Research Article

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The effect of hazelnut roasted skin from different cultivars on the quality attributes, polyphenol content and texture of fresh egg pasta

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Abstract

BACKGROUND: Hazelnut skin is the perisperm of the hazelnut kernel. It is separated from the kernel during the roasting process and is normally discarded. Recent studies have reported that hazelnut skin is a rich source of dietary fibre as well as of natural antioxidants owing to the presence of phenolic compounds. The aim of this study was to assess the use of hazelnut skins obtained from different cultivars for enhancing the nutritional value of fresh egg pasta.

RESULTS: Skins obtained from roasted hazelnuts of four different varieties were used at three concentrations as a flour replacement in fresh egg pasta. Hazelnut skin concentration significantly influenced all evaluated physicochemical parameters as well as consumers' appreciation for the pasta, but significant differences were also observed between the four varieties. Although pasta produced with 10 and 15% hazelnut skin displayed the highest content of polyphenolic compounds and antioxidant activity *in vitro*, pasta containing 5% Tombul hazelnut skin showed maximum consumer preference.

CONCLUSION: The results obtained in the present study highlighted that it is possible to use hazelnut skin in fresh pasta production to obtain a fortified food with high fibre content and antioxidant activity. The characteristics of the resulting pasta were strictly correlated with the hazelnut variety used for skin production and, of course, with the percentage of skin that was added.

Keywords: pasta; dietary fibre; polyphenol; antioxidant capacity; hazelnut skin

INTRODUCTION

Hazelnut skin is the perisperm of hazelnut kernel and represents approximately 2.5% of the total hazelnut kernel weight. The skin is separated from the kernel during hazelnut roasting and is normally discarded. However, recent studies have reported that hazelnut skin is a rich source of dietary fibre[1] as well as of natural antioxidants owing to the presence of phenolic compounds.[2–5] Hazelnut skin is thus referred to as an 'antioxidant dietary fibre' (ADF). Given the relationship between antioxidants and dietary fibre, it has been proposed that hazelnut skin may not only retard human low-density lipoprotein oxidation *in vitro*[6] but also help enhance host gastrointestinal health by promoting a beneficial microbiota profile,[7] thus exerting a significant role in the prevention of human diseases.[8,9]

ADF may be incorporated into flour for making baked goods high in dietary fibre, while the polyphenols in ADF could contribute as antioxidants for improving the colour, aroma and taste of the product. For instance, mango peel powders are used when preparing macaroni to enhance its antioxidant properties.[10] Apple pomace is incorporated into wheat flour as a fibre source to improve the rheological characteristics of cake.[11] Grape pomace is mixed with sourdough in rye bread,[12] and grape seed flour is used for cereal bars, pancakes and noodles.[13]

In recent years, there has been increasing interest in applying fruit-processing wastes as functional food ingredients, because they are a rich source of ADF and because most of the beneficial bioactive compounds remain in these by-products.[14–18]

Thus the aim of this study was to assess the prospective use of hazelnut skins obtained from different cultivars for enhancing the nutritional value of fresh egg pasta.

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Pasta was selected because of its widespread distribution around the world, extended shelf life and compositional characteristics. In addition, the Food and Drug Administration (FDA) has considered pasta a suitable vehicle for the incorporation of nutrients since the 1940s, when, for the first time, enrichment of pasta with vitamins and iron was permitted.[19] In past years, attempts to enhance the nutritional value of pasta have also been made by adding various vegetables, juices and legumes that are rich in protein, fibre, minerals and vitamins.[20–26]

MATERIALS AND METHODS

Materials

The skins of four different hazelnut (*Corylus avellana* L.) varieties supplied by Nocciole Marchisio SpA (Cortemilia, Cuneo, Italy) were studied: 'Tonda Gentile Trilobata' (TGT) and 'San Giovanni' cultivars from Italy, 'Tombul' from Turkey and 'Georgia' from Georgia. Hazelnuts were roasted (150–155 °C, 34–39 min) in an industrial continuous-working rotary oven, and the skins were peeled off and ground using an Ultra Centrifugal Mill ZM 200 (Retsch GmbH, Milan, Italy) with a 500 µm sieve. The skin samples were stored under vacuum and kept at −18 °C until analysis.

Chemicals

All reagents (Folin–Ciocalteu's phenol reagent, 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2′-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) diammonium salt (ABTS), 6-hydroxy-2,5,7,8-tetra methylchroman-2-carboxylic acid (Trolox), 2,2′-azobis(2-amidino propane) dihydrochloride (AAPH) and 3′,6′-dihydroxyspiro[iso benzofuran-1[3*H*],9′[9*H*]-xanthen]-3-one (fluorescein)) and solvents were purchased from Sigma-Aldrich (Milan, Italy). All chemicals were of reagent grade. Ultrapure water was produced with a Milli-Q system (Millipore, Milan, Italy).

Pasta making and cooking

Ingredients for pasta making, such as '00' type soft wheat flour (129 g kg^{-1} moisture, 98 g kg^{-1} protein) (Barilla SpA, Parma, Italy) and chicken-pasteurised whole eggs with a protein content of 120 g kg^{-1} and a lipid content of 110 g kg^{-1} (AIA, San Martino Buon Albergo, Verona, Italy), were purchased at a local market.

Pasta was produced using a Pastamatic Simac PM1400N1 (Simac, Treviso, Italy) and extruded as 'tagliatelle' (length 100 mm, width 6 mm, thickness 1 mm). Control pasta was made using 1 kg of '00' type wheat flour and 400 g of pasteurised eggs, whereas functionalised pasta was made by replacing the wheat flour with ground hazelnut skins in three different amounts: 5, 10 and 15% (w/w).

Three production batches were prepared for each type of pasta.

Uncooked pasta was dried at 65 °C in an oven until a moisture level of approximately 50 g kg^{-1} was reached and then ground using an Ultra Centrifugal Mill ZM 200 (Retsch GmbH) with a 500 µm sieve and stored in amber flasks at −18 °C.

For the assays analysing composition, total phenolic content, antioxidant level and colour of cooked product, the pasta was cooked in distilled water (pasta/water 1:10 w/w) until the white central core of the pasta disappeared, in accordance with AACC method 66–50.[27] After cooking, the pasta was immediately cooled in distilled water at room temperature, dried at 65 °C in an oven until reaching approximately 50 g kg^{-1} of humidity, ground in a similar manner to the uncooked product, sieved and stored at −18 °C.

The cooking water was collected, filtered (0.45 µm) and stored in amber vials at −18 °C until the total phenolic content and antioxidant analyses were performed.

For the consumer preference tests, the pasta was cooked in natural unsalted tap water in an approximately 1:10 (w/w) ratio of pasta to water. After cooking for 4 min, the pasta was removed, drained and served to the consumers in plastic dishes with randomly assigned three-digit codes.

