c	0.02±0.01 ^f	0.54±0.02 ^d	1.63±0.08 ^b
Fe	1.62±0.08 ^e	6.11±0.13 ^d	9.02±0.33 ^c	18.21±1.03 ^a	1.76±0.08 ^e	12.23±0.64 ^b	12.09±0.56 ^b
K	236.57±3.00 ^d	734.61±9.31 ^c	810.98±12.27 ^b	191.44±2.25 ^e	1.60±0.07 ^f	811.10±11.76 ^b	873.65±13.98 ^a
Mg	36.77±1.19 ^f	294.67±3.14 ^c	252.42±2.57 ^d	116.30±2.25 ^e	1.45±0.06 ^g	347.90±3.30 ^b	390.09±11.23 ^a
Mn	0.86±0.05 ^d	2.05±0.10 ^c	2.02±0.09 ^c	0.94±0.05 ^d	0.19±0.02 ^e	7.81±0.14 ^b	8.53±0.18 ^a
P	201.12±3.62 ^f	863.64±14.93 ^c	565.69±6.22 ^d	248.80±2.70 ^e	105.42±2.19 ^g	961.89±15.71 ^b	1,191.13±17.03 ^a
Zn	1.50±0.06 ^e	5.13±0.16 ^b	4.80±0.13 ^b	2.91±0.07 ^d	0.51±0.03 ^f	3.83±0.09 ^c	5.66±0.15 ^a
Colour values							
L^*	88.11±1.02 ^b	53.38±0.18 ^e	36.39±0.24 ^g	51.12±0.14 ^f	96.07±0.34 ^a	74.51±0.17 ^d	77.78±0.13 ^c
a^*	-1.73±0.07 ^g	6.92±0.08 ^b	0.67±0.03 ^e	7.74±0.05 ^a	-0.32±0.01 ^f	3.26±0.06 ^c	2.71±0.08 ^d
b^*	22.53±0.10 ^a	19.82±0.07 ^c	1.61±0.04 ^g	16.28±0.13 ^e	3.99±0.05 ^f	21.29±0.11 ^b	17.03±0.16 ^d
SI	22.59±0.10 ^a	20.99±0.09 ^c	1.74±0.04 ^g	18.02±0.14 ^d	4.00±0.05 ^f	21.54±0.12 ^b	17.24±0.17 ^e
Hue	94.40±0.20 ^a	70.75±0.16 ^c	67.40±0.48 ^d	64.58±0.04 ^e	94.65±0.18 ^a	81.29±0.10 ^b	80.96±0.20 ^b

¹Means with the same letter within a row are not significantly different ($P<0.05$).

²TDF = total dietary fibre; TPC = total phenolic content.

