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Research Article
Improvement of Functional and Technological Characteristics of Spaghetti by the Integration of Pomegranate Peels Powder

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Abstract

Background and Objective: Naturalistic antioxidants have a significant function in protecting the human body from a lot of diseases like as cancer. Pomegranate peels are deemed as a waste by-product which produced throughout the manufacturing of pomegranate, a big quantity of peels were produced and their elimination is considered a big problem and give rise to environmental distortion. So, the aim of the present study was to evaluate the impact of incorporating dried pomegranate peels powder as a source of antioxidants and dietary fiber in spaghetti. **Materials and Methods:** In the current study, the peels were added in different percentages (3, 5 and 7%) throughout spaghetti preparation and their quality, sensory and antioxidant characteristics were estimated. **Results:** There was an increment in spaghetti total dietary fiber content from 2.88-7.86%. The content of polyphenols increased from 102.74-488.96 mg gallic acid equivalent/100 g and flavonoids content increased from 139.72-190.82 mg quercetin equivalent/100 g of spaghetti integrated with 7% pomegranate peel powder. The increment of pomegranate peel powder adding percentages caused a significant increase in solid loss and weight increase (%). Sensory evaluation results revealed that substitution of wheat flour in spaghetti with up to 7% pomegranate peel powder recorded satisfying consumer acceptability. **Conclusion:** The results nominated the possibility of making spaghetti integrated with pomegranate peel powder as a functional food.

Key words: Pomegranate peels powder, spaghetti, naturalistic antioxidant characteristics, dietary fiber content, functional foods

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In recent years, the interest of consumers, researchers and the food industry has grown into functional products which, in addition to basic nutritional role, provide physiological benefits and have an important function in preventing diseases or slowing the progression of chronic diseases[1]. Pomegranate (*Punica granatum*) belongs to the Punicaceae family and is a nutritive food provenance affluent with phytochemical components. Pomegranates are commonly used as fruit and juice, drinks, food products (jams and jellies) and extracts wherein they were applied as vegetal ingredients in herbal medicines and dietary supplements [2]. Wastes of fruits include an elevated percentage of vitamins, fiber, minerals and other bioactive components Ismail *et al.*[3]. Pomegranate peel, a uneatable portion produced during juice production process was found to include a collection of bioactive components, fibers and minerals for several nutritional requirements[4]. Pomegranate peels are an affluent source of crude fiber (12.17%), total polyphenols (249.41 mg g^{-1}) and inorganic remnants that have good healthy features such as preventing the cardiovascular diseases development, anti-inflammatory, hypoglycemic, anti-parasitic, apoptotic and as prebiotic[5,6]. The powder of pomegranate peels was used intelligently in preparation of several types of food such as bakery products, meat products, jellies and edible oils[7-9].

Spaghetti pasta is a conventional food product based on cereal which produced from the first century BC[10]. There was an increment in spaghetti production and consumption rate could be due to its, few production costs, easiness of (production, cooking and transportation) processes, sensory quality and having a long shelf life[11]. It is known that spaghetti has low levels of sodium and lipids with no cholesterol and containing a huge amount of complex carbohydrates[12], producing a lower postprandial level of glucose and insulin in the blood[13]. The World Health Organization and Food and Drug Administration deemed spaghetti macaroni a perfect vehicle to add the important nutrients[14]. In the 1940s, spaghetti macaroni became one of the first foods which the Food and Drug Administration allowed to enrichment with iron and vitamins [15]. A lot of studies were conducted on fortification of macaroni with some agro-industrial wastes as a source of bioactive components such as mango peel powder as a source of antioxidants, grape marc powder and various protein concentrates for improvement its nutritional value[16-18].

The aim of the present study was to evaluate the impact of incorporating dried pomegranate peels powder as a source of antioxidants and dietary fiber in spaghetti. The macaroni was evaluated in relation to their nutritional, cooking and sensory properties.