Compositional analysis

The moisture, fat, ash, protein and dietary fibre (total, soluble and insoluble) contents of hazelnut skin and uncooked pasta were determined in accordance with AOAC methods.[28] Moisture was determined by heating 1 g of sample at 103 °C in an oven until a constant weight was reached. Total protein content (conversion factor 6.25) was estimated using the Kjeldahl method (UDK 130A System, Velp Scientifica, Usmate, Monza-Brianza, Italy). Lipids were extracted using a Soxhlet Velp Extraction System SER 148 (Velp Scientifica) for 6 h with *n*-hexane as the solvent. Ash content was determined in a muffle furnace at 525 ± 25 °C. The carbohydrate value was estimated by difference as 100 − (moisture + fat + protein + ash + dietary fibre). Dietary fibre (total, soluble and insoluble) was measured using a Megazyme Total Dietary Analysis kit (Megazyme International, Bray, Ireland).

Extraction of antioxidant compounds

The extraction of antioxidant compounds from hazelnut skin, uncooked pasta and cooked pasta was performed as reported by Fares *et al.*[29] with slight modifications. Briefly, finely ground samples of pasta (1 g of uncooked or cooked) and hazelnut skin (0.25 g) were extracted twice with 20 mL of a methanol and water solution acidified with formic acid at pH 2 (80:20 v/v) in dark conditions with regular shaking for 2 h. After centrifugation (16 800 × *g*, 15 min, 5 °C), the supernatants were collected, filtered (0.45 µm) and stored in amber vials at −18 °C until the total phenolic content and antioxidant analyses were performed. The extractions were performed in triplicate.

Total phenolic content assay

Total phenolic content (TPC) was assayed spectrophotometrically using a modified Folin–Ciocalteu method.[30] Briefly, 50 µL of extract was mixed with 250 µL of Folin–Ciocalteu reagent and 3 mL of ultrapure water. The mixture was allowed to equilibrate for 3 min at room temperature and then 750 µL of 200 g L^{-1} aqueous sodium carbonate solution was added. After incubation for 2 h in the dark at room temperature, the specific absorbance of the mixture at 765 nm was measured using a UV–visible spectrophotometer (UV-1700 PharmaSpec, Shimadzu, Milan, Italy). A mixture of solvents and reagents was used as a blank. Gallic acid was used as a standard, and results were expressed as mg gallic acid equivalent (GAE) g^{-1} dry weight (DW).

DPPH radical-scavenging capacity assay

Free radical-scavenging capacity (RSC) was determined according to the procedure reported by von Gadow *et al.*[31] using the stable DPPH radical (DPPH•).[31] Briefly, 75 µL of extract was added to 3 mL of 6.1 × 10^{-5} mol L^{-1} DPPH• methanolic solution and incubated for 1 h at room temperature in the dark. After this time, the decrease in absorbance at 515 nm was recorded using methanol as a control

and a methanolic solution of DPPH• as a blank. Results were expressed as μmol Trolox equivalent (TE) g^{-1} DW by means of a dose–response curve for Trolox (0–350 μmol L^{-1}).

Trolox equivalent antioxidant capacity assay

Trolox equivalent antioxidant capacity (TEAC) was determined according to the original analytical procedure described by Re *et al.*[32] The ABTS radical cation ($ABTS^{\bullet+}$) was prepared by reacting 7 mmol L^{-1} ABTS stock solution with 2.45 mmol L^{-1} potassium persulfate (final concentration). The mixture was allowed to stand in the dark at room temperature for 12–16 h before use. Just before the analysis, the $ABTS^{\bullet+}$ stock solution was diluted with ethanol until reaching an absorbance of 0.70 ± 0.02 at 734 nm and then equilibrated at 30 °C. Sample or standard solutions (30 μL) were mixed with the $ABTS^{\bullet+}$ solution (3 mL). Absorbance readings were taken at 30 °C exactly 6 min after initial mixing. An appropriate solvent blank was obtained by mixing the extraction solvent (30 μL) with $ABTS^{\bullet+}$ solution (3 mL), and absolute ethanol was used as a control. Results were expressed as μmol TE g^{-1} DW by means of a dose–response curve for Trolox (0–50 μmol L^{-1}).

Oxygen radical absorbance capacity assay

Oxygen radical absorbance capacity (ORAC) was determined in 96-well black plates using a PerkinElmer 2030 Multilabel Reader (PerkinElmer, Milan, Italy). The reaction was performed in 75 mmol L^{-1} potassium phosphate buffer (pH 7.4) as a blank, and different Trolox solutions ranging from 0.25 to 6 μmol L^{-1} were used as standards.[33] The sample solutions were prepared by diluting antioxidant extracts with phosphate buffer. To start the incubation, 150 μL aliquots of fluorescein solution (48 nmol L^{-1} in potassium phosphate buffer) were dispensed into all wells, followed by 20 μL of either buffer, standard or sample solutions added in duplicate. The plate was covered and incubated in the preheated (37 °C) microplate reader for 10 min, which included shaking for 3 min. At the end, 30 μL of AAPH solution (133 mmol L^{-1} in phosphate buffer) was added, and the reaction started when the plate was reinserted into the reader at 37 °C. All fluorescence measurements were expressed in relation to the initial reading of the fluorescence signal and were repeated every minute for 35 min at an emission wavelength of 535 nm with excitation at 485 nm. The net area under the curve (AUC) was calculated by subtracting the AUC of the blank sample from the AUC of either the standard or the sample. The Trolox equivalent molar concentrations of the samples were calculated using a linear regression equation between the Trolox concentration and the corresponding net AUC. To compare the extracts, relative ORAC values were calculated as μmol TE g^{-1} DW.

Texture analysis

Texture analysis was performed only on cooked pasta using a TAxT2i Texture Analyser (Stable Micro Systems, Godalming, UK) fitted with a 1 mm thick Perspex cutting probe and according to AACC method 66–50.[27] The crosshead speed was 10 mm s^{-1}, the data were acquired with a resolution of 500 Hz and a load cell of 5 kg was used. The test was performed such that the knife descended 5 mm and stopped 0.5 mm from the baseplate before returning to the start position. The cutting-shear test was performed on one 'tagliatelle' strand at a time, and each strand was placed on the HDP/90 instrument platform perpendicular to the base of the knife. Five strands from each cooked batch were analysed.

Texture Export Exceed Release 2.54 (Stable Micro Systems) was used to acquire the force–time curve and to evaluate the maximum cutting force (N) and the total work to cut (mJ).[34]

Colour measurement

A Chroma Meter CR-400 (Konica Minolta, Osaka, Japan) equipped with C illuminant, using the CIE 1976 L^*, a^* and b^* colour scale, was used to measure the colour of the uncooked and cooked pasta samples. For the analyses, 5 g powdered samples were put into 5.5 cm diameter petri dishes until a thickness of 5 mm was obtained. For each sample, five measurements were performed.