Table 2. Colour values and cooking properties of pasta samples.^{1,2}

Factor	n	L*	a*	b*	SI	Hue	WI (%)	VI (%)	CL (%)	Firmness (g)
Ingredients										
Control	4	57.74±8.75 ^b	-0.76±2.09 ^h	30.42±10.05 ^a	30.47±10.08 ^a	90.49±3.77 ^b	132.28±35.79 ^a	188.26±49.88 ^a	3.75±0.75 ^e	74.79±3.41 ^{de}
Flaxseed	4	52.08±9.16 ^e	5.10±0.13 ^f	23.79±7.10 ^e	24.36±6.95 ^e	77.17±3.49 ^e	125.28±33.28 ^{cde}	174.11±42.14 ^b	3.63±0.16 ^{ef}	77.30±11.47 ^d
Black cumin	4	37.95±4.20 ⁱ	1.25±0.04 ^g	6.30±1.85 ⁱ	6.43±1.80 ⁱ	78.01±3.62 ^d	125.71±33.15 ^{cd}	175.23±42.97 ^b	3.60±0.60 ^{ef}	72.81±16.15 ^e
Pomegranate seed	4	42.52±10.90 ^h	9.53±0.51 ^a	18.77±8.68 ^h	21.29±7.88 ^g	60.16±10.48 ⁱ	124.13±33.62 ^{cde}	176.40±43.53 ^b	3.48±0.58 ^f	73.62±4.22 ^e
Wheat fibre	4	67.39±3.11 ^a	-1.60±1.99 ⁱ	25.60±4.14 ^d	25.69±4.24 ^d	93.08±3.94 ^a	117.13±29.02 ^f	144.52±36.29 ^e	4.01±0.72 ^d	103.07±8.07 ^a
Barley fibre	4	55.95±2.90 ^c	6.62±0.46 ^e	27.01±7.55 ^b	27.84±7.44 ^b	75.65±2.95 ^f	129.75±31.88 ^{ab}	169.73±28.13 ^c	5.98±0.91 ^a	93.35±4.22 ^b
Oat fibre	4	55.52±5.13 ^d	5.06±0.33 ^f	26.32±5.85 ^c	26.81±5.80 ^c	78.84±1.77 ^c	128.08±31.74 ^{bc}	167.88±29.10 ^c	5.55±0.80 ^{bc}	91.71±6.00 ^{bc}
Comb1	4	50.54±1.80 ^f	7.68±0.85 ^d	21.40±3.33 ^f	22.74±3.42 ^f	70.16±0.86 ^g	122.03±32.51 ^{de}	149.74±21.91 ^d	5.41±0.73 ^c	90.78±11.08 ^{bc}
Comb2	4	50.61±0.81 ^f	8.19±0.88 ^c	21.12±4.70 ^g	22.67±4.70 ^f	68.45±2.31 ^h	122.66±32.92 ^{de}	150.96±21.34 ^d	5.73±0.96 ^b	91.63±8.71 ^{bc}
Comb3	4	44.55±3.89 ^g	8.32±0.90 ^b	17.60±3.94 ⁱ	19.48±3.95 ^h	64.30±2.64 ⁱ	121.38±32.68 ^e	148.25±21.39 ^d	5.30±0.71 ^c	90.06±6.40 ^c
Treatment										
Fresh	20	56.54±8.38 ^a	4.93±4.74 ^a	26.78±8.17 ^a	27.65±8.07 ^a	78.73±9.84 ^a	96.62±3.80 ^b	135.40±9.48 ^b	4.02±0.91 ^b	79.21±11.33 ^b
Dry	20	46.41±9.35 ^b	4.95±3.04 ^a	16.88±5.35 ^b	17.91±5.11 ^b	72.53±11.05 ^b	153.06±5.84 ^a	193.62±22.38 ^a	5.27±1.10 ^a	92.61±10.30 ^a

¹ Means with same letter within column are not significantly different ($P < 0.05$).

² WI = weight increase; VI = volume increase; CL = cooking loss; Comb1 = 15% oat fibre + 5% flaxseed; Comb2 = 15% barley fibre + 5% flaxseed; Comb3 = 15% oat fibre + 5% flaxseed + 5% pomegranate seed.

Utilisation of different ingredients and application of drying process significantly ($P < 0.05$) altered the cooking properties and firmness value of pasta samples. According to functional ingredients variance source, the values of WI and VI varied between 117.13% and 132.28%, 144.52% and 188.26%, respectively. The highest WI and VI values obtained in control pasta samples, and all of the functional ingredients (except barley fibre) decreased WI and VI values significantly ($P < 0.05$). The studies in this context reveal that WI and VI values of pasta samples are highly dependent on the type of ingredients e.g. their fibre content and solubility behaviour (Aydın and Göçmen, 2011; Bagdi *et al.*, 2014).