MATERIALS AND METHODS

Materials: Pomegranate fruits of "Manfalouti" variety were procured from the local market of Kafr-el-Shiekh governorate, Egypt. Wheat flour (72% extraction) was obtained from Ebn EL-Khatab Mills Company 6th of October City, Egypt.

Chemicals: Gallic acid, pepsin, butylated hydroxyanisole (BHA), pancreatin, (2,2-Diphenyl-1-picrylhydrazyl DPPH) and α-Amylase were purchased from Sigma Aldrich Chemical Co. (St. Louis, M.O, USA). All other chemicals and solvents were of analytical grade.

Preparation of pomegranate peels powder (PPP): Pomegranate peels powder was prepared according to the method described by El-Batawy *et al.*[19] as follows: Pomegranate fruits were washed by distilled water then peeled and their eatable portions were carefully separated. The peels were air dried in a ventilated oven at 50°C for 18 h. Once dried, it was crushed using a hammer mill and then sieved (60 meshes).

Spaghetti preparation: Spaghetti samples were prepared from wheat flour 72% ext., water 35% and salt 1%. Each sample was blended with different level of pomegranate peel (3.0, 5.0 and 7.0% as wheat flour weight). The mixture of ingredients was placed in a mixing bowl (Kitchen Aid Mixer) and mixed at speed 1 for 1 min, water was added and mixing was continued at speed 1 for 2 min, followed by mixing at speed 2 until the dough stiffened. The dough was rounded (shape to ball). Covered with plastic wrap, allowed to rest about 30 min, hand kneaded for about 1 min and sheeted with wooden rolling pin to about 1.5 cm. thickness. The sheet of dough was passed through a hand-operated pasta machine (Ampia, TipoLusso, Model 150, Italy). Spaghetti was cut into strips 5 mm wide, hung on rod, hardened on air dried for 24 h at 25±2°C. The spaghetti was dried to 6.40% moisture in aerated oven at 70°C for 24 h, cooled at room temperature and the produced spaghetti was packed in polyethylene bag until tested.

Proximate composition: Chemical composition of wheat flour and spaghetti samples (moisture, crude protein, ether extract and ash) was estimated using AACC[20] methods, where total carbohydrates were calculated by difference. Dietary fiber, soluble and insoluble dietary fiber contents was analyzed according to AOAC[21].

Evaluation of spaghetti quality

Color evaluation: The color of dried spaghetti pasta was measured with a Hunter Lab Colorimeter (MiniScan XE Plus, Reston, VA) according to Crizel *et al.*[18]. Briefly, spaghetti pasta samples were milled and sieved (0.425 mm mesh). Powder samples were placed in the colorimeter and the color readings expressed by Hunter L*, a* and b* values. The color values were recorded as L* = lightness (0 = Black, 100 = White), a* (-a* = Greenness, +a* = Redness) and b* (-b* = Blueness, +b* = Yellowness).

Results were expressed as color differential (ΔE) between control (noodles with 0% of PP) and substituted noodles, calculated as follows:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

Where:
ΔL was calculated as: ΔL sample-ΔL control
Δa was calculated as: Δa sample-Δa control
Δb was calculated as: Δb sample-Δb control

Spaghetti cooking quality: Cooking qualities of spaghetti under investigation namely optimum cooking time, spaghetti cooking weight, cooking loss and swelling index were measured by the method of AACC[20]. Tap water (about 300 mL) was brought to a boil in a 1 L saucepan with the lid on to prevent any water loss. When the water started boiling, a 100 g of dry pasta was added. The cooking temperature was retained at 98-100°C during the cooking operation. The period when the macaroni white internal core vanished was recorded as the optimal cooking time. After cooking, the macaroni was removed from the saucepan, rinsed and cooled in running cold tap water for 1 min. Cooking loss was measured by evaporating the cooking water to dryness in an oven at 105°C. The percentage of weight increase was determined by weighting macaroni after cooking. All experiments were done in triplicate.