Consumer preference test

To evaluate pasta quality, 82 consumers (37 males and 45 females aged between 26 and 65 years) were recruited to conduct acceptance testing. The participant recruitment criteria were that they ate pasta at least three times per week and had no food allergies.

Testing was performed in a heated/air-conditioned meeting room with white lights. The temperature was approximately 21 °C and the relative humidity was approximately 50%. Tests were performed starting at 11:00 over 3 days.

For each session, five samples of pasta (approximately 30 g for each sample), without dressing, were presented in a completely randomised and balanced order. The samples were offered to the consumers in coded opaque white plastic cups hermetically sealed with plastic lids. Plastic forks, napkins and bottled water were provided for each participant.

Consumers rated the appearance, texture and overall enjoyment of each pasta sample on a nine-point hedonic category scale ranging from 'dislike extremely' (1) to 'like extremely' (9). A 5 min gap between samples was enforced. Consumers were required to rinse their mouth with still water during this interval. Paper score-sheets were used for data collection.

Statistical analysis

Experimental data were analysed by one-way analysis of variance (ANOVA) with Duncan's test ($P \leq 0.05$) as a multiple range test using STATISTICA for Windows Release 7.0 (StatSoft Inc., Tulsa, OK, USA).

RESULTS AND DISCUSSION

Hazelnut skins

The proximate composition of hazelnut skins is shown in Table 1. In accordance with the results reported by Anil[35] and Montella *et al.*,[5] total dietary fibre was the major component, with a range between 542.9 and 568.5 g kg^{-1} and with significant differences among the cultivars. An average of 86% of the total dietary fibre consisted of insoluble fibre, with values also differing significantly among the cultivars. The second most abundant component was carbohydrate (ranging from 183.4 to 197.0 g kg^{-1}), with the exception of Tombul hazelnut skin (whose carbohydrate content was 24.3 g kg^{-1}). It is important also to underscore the lipid content, which ranged from 109.9 to 287.8 g kg^{-1}.

Recent studies have shown that hazelnut skins are also rich in phenolic compounds and possess stronger antioxidant activity than the kernel and other tree nut by-products.[36] As reported by Schmitzer *et al.*,[37] a significant decrease in individual phenolics resulting in lower total phenolic content and antioxidant potential was detected after skin removal in different hazelnut cultivars.

The TPC and antioxidant capacity (AC) values assessed in hazelnut skin extracts and expressed per sample dry basis were clearly

Table 1. Proximate composition, total phenolic content (TPC), radical-scavenging capacity (RSC), Trolox equivalent antioxidant capacity (TEAC) and oxygen radical absorbance capacity (ORAC) of roasted hazelnut skins and results of analysis of variance with Duncan's test

Parameter	Hazelnut variety				Significance
	Georgia	Tombul	San Giovanni	TGT	
Moisture (g kg^{-1})	43.1 ± 0.2b	37.2 ± 0.3a	60.2 ± 0.2c	47.2 ± 0.2b	**
Protein (g kg^{-1} DW)	93.9 ± 1.4a	97.7 ± 1.4b	91.7 ± 1.0a	88.5 ± 1.1a	***
Total lipid (g kg^{-1} DW)	109.9 ± 1.7a	287.8 ± 1.6d	187.6 ± 1.8c	172.0 ± 1.6b	***
Carbohydrates (g kg^{-1} DW)	197.0 ± 4.6c	24.3 ± 1.3a	183.4 ± 1.3b	191.0 ± 2.1c	***
Ash (g kg^{-1} DW)	21.6 ± 0.5a	22.5 ± 0.2b	26.0 ± 0.7c	24.7 ± 0.6c	***
Total dietary fibre (g kg^{-1} DW)	568.5 ± 5.6b	557.7 ± 10.5b	543.4 ± 18.0a	542.9 ± 29.8a	**
Soluble dietary fibre (g kg^{-1} DW)	87.6 ± 1.8c	102.5 ± 1.2d	54.3 ± 5.6b	45.1 ± 2.1a	***
Insoluble dietary fibre (g kg^{-1} DW)	499.4 ± 3.6c	477.4 ± 3.3b	464.6 ± 5.1a	466.7 ± 5.0ab	***
TPC (mg GAE g^{-1} DW)	195.76 ± 4.93c	102.19 ± 1.43a	153.29 ± 5.95b	160.05 ± 2.84b	***
RSC (μmol TE g^{-1} DW)	1004.98 ± 21.23c	655.65 ± 6.14a	984.66 ± 16.78c	854.47 ± 21.59b	***
TEAC (μmol TE g^{-1} DW)	1032.00 ± 56.38c	546.32 ± 21.49a	888.94 ± 29.27b	827.67 ± 11.13b	***
ORAC (μmol TE g^{-1} DW)	1227.67 ± 41.9b	806.50 ± 69.15a	1141.83 ± 128.26b	1124.50 ± 141.76b	***

Data are expressed as mean ± standard deviation. Values in each row having different letters are significantly different at $P < 0.05$.
** $P < 0.01$
*** $P < 0.001$.
DW, dry weight; GAE, gallic acid equivalent; TE, Trolox equivalent.

distinct among the cultivars. The highest values were always measured in Georgia skin extracts and the lowest in Tombul skin extracts. The results obtained from TGT and San Giovanni were always similar. The TPC ranged from 102.2 to 195.8 mg GAE g^{-1} DW. The use of different extraction methods and/or different data expression methods prevented the comparison of our results with those published by other authors. In a previous report a TPC of 116.5 mg GAE g^{-1} was detected in dry TGT hazelnut skin extracted with 80% ethanol.[4] For the same cultivar, Del Rio *et al.*[3] reported a TPC of 111 mg GAE g^{-1} in skin extracted with 1% aqueous formic acid, whereas Monagas *et al.*[38] reported a TPC of 107 mg GAE g^{-1} in an acidified methanolic extract of Giresun hazelnut skin.

The results of the RSC, TEAC and ORAC assays revealed the same trend as the TPC, with the highest values found for the Georgia samples followed by San Giovanni, TGT and Tombul. All assays were able to significantly discriminate between the cultivars, with the ORAC assay showing the least difference between cultivars. Our data appear to be consistent with the results reported by Li and Parry,[39] who found ORAC values of 683.1 and 1166.2 μmol TE g^{-1} in Oregon and Turkish roasted hazelnut skins respectively. The comparison with RSC and TEAC values reported by other authors is even more difficult, because they are often expressed on a dry extract basis.

Uncooked pasta

Table 2 shows the chemical composition of uncooked pasta. With the exception of protein and soluble fibre, the values of all other parameters increased significantly ($P < 0.001$) for all cultivars according to the level of fortification, as expected.