In the current study, the drying process applied on pasta samples enhanced the WI and VI values. As can be seen in Table 2, all the antioxidants sources used in this study slightly decreased the CL values as compared with the control sample. Our findings perfectly align with the results from Marinelli *et al.* (2015) who has also reported a decrease in CL values of pasta samples enriched with grape marc due to its antioxidant activity. Similarly, Rizk *et al.* (2014) found a reduction in CL of spaghetti samples containing antioxidant compounds from tomato peels (carotenoids) in comparison to control sample. Those CL decreases were explained that antioxidant compounds together with proteins formed a complex structure around the starch granule, encapsulating them during cooking and restricting excessive swelling and diffusion of the amylose content (Marinelli *et al.*, 2015; Rizk *et al.*, 2014). Pasta formulation containing dietary fibre demonstrated higher CL values. Although this is not preferable because of high dry matter loss, however, our results were still below the technologically acceptable limit (8%) (Özyurt *et al.*, 2015). Furthermore, the effect of functional ingredients and drying process on the firmness of pasta samples investigated. While dietary fibres and their combinations resulted in a firmer texture, none of the antioxidants caused a noteworthy difference in the firmness when used individually. A scan of literature shows that existing studies of this context report different results according to sources of dietary fibres. For example, Foschia *et al.* (2015) reported that while firmness value of control pasta sample (prepared using semolina) was found as 2.81 N, this value varied in the range of 1.28-3.03 N for pasta substituted with ten different dietary fibres. Similarly, Rakhesh *et al.* (2015) enriched the spaghetti with different dietary fibre and they observed that inulin and bran declined the firmness value of pasta, whereas pollard and β -glucan (Barley Balance™) caused firmer texture. Table 2 also shows the effect of drying process on firmness. Mean of firmness value of fresh and dry pasta was determined as 79.21 g and 92.61 g, respectively. The enhanced firmness of dry pasta could be associated with the temperature applied throughout the drying process. The formation of large polymeric protein aggregates could be increased the firmness of pasta (Lamacchia *et al.*, 2007).

Antioxidant activity, total phenolic and phytic acid contents of raw and cooked pasta

Table 3 presents the results of antioxidant activity, total phenolic and phytic acid contents of fresh and dry pasta samples. Those analyses were conducted in the raw and cooked form of fresh and dry pasta. Functional ingredients have significantly increased ($P<0.05$) the antioxidant activity of pasta samples at the raw and cooked form. Similar changes were also observed in phenolic contents of pasta containing those ingredients except for wheat fibre and flaxseed. Functional ingredients other than wheat fibre demonstrated a higher phytic acid content in both raw and cooked pasta samples compared to control. Moreover, combined pasta formulations were the richest in terms of antioxidant activity, total phenolic and phytic acid content. Combination-3 (pomegranate seeds and oat fibre) revealed the highest antioxidant activity and total phenolic content in raw and cooked pasta samples, whereas combination-1 (flaxseed and oat fibre) was the richest in terms of phytic acid. Drying process significantly ($P<0.05$) decreased the phytic acid content of both raw and cooked form of pasta samples. It has been reported that phytic acid content of pasta decreased by 21.26-23.44% during pasta production process (including drying) due to hydrolysis of phytate by phytase enzyme (Yılmaz and Ünal, 1993).

Table 4 shows chemical properties of fresh pasta prepared with different ingredients. Ash, protein, fat and total dietary fibre contents of control pasta were determined as 0.83%,

10.53%, 0.47% and 5.34 g/100 g, respectively (Table 4). These results are in great agreement with the previous studies (Aravind *et al.*, 2012; Tazrart *et al.*, 2016; Torres *et al.*, 2007). Wheat fibre resulted in a decrease on the chemical parameters of pasta except total dietary fibre content. The reason for such an exception might arise from the high total dietary fibre content of wheat fibre (95.04%). Pasta samples containing combination-1 and combination-2 presented the highest fat content due to high fat content of flaxseed (29.85%).

Mineral matter content of pasta samples are given in Table 5. As can be seen from these values all the combined pasta samples were found to be rich in point of mineral content. Control sample and pasta containing wheat fibre presented the lowest mineral content. Combination 1 and combination 3 were revealed the highest P and Fe content, respectively. The recommended dietary allowances (RDA) for adult males are 800 mg of Ca, 10 mg of Fe, 1.6-2.0 g of K, 350 mg of Mg, 800 mg of P and 15 mg of Zn (Demirci, 2007). When 100-g (dry matter) of combined pasta samples were consumed 6.8-7.5%, 35.0-40.9%, 18.5-20.0%, 27.2-29.9%, 43.8-48.4% and 13.6-15.5% of RDA for Ca, Fe, K, Mg, P and Zn, respectively, could be provided.