Sensory evaluation of spaghetti: The spaghetti samples were cooked as described before. Fifty semi-trained panelists from Food Technology Department, Kafr-el-Shiekh University evaluated texture, taste, color and overall acceptability according to the method of Choo and Abdul Aziz[22].

Extraction of bioactive compounds: The powdered of pomegranate peels, control and pomegranate incorporated spaghetti (1 g) were extracted with 20 mL of 80% acetone for 1 h with occasional stirring using a vertex mixer. The extract was centrifuged at 8000 rpm. The supernatant obtained was subjected for total phenolics as described by the method of Ghasemzadeh *et al.*[23] and expressed as mg gallic acid equivalent (GAE) g^{-1} dry extract. Total flavonoid content (TFC) was estimated as described by Chlopicka *et al.*[24] and expressed as mg quercetin equivalent (QE) g^{-1} extract. Free radical scavenging activity was measured by using DPPH radical solution (6×10^{25} M in HPLC grade methanol) according to Abdel-Hameed[25] and expressed in the terms of antiradical power described by Roby *et al.*[26].

Statistical analysis: General linear model of SPSS (ver. 16.0)[27] was used to conduct one-way ANOVA with Tukey's B-test for determination of differences between means. The probability levels of $p\leq0.01$ and $p\leq0.05$ were considered to be significant for statistical procedures. All measurements and trials were done in triplicate.

RESULTS AND DISCUSSION

Chemical composition of wheat flour and pomegranate peel powder: Results in Table 1 revealed that, the protein, crude fat, crude fiber, ash and total carbohydrates on dry weight basis, for wheat flour (72% ext.) and pomegranate peel powder (PPP). Results presented that the pomegranate peel powder (PPP) has a great percentage of total fiber and ash. Also it can be noticed that the pomegranate peels have a high content of dietary fiber, the soluble part was about 39.20% of the total amount of dietary fiber. Whereas, wheat flour displayed a high content of protein and total carbohydrates and it contained a low content of total fiber and ash comparing with (PPP). Therefore, enrichment of wheat flour with nutritionally rich (PPP) will enhance the nutritional quality of the product.

Chemical composition of prepared spaghetti: The chemical composition of spaghetti enriched with different levels of (PPP) (3, 5 and 7%) and control spaghetti was presented in Table 2. As can be observed, moisture content was the lowest in control spaghetti. The increase in pomegranate peel level led to increase the moisture contents of spaghetti. Similar results were reported when orange fiber byproducts added to pasta[18]. From the same table, it can be noticed that the addition of pomegranate peel (which has high ash content) slightly increased the ash content in the produced spaghetti. There was a slight non-significant difference in protein content as the pomegranate peels were poor in protein (3.2 g/100 g).

Table 1: Chemical composition of wheat flour and pomegranate peel powder (on dry weight basis)*

Chemical composition	Flour (72% ext.)	Pomegranate peel
Protein (%)	12.25±0.07[a]	3.20±0.06[b]
Crude fat (%)	0.78±0.03[b]	1.43±0.09[a]
Crude fiber (%)	0.52±0.27[b]	12.70±0.32[a]
Ash (%)	0.95±0.12[b]	3.87±0.40[a]
**Total carbohydrates (%)	85.50±0.41[b]	78.80±0.52[a]
Total dietary fiber (g/100 g)	2.78±0.39[b]	56.22±0.98[a]
Soluble dietary fiber (g/100 g)	1.25±0.18[b]	22.04±0.53[a]
Insoluble dietary fiber (g/100 g)	1.53±0.15[b]	34.18±0.46[a]

*All data are the Mean±SD of three replicates. Mean followed by different letters in the same row differs significantly ($p \leq 0.05$), **Calculated on dry weight basis as 100-ash+protein+fiber+fat

Table 2: Chemical composition of spaghetti produced by flour (72% ext) and pomegranate peel (on dry weightbasis)*