Moisture, lipid and carbohydrate content differences among the cultivars were also observed. In particular, for lipids, significant differences ($p < 0.001$) were observed for all added amounts of hazelnut skin, and the Tombul cultivar displayed the highest values for all added amounts.

The addition of hazelnut skin substantially changed the colour of the uncooked pasta samples, and significant differences between all percentages of fortification and between the hazelnut varieties were observed for the L^*, a^* and b^* colour coordinates.

For the L^* parameter, the use of hazelnut skin resulted in an increase in sample darkness with increased amounts of fortification, regardless of the type of hazelnut skin used for fortification. With 5% addition, no differences were observed between fresh pasta samples fortified with hazelnut skin from different varieties, whereas at the 10% level the lowest L^* parameter values were observed for pasta fortified with San Giovanni or Georgia skin. At 15% fortification the lowest values were instead observed for pasta fortified with San Giovanni or TGT skin.

For the a^* parameter, lower values were generally observed for pasta fortified with Tombul skin, whereas higher values were observed for pasta fortified with Georgia skin.

For the b^* parameter, only additions of 10 and 15% hazelnut skin led to significant differences among the hazelnut varieties, with generally lower values observed for San Giovanni.

As expected, with increased levels of fortification, the amount of total phenolic compounds and the AC increased accordingly. Similarly, for each skin addition level, the behaviour of the cultivars was significantly different despite not following a uniform trend. We observed different trends for different assays and for different levels of fortification. At 15% fortification, when the effect of skin addition was the most sizable, raw pasta fortified with Georgia hazelnut skin exhibited the highest values of TPC, TEAC and ORAC, whereas the lowest values were detected in Tombul pasta samples. The results of the RSC assay were often in disagreement with those of the other assays. Pasta extracts containing hazelnut skins exhibited higher phenolic and antioxidant contents compared with controls; however, low levels of TPC (1.65 mg GAE g^{-1} DW) and AC (3.21, 0.63 and 15.47 μmol TE g^{-1} DW for the RSC, TEAC and ORAC assays respectively) were also observed in the control samples. These results could be explained by the presence of natural antioxidants in flour and eggs. Indeed, it is well known that whole wheat grain contains a certain amount of phytochemicals that includes phenolics, carotenoids, vitamin E and lignans,[40] whereas some phenolic compounds such as the amino acids tyrosine and tryptophan determine the antioxidant properties of eggs.[41]

Table 2. Proximate composition, colour parameter values, total phenolic content (TPC), radical-scavenging capacity (RSC), Trolox equivalent antioxidant capacity (TEAC) and oxygen radical absorbance capacity (ORAC) of uncooked pasta and results of analysis of variance with Duncan's test

	Hazelnut skin					
Level of skin addition	Georgia	Tombul	San Giovanni	TGT	Control (0%)	Significance
Moisture (g kg^{-1})						
Control (0%)	313.5 ± 1.7B	313.5 ± 1.7B	313.5 ± 1.7B	313.5 ± 1.7B		
5%	309.6 ± 0.3A	309.5 ± 0.4A	310.2 ± 0.2AB	309.7 ± 0.2A	–	NS
10%	306.4 ± 0.1a,A	306.6 ± 0.6a,A	308.0 ± 0.5b,A	306.6 ± 0.3a,A	–	**
15%	303.4 ± 0.2a,A	303.1 ± 0.5a,A	305.5 ± 0.5b,A	303.8 ± 0.1a,A	–	***
Significance	***	***	**	***		
Protein (g kg^{-1} DW)						
Control (0%)	153.7 ± 1.6	153.7 ± 1.7	153.7 ± 1.6	153.7 ± 1.5		
5%	152.5 ± 1.3	152.1 ± 1.8	152.5 ± 1.2	152.1 ± 1.4	–	NS
10%	151.0 ± 1.7	151.8 ± 1.5	151.3 ± 1.5	150.6 ± 1.7	–	NS
15%	150.2 ± 1.5	150.8 ± 1.4	150.1 ± 1.4	149.5 ± 1.4	–	NS
Significance	NS	NS	NS	NS		
Total lipid (g kg^{-1} DW)						
Control (0%)	48.8 ± 1.9A	48.8 ± 1.7A	48.8 ± 1.5A	48.8 ± 1.6A		
5%	53.1 ± 1.9a,B	62.6 ± 2.2c,B	57.1 ± 2.1b,B	56.1 ± 1.7ab,B	–	***
10%	58.1 ± 1.7a,C	75.5 ± 1.7c,C	65.3 ± 1.3b,C	63.5 ± 2.0b,C	–	***
15%	62.6 ± 1.6a,D	88.6 ± 1.5d,D	74.9 ± 1.5c,D	71.2 ± 1.7bc,D	–	***
Significance	***	***	***	***		
Carbohydrates (g kg^{-1} DW)						
Control (0%)	782.6 ± 1.8B	782.6 ± 1.8D	782.6 ± 1.8C	782.6 ± 1.8D		
5%	748.8 ± 6.0AB	744.5 ± 2.2C	750.8 ± 2.8B	749.2 ± 5.3C	–	NS
10%	719.3 ± 5.1b,A	703.6 ± 4.0a,B	717.7 ± 8.6b,A	719.4 ± 5.2b,B	–	*
15%	693.5 ± 2.2b,A	666.1 ± 2.8a,A	694.5 ± 3.9b,A	691.5 ± 2.3b,A	–	***
Significance	***	***	***	***		
Ash (g kg^{-1} DW)						
Control (0%)	4.5 ± 0.3A	4.5 ± 0.3A	4.5 ± 0.3A	4.5 ± 0.3A		
5%	5.5 ± 0.6BC	5.4 ± 0.4B	5.6 ± 0.5B	5.5 ± 0.3A	–	NS
10%	6.6 ± 1.0CD	6.2 ± 0.2C	6.6 ± 0.4C	6.6 ± 0.6B	–	NS
15%	7.6 ± 1.3D	7.1 ± 0.2D	7.7 ± 0.5D	8.3 ± 1.0C	–	NS
Significance	**	***	***	***		
Total dietary fibre (g kg^{-1} DW)						
Control (0%)	59.0 ± 1.8A	59.0 ± 1.8A	59.0 ± 1.8A	59.0 ± 1.8A		
5%	83.4 ± 2.1B	80.6 ± 7.3B	83.9 ± 3.0B	86.3 ± 7.0B	–	NS
10%	113.3 ± 7.7C	106.2 ± 6.0C	106.2 ± 2.4C	109.2 ± 7.6C	–	NS
15%	137.2 ± 6.9D	138.5 ± 7.7D	128.2 ± 1.9D	127.6 ± 1.6D	–	NS
Significance	***	***	***	***		
Soluble dietary fibre (g kg^{-1} DW)						
Control (0%)	27.4 ± 5.6	27.4 ± 5.6	27.4 ± 5.6	27.4 ± 5.6		
5%	29.3 ± 3.8	29.4 ± 2.6	26.7 ± 2.5	26.5 ± 2.6	–	NS
10%	32.2 ± 3.6	36.2 ± 7.6	27.1 ± 1.6	28.9 ± 5.1	–	NS
15%	35.2 ± 3.8	40.0 ± 7.6	28.2 ± 1.5	30.4 ± 6.2	–	NS
Significance	NS	NS	NS	NS		
Insoluble dietary fibre (g kg^{-1} DW)						
Control (0%)	45.7 ± 4.9A	45.7 ± 4.9A	45.7 ± 4.9A	45.7 ± 4.9A		
5%	70.1 ± 8.4B	68.0 ± 6.5B	66.8 ± 6.3B	67.3 ± 6.5B	–	NS
10%	90.6 ± 6.9C	88.8 ± 5.8C	86.5 ± 5.8C	87.2 ± 5.8C	–	NS
15%	112.6 ± 5.9D	110.3 ± 6.6D	108.6 ± 9.6D	108.1 ± 7.0D	–	NS
Significance	***	***	***	***		
L^*						
Control (0%)	88.82 ± 0.72C	88.82 ± 0.72C	88.82 ± 0.72D	88.82 ± 0.72D		
5%	66.89 ± 0.66B	72.90 ± 1.87B	65.43 ± 0.74C	67.35 ± 1.38C	–	NS
10%	56.53 ± 0.59a,A	60.52 ± 2.08b,A	57.19 ± 2.03a,B	61.33 ± 1.28b,B	–	***
15%	55.52 ± 3.47b,A	56.15 ± 1.27b,A	49.27 ± 3.14a,A	51.45 ± 3.37a,A	–	***