Sensory properties of the pasta samples

Sensory properties of pasta samples are presented in Figure 1 and 2. In general, fresh pasta samples had the higher sensory scores in terms of colour, appearance, taste,

Table 3. Antioxidant activity, total phenolic content and phytic acid content of raw and cooked pasta samples.^{1,2}

Factor	n	Raw pasta			Cooked pasta		
		AA (%)	TPC (mgGAE/g)	PA (mg/100 g)	AA (%)	TPC (mgGAE/g)	PA (mg/100 g)
Ingredients							
Control	4	15.80±0.56 ^g	0.48±0.04 ^f	196.50±11.74 ⁱ	13.55±0.74 ^j	0.42±0.02 ^{de}	189.70±11.19 ⁱ
Flaxseed	4	18.97±1.05 ^f	0.51±0.06 ^f	294.48±11.91 ^f	16.53±0.78 ^h	0.44±0.04 ^d	283.70±10.87 ^f
Black cumin	4	23.79±0.58 ^e	0.61±0.03 ^e	258.79±13.49 ^g	19.72±1.24 ^g	0.53±0.04 ^c	249.81±13.59 ^g
Pomegranate seed	4	34.06±0.55 ^d	0.69±0.05 ^{ode}	227.59±14.63 ^h	28.02±1.99 ^f	0.59±0.07 ^{bc}	219.51±14.96 ^h
Wheat fibre	4	17.95±0.49 ^f	0.42±0.08 ^f	184.35±9.96 ^j	14.68±0.51 ⁱ	0.35±0.02 ^e	177.52±10.24 ⁱ
Barley fibre	4	40.18±0.71 ^c	0.64±0.03 ^{de}	639.06±14.24 ^e	32.70±1.18 ^e	0.53±0.05 ^c	616.66±12.12 ^e
Oat fibre	4	46.30±0.83 ^b	0.78±0.06 ^{abc}	692.21±15.88 ^d	38.32±1.82 ^c	0.65±0.05 ^{ab}	665.89±13.97 ^d
Comb1	4	49.23±1.41 ^a	0.80±0.07 ^{ab}	789.04±14.09 ^a	40.05±0.97 ^b	0.66±0.06 ^{ab}	759.81±12.34 ^a
Comb2	4	45.72±1.06 ^b	0.73±0.07 ^{bcd}	738.87±13.38 ^b	36.60±1.76 ^d	0.60±0.06 ^{bc}	712.27±13.19 ^b
Comb3	4	49.93±0.77 ^a	0.86±0.06 ^a	723.87±13.10 ^c	41.12±1.50 ^a	0.70±0.05 ^a	696.72±12.98 ^c
Treatment							
Fresh	20	34.03±13.41 ^a	0.64±0.15 ^a	484.42±253.13 ^a	29.15±11.12 ^a	0.56±0.12 ^a	465.93±243.41 ^a
Dry	20	34.35±13.63 ^a	0.66±0.15 ^a	464.53±252.50 ^b	27.11±10.61 ^b	0.53±0.11 ^a	448.39±243.38 ^b

¹ Means with same letter within column are not significantly different ($P<0.05$).

² AA = antioxidant activity; TPC = total phenolic content; PA = phytic acid; Comb1 = 15% oat fibre + 5% flaxseed; Comb2 = 15% barley fibre + 5% flaxseed; Comb3 = 15% oat fibre + 5% pomegranate seed.