Treatments	Control	Spaghetti with 3% Pomegranate peel	Spaghetti with 5% Pomegranate peel	Spaghetti with 7% Pomegranate peel
Moisture	9.95±0.13[c]	10.07±0.28[bc]	10.14±0.26[ab]	10.22±0.09[a]
Protein (%)	12.43±0.80[a]	12.15±0.50[b]	11.97±0.12[c]	11.48±0.41[d]
Crude fat (%)	0.80±0.26[d]	0.82±0.18[cd]	0.83±0.26[bc]	0.85±0.20[ab]
Crude fiber (%)	0.84±0.17[d]	1.29±0.25[c]	1.49±0.42[b]	1.75±0.38[a]
Ash (%)	1.32±0.81[c]	1.40±0.49[b]	1.45±0.36[b]	1.56±0.22[a]
*Total carbohydrates (%)	84.61±0.98[a]	84.34±0.76[ab]	84.26±0.55[bc]	84.36±0.69[c]
Total dietary fiber (g/100 g)	2.88±0.31[d]	4.06±0.40[c]	5.78±0.48[b]	7.86±0.32[a]
Soluble dietary fiber (g/100 g)	1.19±0.02[d]	1.52±0.13[c]	2.14±0.33[b]	2.91±0.028[a]
Insoluble dietary fiber (g/100 g)	0.69±0.09[d]	2.54±0.26[c]	3.64±0.33[b]	4.95±0.49[a]

*All data are the Mean±SD of three replicates, Mean followed by different letters in the same row differs significantly ($p \leq 0.05$), *Calculated on dry weight basis as 100-ash+protein+fiber+fat

Table 3: Color Measurement of Ingredients and pomegranate peel powder enriched spaghetti*

Treatments	L*	a*	b*	ΔE
Flour (72% ext.)	85.43±0.01	0.10±0.03	11.69±0.17	-
Pomegranate peel	90.68±0.02	41.12±0.01	22.28±1.06	-
Control	76.57±4.78	-1.32±0.02	19.86±0.93	-
Spaghetti with 3% pomegranate peel	59.82±3.64	2.33±0.04	20.47±0.76	17.15±1.79
Spaghetti with 5% pomegranate peel	55.16±1.94	1.85±0.20	20.89±0.44	21.67±0.51
Spaghetti with 7% pomegranate peel	50.78±2.26	1.49±0.03	21.35±0.82	25.99±1.12

* All data are the Mean±SD of three replicates

It can be noticed that there was a high increase in fiber content with the increased amount of pomegranate peel added. The dietary fiber content of spaghetti enriched with pomegranate peel powder was threefold as the pomegranate peel content reached 7%. This was due to the high fiber content of pomegranate peel which also, contains high amounts of dietary fiber (56.22 g/100 g).

Spaghetti color evaluation: Table 3 showed the L*, a* and b* values of raw materials and spaghetti. The L* value (Lightness) of the spaghetti with pomegranate peels decreased as the quantity of the pomegranate peels in the spaghetti increased. All the spaghetti prepared from wheat flour mixed with the pomegranate peels had higher a* and b* values and lower L* values than the control (L* = 76.57, a* = -1.32, b* = 19.86) due to the darker color of pomegranate peel (L* = 90.68, a* = 41.12, b* = 22.28) than wheat flour (L* = 85.43, a* = 0.10, b* = 11.69). The pomegranate peels fortified spaghetti was significantly more red, more yellow and darker than the control. Current findings agreed with those of Gallegos-Infante *et al.*[28], who studied pasta enriched with Mexican common bean flour and found that an increase of bean flour in pasta enhanced the color change.