Table 2. Continued

Level of skin addition	Hazelnut skin: Georgia	Tombul	San Giovanni	TGT	Control (0%)	Significance
Significance	***	***	***	***		
a^*						
Control (0%)	−2.10 ± 0.18A	−2.10 ± 0.18A	−2.10 ± 0.18A	−2.10 ± 0.18A		
5%	3.76 ± 0.06c,B	2.34 ± 1.13a,B	3.29 ± 0.17bc,B	2.80 ± 0.13ab,B	–	***
10%	5.65 ± 0.24c,C	4.35 ± 0.18a,C	4.71 ± 0.10b,C	4.20 ± 0.16a,C	–	***
15%	6.09 ± 0.21c,D	5.31 ± 0.09a,D	5.76 ± 0.27b,D	5.96 ± 0.26bc,D	–	***
Significance	***	***	***	***		
b^*						
Control (0%)	19.41 ± 1.51B	19.41 ± 1.51B	19.41 ± 1.51B	19.41 ± 1.51B		
5%	15.77 ± 0.11A	13.83 ± 5.89A	15.18 ± 0.39A	16.45 ± 0.23A	–	NS
10%	15.95 ± 0.54b,A	15.40 ± 0.24a,AB	15.22 ± 0.15a,A	16.36 ± 0.08b,A	–	***
15%	16.14 ± 0.39ab,A	16.22 ± 0.27bc,B	15.64 ± 0.45a,A	16.69 ± 0.34c,A	–	***
Significance	***	***	***	***		
TPC (mg GAE g^{-1} DW)						
Control (0%)	1.65 ± 0.08A	1.65 ± 0.08A	1.65 ± 0.08A	1.65 ± 0.08A		
5%	2.02 ± 0.04c,A	1.28 ± 0.13a,B	2.20 ± 0.02d,B	1.70 ± 0.02b,A	1.65 ± 0.08b	***
10%	4.58 ± 0.10c,B	2.56 ± 0.18b,C	4.26 ± 0.19c,C	3.01 ± 0.69b,B	1.65 ± 0.08a	***
15%	6.94 ± 0.71d,C	3.71 ± 0.24b,D	5.80 ± 0.16c,D	6.89 ± 0.06d,C	1.65 ± 0.08a	***
Significance	***	***	***	***		
RSC (μmol TE g^{-1} DW)						
Control (0%)	3.21 ± 0.17A	3.21 ± 0.17A	3.21 ± 0.17A	3.21 ± 0.17A		
5%	10.72 ± 0.38d,B	7.24 ± 0.28b,B	11.80 ± 0.31e,B	9.63 ± 0.23c,B	3.21 ± 0.17a	***
10%	22.87 ± 0.15c,C	13.91 ± 1.19b,C	23.45 ± 0.63c,C	24.08 ± 0.53c,C	3.21 ± 0.17a	***
15%	31.72 ± 1.61c,	23.05 ± 0.58b,D	31.23 ± 0.16c,D	36.17 ± 1.03d,D	3.21 ± 0.17a	***
Significance	***	***	***	***		
TEAC (μmol TE g^{-1} DW)						
Control (0%)	0.63 ± 0.10A	0.63 ± 0.10A	0.63 ± 0.10A	0.63 ± 0.10A		
5%	7.99 ± 0.75e,B	4.34 ± 0.12b,B	7.10 ± 0.16d,B	5.99 ± 0.26c,B	0.63 ± 0.10a	***
10%	19.73 ± 1.11e,C	9.13 ± 0.40b,C	15.60 ± 0.16d,C	13.81 ± 0.94c,C	0.63 ± 0.10a	***
15%	31.63 ± 3.18d,D	14.88 ± 1.12b,D	26.56 ± 1.47c,D	24.30 ± 0.47c,D	0.63 ± 0.10a	***
Significance	***	***	***	***		
ORAC (μmol TE g^{-1} DW)						
Control (0%)	15.47 ± 2.71A	15.47 ± 2.71A	15.47 ± 2.71A	15.47 ± 2.71A		
5%	25.94 ± 4.76c,B	19.41 ± 5.75ab,A	27.98 ± 3.45c,B	24.41 ± 4.54bc,AB	15.47 ± 2.71a	***
10%	55.90 ± 5.53d,C	27.80 ± 2.48b,B	41.68 ± 4.66c,C	33.11 ± 2.65b,B	15.47 ± 2.71a	***
15%	73.89 ± 5.01d,D	31.79 ± 6.55b,B	51.97 ± 15.71c,C	54.45 ± 11.68c,C	15.47 ± 2.71a	***
Significance	***	***	***	***		

Data are expressed as mean ± standard deviation. Values in each row having different lowercase letters are significantly different at $P < 0.05$. Values in each column having different capital letters are significantly different at $P < 0.05$. NS, not significant

*$P < 0.05$

**$P < 0.01$

***$P < 0.001$.

DW, dry weight; GAE, gallic acid equivalent; TE, Trolox equivalent.