Table 4. Chemical analysis results of fresh pasta samples.^{1,2}

Ingredients	Ash (%)	Protein (%)	Fat (%)	TDF (g/100 g)
Control	0.83±0.04 ^{de}	10.53±0.21 ^c	0.47±0.07 ^d	5.34±0.08 ^f
Flaxseed	0.96±0.06 ^{cd}	10.80±0.13 ^{abc}	1.75±0.10 ^{bc}	7.48±0.13 ^e
Black cumin	1.06±0.08 ^c	10.95±0.14 ^{abc}	2.04±0.11 ^b	7.01±0.10 ^e
Pomegranate seed	0.91±0.05 ^{cde}	10.65±0.10 ^{bc}	0.70±0.08 ^d	6.93±0.07 ^e
Wheat fibre	0.71±0.03 ^e	9.32±0.11 ^d	0.37±0.06 ^d	19.04±0.54 ^a
Barley fibre	1.46±0.04 ^b	11.23±0.20 ^{ab}	1.74±0.10 ^{bc}	12.85±0.42 ^{cd}
Oat fibre	1.57±0.07 ^{ab}	10.43±0.13 ^c	1.63±0.07 ^c	12.23±0.37 ^d
Comb1 ³	1.72±0.08 ^a	10.73±0.16 ^{bc}	3.16±0.13 ^a	14.60±0.49 ^b
Comb2 ⁴	1.66±0.04 ^{ab}	11.35±0.14 ^a	3.27±0.11 ^a	14.28±0.58 ^{bc}
Comb3 ⁵	1.64±0.04 ^{ab}	10.60±0.16 ^c	2.10±0.10 ^b	14.09±0.40 ^{bc}

¹ Means with same letter within column are not significantly different ($P<0.05$).

² TDF = total dietary fibre; Comb1 = 15% oat fibre + 5% flaxseed; Comb2 = 15% barley fibre + 5% flaxseed; Comb3 = 15% oat fibre + 5% pomegranate seed.

Table 5. Mineral contents of fresh pasta samples (mg/100 g).^{1,2}

Ingredients	Ca	Cu	Fe	K	Mg	Mn	P	Zn
Control	26.69±0.76 ^e	0.30±0.04 ^{bc}	1.69±0.07 ^e	237.96±2.90 ^d	36.06±1.29 ^{ef}	0.85±0.06 ^b	202.70±2.16 ^f	1.51±0.08 ^{de}
Flaxseed	33.47±0.83 ^d	0.39±0.08 ^{abc}	1.96±0.10 ^{de}	263.90±2.46 ^c	48.85±1.43 ^d	0.92±0.07 ^b	238.42±2.81 ^d	1.68±0.10 ^{cd}
Black cumin	46.94±0.93 ^c	0.37±0.01 ^{abc}	2.15±0.08 ^d	267.56±3.25 ^c	45.94±1.56 ^d	0.92±0.05 ^b	219.65±3.31 ^e	1.66±0.04 ^{cd}
Pomegranate seed	32.15±0.79 ^d	0.36±0.10 ^{abc}	2.55±0.11 ^c	236.41±3.85 ^d	40.53±1.40 ^{de}	0.86±0.04 ^b	206.51±2.53 ^{ef}	1.56±0.07 ^{de}
Wheat fibre	25.30±0.25 ^e	0.26±0.01 ^c	1.70±0.04 ^e	203.99±1.51 ^e	28.51±0.71 ^f	0.74±0.07 ^b	186.30±1.80 ^g	1.35±0.03 ^e
Barley fibre	47.16±0.85 ^c	0.34±0.03 ^{abc}	3.30±0.08 ^b	325.94±3.51 ^b	83.46±1.82 ^c	1.90±0.06 ^a	317.03±4.71 ^c	1.86±0.10 ^{bc}
Oat fibre	53.10±0.65 ^b	0.51±0.10 ^{abc}	3.25±0.10 ^b	335.13±3.93 ^b	91.58±2.14 ^{bc}	2.02±0.11 ^a	353.20±5.18 ^b	2.14±0.06 ^{ab}
Comb1	60.04±1.39 ^a	0.58±0.04 ^a	3.50±0.08 ^b	360.55±5.64 ^a	104.59±4.71 ^a	2.11±0.09 ^a	387.53±3.87 ^a	2.33±0.08 ^a
Comb2	54.43±0.69 ^b	0.42±0.08 ^{abc}	3.52±0.10 ^b	351.62±3.62 ^a	96.98±1.07 ^{ab}	1.99±0.07 ^a	350.15±4.14 ^b	2.04±0.10 ^{ab}
Comb3	57.83±0.55 ^a	0.56±0.07 ^{ab}	4.09±0.08 ^a	333.22±4.74 ^b	95.27±2.94 ^b	2.06±0.09 ^a	356.19±3.08 ^b	2.18±0.03 ^a

¹ Means with same letter within column are not significantly different ($P<0.05$).