Spaghetti cooking properties: Cooking quality is an important parameter for evaluation of macaroni. The cooking quality parameters of macaroni products prepared with wheat flour and wheat flour incorporated with 3, 5 and 7% of PPP as shown in Table 4. For all pasta samples, the optimum cooking time was approximately 5 min and the other cooking characteristics (solid loss and percentage weight increase) were estimated at this standard cooking time. During

Table 4: Cooking properties of control and pomegranate peel powder-enriched spaghetti*

Samples	Solid loss (%)[1]	Weight increase (%)[1]
Control	5.48±0.12[a]	92.80±1.64[d]
Spaghetti with 3% pomegranate peel	5.97±0.29[a]	112.00±2.01[c]
Spaghetti with 5% pomegranate peel	7.81±0.56[b]	123.50±1.33[b]
Spaghetti with 7% pomegranate peel	7.85±0.44[b]	134.20±1.65[a]

All data are the Mean±SD of three replicates. Mean followed by different letters in the same column differs significantly ($p \leq 0.05$).*Cooking time: 5 min

Table 5: Influence of pomegranate peels powder on the sensory acceptability of spaghetti*

	Treatments			
Sensory	Control	Spaghetti with 3% Pomegranate peel	Spaghetti with 5% Pomegranate peel	Spaghetti with 7% Pomegranate peel
Appearance	8.60±0.77[d]	8.73±0.53[c]	9.25±0.49[b]	9.50±0.49[a]
Taste	8.33±0.35[d]	8.65±0.52[c]	9.00±0.23[b]	9.32±0.40[a]
Colour	8.00±0.41[d]	8.33±0.55[c]	8.65±0.16[b]	8.79±0.36[a]
Odour	8.67±0.53[d]	9.15±0.31[c]	9.31±0.25[b]	9.60±0.25[a]
Texture	9.00±0.56[a]	8.50±0.66[b]	8.24±0.37[c]	8.00±0.71[d]
Total acceptability	8.52±0.49[d]	8.67±0.92[c]	8.89±0.30[b]	9.04±0.12[a]

*All data are the Mean±SD of twenty replicates. Mean followed by different letters in the same row differs significantly ($p \leq 0.05$)

macaroni cooking, soluble parts of starch and other soluble components including non-starch polysaccharides leach into the water. As can be observed in Table 4, spaghetti contained 3% PPP was not significantly different compared to control macaroni in solid loss. However, the solid loss significantly increased when the incorporation of pomegranate peel fiber was 5 and 7 %. Giuberti *et al.*[29], reported that cooking loss for good quality pasta should be lower than 12% and in the present study cooking loss by the incorporation PPP was found to be less than 12% (Table 4). The same results were found in case of adding soy flour, wheat bran and unripe banana flour to pasta[30-31]. Ingredients other than wheat flour such as pomegranate peel, which is rich in dietary fiber content, may cause changes in the gluten protein network resulting in more leaching out of solids from pasta into the cooking water[11]. The addition of pomegranate peels powder led to an increase in the percent of weight (92.8, 112, 123.5 and 134.2% for control, spaghetti with 3% pomegranate peels, spaghetti with 5% pomegranate peels and spaghetti with 7% pomegranate peels, respectively). The addition of pomegranate peels had a positive effect on water absorption evidence by a significant difference in uncooked to cooked weight ratio due to the increase in dietary fiber content of pomegranate peels noodles. These results agreed with work by Ajila *et al.*[16].

Sensory evaluation: In the present research, the sensory evaluation of cooked macaroni containing 3, 5 and 7% PPP were shown in Table 5. The results indicated that macaroni contained pomegranate peels had higher, significant, sensory scores, except in texture, in comparison with control. A reduction in sensory texture value was obtained by increasing level of pomegranate peels in spaghetti, due to the increase in pomegranate peels fiber. Pomegranate peel, which was rich in dietary fiber content, may cause changes in the gluten protein network resulting a decrease in sensory texture value of pasta[11]. The same results were obtained by Sant'Anna *et al.*[17] in their study on macaroni supplemented with 2.5, 5.5 and 7.5% of grape marc powder since gluten has been reported to be responsible for firmness of macaroni. Pomegranate peels fortified spaghetti had a significant higher taste scores than control and the taste score increased with the increase of pomegranate peels level. The total acceptability value had a significant increase as pomegranate peels content increased. However, it could be observed that supplemented of spaghetti with pomegranate peels powder led to significant increase the appearance, taste, color, odour and overall acceptability at all supplementation levels relative to control. From the sensory analyses, it was concluded that pomegranate peel powder could be incorporated up to 7% level in the formulation of spaghetti without affecting its sensory quality.