Cooked pasta

The TPC and the antioxidant indices of cooked pasta fortified with hazelnut skins and in the cooking water are summarised in Tables 3 and 4. For all examined parameters, there were significant differences between the uncooked and cooked pasta samples, with a 63% decrease in the TPC of the control sample after cooking. The average decrease in TPC in fortified pasta samples ranged from 54 to 60% (Table 5). Retention of phenolic content was significantly higher in pasta fortified with TGT skin, followed by pasta fortified with San Giovanni, Georgia, and Tombul skins. Different behaviours were observed for different antioxidant assays. Nevertheless, Tombul skin addition resulted in the lowest efficacy across all assays. This could be due to the leaching of phenolic compounds into the cooking medium; however, the cooking medium also showed low phenol content (0.01–0.11 mg GAE mL^{-1}) and AC (TEAC ranged between 0.01 and 0.99 μmol TE mL^{-1}) values. Similarly, Hirawan *et al.*[42] have reported a 40% reduction in the TPC of both regular and whole wheat spaghetti after cooking.

For the L^* parameter, the control pasta exhibited the highest brightness values (because hazelnut skin powder is a dark-coloured ingredient), followed by the pasta with added Tombul skin at all percentages added.

The decrease in the degree of redness (a^* value) was lowest for the pasta fortified with Georgia skin at 15%. The highest

Table 3. Total phenolic content (TPC), radical-scavenging capacity (RSC), Trolox equivalent antioxidant capacity (TEAC), oxygen radical absorbance capacity (ORAC), colour parameter values, texture properties and consumers' liking values of cooked skin-incorporated pasta and results of analysis of variance with Duncan's test

	Hazelnut skin					
Level of skin addition	Georgia	Tombul	San Giovanni	TGT	Control (0%)	Significance
TPC (mg GAE g^{-1} DW)						
Control (0%)	0.61 ± 0.01A	0.61 ± 0.01A	0.61 ± 0.01A	0.61 ± 0.01A		
5%	0.65 ± 0.04a,A	0.45 ± 0.09a,A	1.00 ± 0.23b,B	1.09 ± 0.03b,B	0.61 ± 0.01a	***
10%	1.67 ± 0.03b,B	0.67 ± 0.13a,B	2.06 ± 0.29c,C	2.32 ± 0.02d,C	0.61 ± 0.01a	***
15%	1.99 ± 0.13c,C	1.23 ± 0.14b,C	2.84 ± 0.20d,D	3.20 ± 0.08e,D	0.61 ± 0.01a	***
Significance	***	***	***	***		
RSC (μmol TE g^{-1} DW)						
Control (0%)	1.04 ± 0.25A	1.04 ± 0.25A	1.04 ± 0.25A	1.04 ± 0.25A		
5%	6.97 ± 0.24c,B	4.27 ± 0.55b,B	5.82 ± 0.18c,B	6.31 ± 0.14c,B	1.04 ± 0.25a	***
10%	12.54 ± 0.43c,C	7.42 ± 0.18b,C	10.41 ± 0.33c,C	13.03 ± 0.27c,C	1.04 ± 0.25a	***
15%	15.07 ± 0.46c,D	12.45 ± 0.18b,D	15.34 ± 0.48c,D	17.71 ± 0.03d,D	1.04 ± 0.25a	***
Significance	***	***	***	***		
TEAC (μmol TE g^{-1} DW)						
Control (0%)	0.04 ± 0.01A	0.04 ± 0.01A	0.04 ± 0.01A	0.04 ± 0.01A		
5%	5.29 ± 0.29d,B	2.52 ± 0.20b,B	4.21 ± 0.06c,B	4.23 ± 0.11c,B	0.04 ± 0.01a	***
10%	11.17 ± 0.88d,C	5.77 ± 0.34b,C	9.18 ± 0.48c,C	8.91 ± 0.73c,C	0.04 ± 0.01a	***
15%	14.92 ± 1.43c,D	9.96 ± 0.13b,D	15.35 ± 0.69c,D	14.24 ± 1.47c,D	0.04 ± 0.01a	***
Significance	***	***	***	***		
ORAC (μmol TE g^{-1} DW)						
Control (0%)	12.75 ± 1.99A	12.75 ± 1.99A	12.75 ± 1.99A	12.75 ± 1.99A		
5%	28.69 ± 4.78c,B	17.98 ± 1.96ab,A	27.51 ± 7.97c,B	22.89 ± 5.31bc,A	12.75 ± 1.99a	***
10%	44.00 ± 8.41c,C	27.34 ± 5.52b,AB	30.61 ± 4.41b,BC	35.61 ± 7.30bc,B	12.75 ± 1.99a	***
15%	35.47 ± 2.54b,BC	33.93 ± 18.34b,B	36.53 ± 1.80b,C	42.51 ± 12.90b,B	12.75 ± 1.99a	**
Significance	***	*	***	***		
L^*						
Control (0%)	91.52 ± 0.41D	91.52 ± 0.41D	91.52 ± 0.41D	91.52 ± 0.41D		
5%	75.30 ± 0.77b,C	77.90 ± 1.33c,C	72.31 ± 2.50a,C	75.84 ± 0.37b,C	91.52 ± 0.41d	***
10%	66.87 ± 1.54b,B	67.35 ± 2.71b,B	63.61 ± 1.58a,B	66.63 ± 0.40b,B	91.52 ± 0.41c	***
15%	63.80 ± 0.73c,A	65.23 ± 0.76c,A	55.62 ± 2.62a,A	60.45 ± 3.25b,A	91.52 ± 0.41d	***
Significance	***	***	***	***		
a^*						
Control (0%)	−3.07 ± 0.19A	−3.07 ± 0.19A	−3.07 ± 0.19A	−3.07 ± 0.19A		
5%	2.37 ± 0.11d,B	1.27 ± 0.19b,B	2.58 ± 0.20e,B	1.78 ± 0.03c,B	−3.07 ± 0.19a	***
10%	4.70 ± 0.15d,C	3.50 ± 0.29b,C	4.97 ± 0.18e,C	3.79 ± 0.08c,C	−3.07 ± 0.19a	***
15%	5.69 ± 0.12d,D	4.42 ± 0.10b,D	6.39 ± 0.21e,D	5.35 ± 0.24c,D	−3.07 ± 0.19a	***
Significance	***	***	***	***		
b^*						
Control (0%)	15.97 ± 0.62C	15.97 ± 0.62D	15.97 ± 0.62B	15.97 ± 0.62B		
5%	13.53 ± 0.17a,A	13.34 ± 0.16a,A	14.11 ± 0.40b,A	13.70 ± 0.14ab,A	15.97 ± 0.62c	***
10%	14.89 ± 0.27ab,B	14.37 ± 0.49a,B	15.75 ± 0.38 cd,B	15.20 ± 0.19bc,A	15.97 ± 0.62d	***
15%	15.38 ± 0.21a,B	15.42 ± 0.13a,C	16.29 ± 0.33b,B	16.09 ± 0.13b,B	15.97 ± 0.62b	***
Significance	***	***	***	***		
Maximum cutting force (N)						
Control (0%)	0.87 ± 0.07B	0.87 ± 0.07C	0.87 ± 0.07A	0.87 ± 0.07C		
5%	1.00 ± 0.01b,C	0.86 ± 0.06a,C	0.91 ± 0.06a,AB	0.90 ± 0.13a,C	0.87 ± 0.07a	*
10%	0.83 ± 0.07bc,AB	0.75 ± 0.08b,B	1.05 ± 0.02d,C	0.64 ± 0.08a,B	0.87 ± 0.07c	***
15%	0.76 ± 0.07b,A	0.49 ± 0.03a,A	0.97 ± 0.02d,B	0.45 ± 0.05a,A	0.87 ± 0.07c	***
Significance	***	***	***	***		
Total work to cut (mJ)						
Control (0%)	0.50 ± 0.03A	0.50 ± 0.03C	0.50 ± 0.03A	0.50 ± 0.03C		
5%	0.85 ± 0.08c,C	0.43 ± 0.06a,B	0.51 ± 0.07a,A	0.63 ± 0.10b,D	0.50 ± 0.03a	***
10%	0.65 ± 0.04c,B	0.41 ± 0.01a,B	0.74 ± 0.05d,B	0.39 ± 0.02a,B	0.50 ± 0.03b	***
15%	0.55 ± 0.04b,A	0.34 ± 0.02a,A	0.73 ± 0.07c,B	0.29 ± 0.04a,A	0.50 ± 0.03b	***
Significance	***	***	***	***		