² Comb1 = 15% oat fibre + 5% flaxseed; Comb2 = 15% barley fibre + 5% flaxseed; Comb3 = 15% oat fibre + 5% pomegranate seed.

odour and overall acceptability compared to dry samples. After control sample, combined pasta sample including flaxseed and barley fibre was the most preferable in terms of stickiness parameter. Moreover, flaxseed resulted in the highest taste and odour parameters for both fresh and dried pasta samples. Following the control, pasta sample produced with 5% flaxseed had the highest score in the overall acceptability parameter. Usage of black cumin caused an adverse effect on the colour, appearance, taste, odour and overall acceptability score in both fresh and dry pasta formulations. After black cumin, utilisation of 5% pomegranate seed in pasta formulation gave the low scores for colour, taste, odour and overall acceptability. Although it is very well known that dietary fibres and antioxidants have positive health benefits, their use in pasta production may result in undesirable sensory properties in terms of colour and overall acceptability (Aravind *et al.*, 2012; Bagdi *et al.*,

2014; Kaur *et al.*, 2012). The current study has indicated lower sensory scores for pasta samples with usage of black cumin and pomegranate seed despite their high antioxidant activity.

4. Conclusions

This study aimed to formulate fresh and dry pasta with improved functional properties using a variety of antioxidant and dietary fibres. Total dietary fibre content for functional ingredients can be ranked in the order of wheat fibre>oat fibre>barley fibre>flaxseed>black cumin>pomegranate seed. Despite the low dietary fibre content of pomegranate seed, it has the highest antioxidant activity and total phenolic content among all the ingredients investigated. Combined pasta formulations revealed the richest parameters in terms of ash, total dietary fibre,