Bioactive compounds in spaghetti: Total phenolic contents, total flavonoids and DPPH radical scavenging activity of pomegranate peels powder and spaghetti enriched with different levels of pomegranate peels powder was presented in Table 6. From the data presented in Table 6, it could be noticed that, the pomegranate peels powder is a good source of total phenolic content 5648 mg gallic acid/100 g, total flavonoids 870 mg quercetin/100 g and had a great free radical scavenging activity (DPPH) 86.15%. Substitution of wheat flour with 3, 5 and 7% of PPP for making spaghetti resulted in significant increases in total phenolics, flavonoids

Table 6: Total polyphenols content, total flavonoids and antioxidant activity of spaghetti enriched with different levels of pomegranate peel powder*

Samples	Total phenols (mg/100 g)	Total flavonoids (mg/100 g)	DPPH. scavenging activity (%)
Flour (72% ext.)	46.18±0.96^{e}	126.32±0.85^{e}	27.18±2.30^{e}
Pomegranate peel	5648.00±3.29^{a}	870.00±2.71^{a}	86.15±1.86^{a}
Control	102.74±1.33^{d}	139.72±1.80^{d}	31.15±2.25^{e}
Spaghetti with 3% pomegranate peel	267.18±2.25^{c}	159.62±1.70^{d}	43.83±2.00^{d}
Spaghetti with 5% pomegranate peel	378.15±2.01^{bc}	176.22±1.55^{c}	61.98±1.60^{c}
Spaghetti with 7% pomegranate peel	488.96±2.44^{b}	190.82±1.98^{b}	81.62±2.12^{b}

*All data are the Mean±SD of three replicates. Mean followed by different letters in the same column differs significantly ($p \leq 0.05$)

and DPPH, respectively. The phenol content significantly increase to 267.18, 378.15 and to 488.96 mg gallic acid/100 g when the pomegranate peels was added in spaghetti by 3, 5 and 7%, respectively. Also data in the same table indicated that the flavonoids content significantly increased to 159.62, 176.22 and to 190.82 mg quercetin/100 g dry weight when the pomegranate peels was added by 3, 5 and 7% in spaghetti, respectively. The increase in total phenols was due to the high content of phenols in pomegranate peels. Finally, the results in the same table revealed that, the antioxidant activity of control spaghetti is found to be 38.21%. The antioxidant activity increased 1.41 folds by the addition of 3% pomegranate peels, while the increase of pomegranate peels to 5 and 7% increased the antioxidant by 1.99 and 2.62 folds, respectively. The increase in antioxidant was due to the addition of pomegranate peels which has a high content of antioxidant.

The results indicated that total phenolic, total flavonoids and DPPH increased of enriched spaghetti by increasing of substitution levels. This could be due to pomegranate peels powder contains phenols and flavonoids more than wheat flour, subsequently increase DPPH of enriched spaghetti formulas.

CONCLUSION

The current study concluded that pomegranate peels powder can be used in spaghetti preparation in order to enhance its functional properties. In the light of the present data it can also be concluded that the 7% PPP supplementation was the optimal for improving the antioxidant potential as well as dietary fiber of spaghetti. Therefore, using agro-industrial wastes as a food ingredient will prevent environmental pollution and increase the amount of available nutrients.

SIGNIFICANCE STATEMENTS

This study discovers the utilization of dried pomegranate peels powder as a source of antioxidants and dietary fiber that can be beneficial for preventing the cardiovascular diseases development, anti-inflammatory, hypoglycemic, anti-parasitic and apoptotic. This study will help the researchers to reveal its potential use for value addition in food products especially in spaghetti to enhance functional characteristics and overall antioxidant potential of final food products.

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