Table 3. Continued

Level of skin addition	Hazelnut skin					Significance
	Georgia	Tombul	San Giovanni	TGT	Control (0%)	
Appearance						
Control (0%)	8.1 ± 0.8D	8.1 ± 0.8B	8.1 ± 0.8C	8.1 ± 0.8D		
5%	7.6 ± 0.6a,C	8.7 ± 0.6c,C	8.2 ± 0.5b,C	7.5 ± 0.6a,C	8.1 ± 0.8b	***
10%	6.2 ± 0.8a,B	7.4 ± 0.6b,B	6.4 ± 0.6a,B	6.2 ± 0.5a,B	8.1 ± 0.8c	**
15%	4.6 ± 0.6a,A	6.2 ± 0.5c,A	5.2 ± 0.5b,A	4.8 ± 0.5ab,A	8.1 ± 0.8d	***
Significance	***	***	***	***		
Texture						
Control (0%)	8.0 ± 0.7C	8.0 ± 0.7C	8.0 ± 0.7C	8.0 ± 0.7D		
5%	7.5 ± 0.5a,BC	8.1 ± 0.4b,C	8.5 ± 0.5c,C	7.6 ± 0.5a,C	8.0 ± 0.7b	***
10%	6.3 ± 0.5ab,AB	6.3 ± 0.5ab,B	6.5 ± 0.5b,B	6.1 ± 0.5a,B	8.0 ± 0.7c	***
15%	5.7 ± 0.5b,A	5.7 ± 0.8b,A	4.5 ± 0.5a,A	4.4 ± 0.6a,A	8.0 ± 0.7c	**
Significance	**	***	***	***		
Overall impression						
Control (0%)	8.0 ± 0.5C	8.0 ± 0.5	8.0 ± 0.5C	8.0 ± 0.5D		
5%	7.6 ± 0.2a,BC	8.4 ± 0.4c	8.4 ± 0.4c,C	7.5 ± 0.4a,C	8.0 ± 0.5b	***
10%	6.3 ± 0.6a,AB	6.9 ± 0.4b	6.5 ± 0.3b,B	6.2 ± 0.4a,B	8.0 ± 0.5c	***
15%	5.2 ± 0.4b,A	6.0 ± 0.5c	4.9 ± 0.2a,A	4.6 ± 0.4a,A	8.0 ± 0.5d	***
Significance	***	***	***	***		

Data are expressed as mean ± standard deviation. Values in each row having different lowercase letters are significantly different at $P < 0.05$. Values in each column having different capital letters are significantly different at $P < 0.05$.
*$P < 0.05$
**$P < 0.01$
***$P < 0.001$.
DW, dry weight; GAE, gallic acid equivalent; TE, Trolox equivalent.

decrease was instead observed for pasta samples fortified with 5% Georgia skin.

The yellowness parameter (b^* value) was most affected by the cooking process. The decrease in the degree of yellowness, which was most likely due to leaching and thermal degradation of pigments, was lowest for pasta samples containing TGT skin at 15%, and the highest decrease was observed for control pasta samples followed by pasta samples containing Georgia skin at 5%. Similar decreases in b^* value were highlighted by Sant'Anna *et al.*[26] in fettuccini fortified with grape marc. For cooked pasta, we also evaluated textural properties that are generally recognised as the most important parameters in evaluating overall quality and that play a crucial role in consumer acceptability.[34,43] Thus any addition made should not preclude its commercial value.

Two of the variables investigated, maximum cutting force (N) and total work to cut (mJ), displayed a similar textural behaviour. In fact, significant effects in both parameters were observed according to the percentage of skin used as well as to the hazelnut skin variety.

With only a few exceptions, an increase in the percentage of skin used was generally associated with a decrease in maximum cutting force values, although this association was not always proportional. Significantly different values were detected between control samples and pasta supplemented with hazelnut skins, and pasta with San Giovanni hazelnut skin at 10% addition level displayed the highest value of cutting force (1.05 N). The total work to cut, defined as the energy required to cut the sample, displayed different trend behaviours between the products. Pasta fortified with Georgia, Tombul and TGT skins displayed a decrease in cutting force values with an increase in the percentage of skin used. Only in pasta fortified with Tombul skin did the control samples exhibit higher values than the fortified samples. In contrast, in pasta containing added San Giovanni hazelnut skins, the 10 and 15% addition levels displayed higher values compared with 5% fortified samples and controls (>0.70 mJ). Higher cut energy was detected in pasta containing Georgia skin at 5% (0.85 mJ). To the best of our knowledge, in the scientific literature, data on the mechanical properties of 'tagliatelle' pasta are scarce, and some studies have reported rheological and physicomechanical information only for fresh 'tagliatelle' products.[21]

The first textural characteristics of cooked 'tagliatelle' pasta were described by a texture profile analysis test that involved subjecting the strand to two complete cycles of compression–relaxation–tension.[44] In another study the same authors reported data on cooked 'tagliatelle' that were derived after applying a frozen cutting-shear test.[45] However, because of the different operative conditions applied in the test, in particular the probe used (Volodkevich Bite Jaws HDP/VP, Stable Micro Systems), our data cannot be compared with their results. In this study a 1 mm thick blade was used as the cutting probe. This probe is widely employed in the analysis of spaghetti, noodles and pasta-like products.[34,46] The results reported for control samples are useful for the initial characterisation of the mechanical behaviour of this type of cooked pasta.