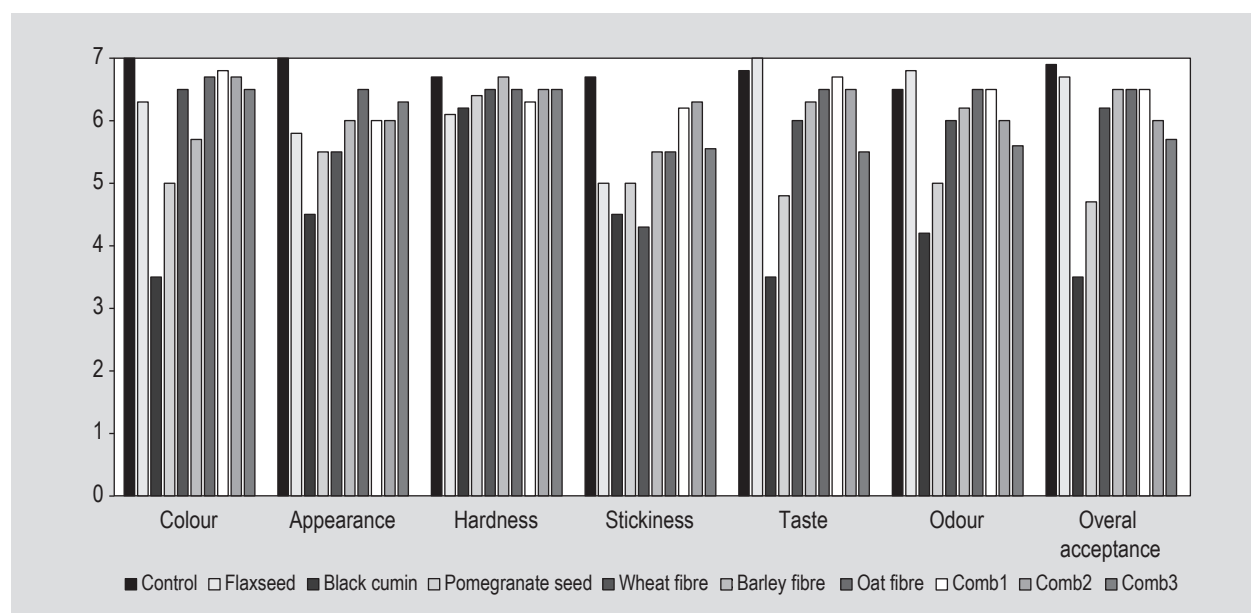


Figure 1. Sensory properties of fresh pasta samples. Comb1 = 15% oat fibre + 5% flaxseed; Comb2 = 15% barley fibre + 5% flaxseed; Comb3 = 15% oat fibre + 5% pomegranate seed.

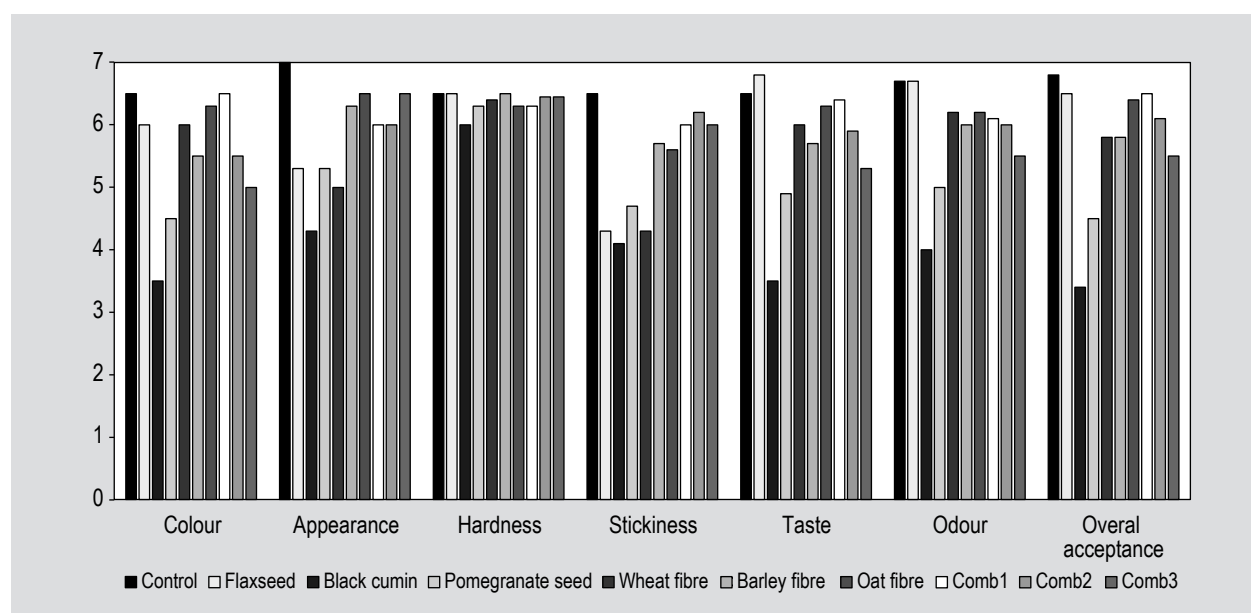


Figure 2. Sensory properties of dry pasta samples. Comb1 = 15% oat fibre + 5% flaxseed; Comb2 = 15% barley fibre + 5% flaxseed; Comb3 = 15% oat fibre + 5% pomegranate seed.

mineral matter, antioxidant activity, total phenolic and phytic acid content. With this in mind, this study highlights the importance of novel pasta combinations with improved functional/nutritional properties. Another objective of this study was to investigate the effect of drying process on pasta quality. Drying process resulted in darker colour on pasta samples compared to fresh pasta due to the Maillard reaction, and increased the firmness along with the cooking loss. Moreover, there was not a noteworthy difference in the antioxidant activity and total phenolic content values of

raw pasta samples during drying process, however, phytic acid content significantly ($P < 0.05$) decreased with drying. Follow up studies will focus on the different applications such as pasteurisation and modified atmosphere packaging to extend the shelf life of functional-fresh pasta samples.

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