The consumer test results showed that consumers preferred pasta fortified with 5% hazelnut skin the best, with reported means of higher than 7 ('like moderately') and 8 ('like very much').

Pasta with 10 or 15% hazelnut skin was rated significantly lower than pasta with 5% skin. Generally, the mean values of consumer evaluations for pasta with 10% skin addition were 6 ('like slightly'), 5 ('neither like nor dislike') or 4 ('dislike slightly') for pasta with 15% skin addition.

In regard to the appearance of pasta, the hedonic rating was related to the hazelnut variety used for fortification. Lower ratings were obtained with pasta fortified with TGT and Georgia skins,

Table 4. Total phenolic content (TPC), radical-scavenging capacity (RSC) and Trolox equivalent antioxidant capacity (TEAC) of cooking waters and results of analysis of variance with Duncan's test

Level of skin addition	Hazelnut skin					Significance
	Georgia	Tombul	San Giovanni	TGT	Control (0%)	
TPC (mg GAE mL^{-1})						
Control (0%)	0.01 ± 0.00A	0.01 ± 0.00A	0.01 ± 0.00A	0.01 ± 0.00A		
5%	0.04 ± 0.00e,B	0.02 ± 0.00b,B	0.03 ± 0.00d,B	0.02 ± 0.00c,B	0.01 ± 0.00a	***
10%	0.07 ± 0.00e,C	0.04 ± 0.00c,C	0.07 ± 0.00d,C	0.04 ± 0.00b,C	0.01 ± 0.00a	***
15%	0.10 ± 0.00c,C	0.06 ± 0.00b,D	0.11 ± 0.00d,D	0.10 ± 0.00c,D	0.01 ± 0.00a	***
Significance	***	***	***	***		
RSC (μmol TE mL^{-1})						
Control (0%)	0.02 ± 0.05A	0.02 ± 0.05A	0.02 ± 0.05A	0.02 ± 0.05A		
5%	0.18 ± 0.04c,B	0.03 ± 0.00a,A	0.14 ± 0.01b,B	0.16 ± 0.01bc,B	0.02 ± 0.05a	***
10%	0.52 ± 0.01e,C	0.23 ± 0.00b,B	0.45 ± 0.00d,C	0.30 ± 0.00c,C	0.02 ± 0.05a	***
15%	0.78 ± 0.02c,D	0.34 ± 0.01b,C	0.83 ± 0.01d,D	0.88 ± 0.01e,D	0.02 ± 0.05a	***
Significance	***	***	***	***		
TEAC (μmol TE mL^{-1})						
Control (0%)	0.01 ± 0.00A	0.01 ± 0.00A	0.01 ± 0.00A	0.01 ± 0.00A		
5%	0.23 ± 0.01b,B	0.38 ± 0.00c,B	0.24 ± 0.09b,B	0.17 ± 0.00b,B	0.01 ± 0.00a	***
10%	0.55 ± 0.03d,C	0.71 ± 0.02e,C	0.49 ± 0.00c,C	0.29 ± 0.04b,C	0.01 ± 0.00a	***
15%	0.84 ± 0.01d,D	0.99 ± 0.01e,D	0.64 ± 0.01b,D	0.67 ± 0.01c,D	0.01 ± 0.00a	***
Significance	***	***	***	***		

Data are expressed as mean ± standard deviation. Values in each row having different lowercase letters are significantly different at $P < 0.05$. Values in each column having different capital letters are significantly different at $P < 0.05$.
***$P < 0.001$.
GAE, gallic acid equivalent; TE, Trolox equivalent.

Table 5. Mean values of total phenolic content (TPC), radical-scavenging capacity (RSC) and Trolox equivalent antioxidant capacity (TEAC) for uncooked and cooked skin-incorporated pasta extracts and results of analysis of variance

Level of skin addition		TPC (mg GAE g^{-1} DW)	RSC (μmol TE g^{-1} DW)	TEAC (μmol TE g^{-1} DW)
Control (0%)	Uncooked	1.65 ± 0.06	3.21 ± 0.15	0.63 ± 0.08
	Cooked	0.61 ± 0.01	1.04 ± 0.22	0.04 ± 0.01
	Significance	***	***	***
5%	Uncooked	1.8 ± 0.37	9.85 ± 1.78	6.36 ± 1.47
	Cooked	0.8 ± 0.29	7.61 ± 3.38	4.06 ± 1.05
	Significance	***	NS	***
10%	Uncooked	3.67 ± 1.02	21.08 ± 4.39	14.56 ± 4.02
	Cooked	1.68 ± 0.67	14.21 ± 6.26	8.76 ± 2.09
	Significance	***	**	***
15%	Uncooked	5.84 ± 1.41	30.54 ± 5.02	24.34 ± 6.54
	Cooked	2.32 ± 0.81	19.19 ± 7.70	13.62 ± 2.43
	Significance	***	***	***

Data are expressed as mean ± standard deviation. NS, not significant
**$P < 0.01$
***$P < 0.001$.
DW, dry weight; GAE, gallic acid equivalent; TE, Trolox equivalent.

whereas higher ratings were associated with pasta containing added Tombul skin. The consumer rating for this product was even higher than that obtained for the control, which could be because the colour was slightly brown.

Pasta produced with added Tombul and San Giovanni skins obtained the higher consumer ratings for texture. In this case the mean rating for the control product was only 7 ('like moderately') or 8 ('like very much') for pasta with Tombul or San Giovanni skins.

The mean ratings for overall preference were similar to those obtained for texture. Pasta fortified with Tombul and San Giovanni skins obtained the highest ratings, whereas products containing TGT and Georgia skins achieved lower values. The control pasta had intermediate average ratings.

CONCLUSIONS

The results obtained in the present study highlighted that it is possible to use hazelnut skin in fresh pasta production to obtain a fortified food with high fibre content and antioxidant activity. The characteristics (compositional, textural and sensory) of the obtained pasta are strictly correlated with the hazelnut variety used for skin production and, of course, with the percentage

of hazelnut skin that is added. Consumer preference is another important parameter to assess. The preliminary results obtained in this study revealed a positive effect on consumer preference of pasta produced with the addition of a low quantity (~5%) of hazelnut skin. Higher quantities reduced product acceptability independently of skin origin.

Future studies are necessary to confirm the varietal and environmental effects across multiple years and to define the effect of other hazelnut varieties and roasting methods on the chemical-physical characteristics and shelf life of functionalised pasta.

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