UNIVERSITÀ DEGLI STUDI DI TORINO

Effect of adding hazelnut roasted skin of different cultivars on the quality attributes, polyphenols contents and texture of fresh egg pasta

Running title : Hazelnut roasted skin as ingredient for pasta

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Abstract

BACKGROUND - Hazelnut skin is the perisperm of hazelnut kernel. This structure is separated from the kernel during the roasting and is normally discarded. Recent studies have reported that hazelnut skin is a rich source of dietary fibre as well as natural antioxidants due 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 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. Skin concentration significantly influenced all physicochemical parameters determined and consumers' appreciation but significant differences were also due to varieties. Although pasta produced with 10% and 15% of hazelnut skin displayed *in vitro* the highest functional quality, pasta with 5% added Tombul hazelnut skin showed the maximum rating.

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 obtained pasta are strictly correlated to the hazelnut varieties used for skin production and,

of course, to the percentage of addition.

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

INTRODUCTION

Among edible nuts, hazelnut represent one of the most cultivated with about 743.000 t. Turkey is the world's largest hazelnut producer (54%), followed by Italy (13%). The in-shell consumption of hazelnut accounts for only 10%; the rest is shelled and mainly used for industrial purposes. Hazelnut skin is the perisperm of hazelnut kernel and represents approximately 2.5% of the total hazelnut kernel weight. This structure is separated from the kernel during the 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 natural antioxidants due to the presence of phenolic compounds[2-5] thus it can be referred to as "antioxidant dietary fibre" (ADF). Related to the relationship between antioxidant and dietary fibre it has been proposed that these food components not only retarded human low-density lipoprotein oxidation in vitro[6] but also helped enhance the gastrointestinal health of the host by promoting a beneficial microbiota profile[7] and have a significant role in prevention of human diseases.[8,9]

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

In the last years there are increasing interests in applying fruit processing wastes as functional food ingredients since they are rich source of ADF and most of the beneficial bioactive compounds remained in those 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 nutritional value of fresh egg pasta.

Pasta was selected because of its high diffusion around the world, extended shelf life and compositional characteristics. In addition, the Food and Drug Administration (FDA) considers pasta a suitable vehicle for the incorporation of nutrients, and in the 1940s, for the first time, its enrichment with vitamin and iron was permitted.[19] In past years, attempts to enhance the nutritional value of pasta was also performed by adding various vegetables and cereal bran and leguminoses, which are rich in proteins, fibres, minerals and vitamins. [20-26]

MATERIAL AND METHODS

Materials

The skins of four different hazelnut (*Corylus avellana* L.) varieties supplied by Nocciole Marchisio S.p.A. (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 minutes) with an industrial continuous-working rotary oven, and then the skins were peeled off and ground with an Ultra Centrifugal Mill ZM 200 (Retsch GmbH, Milano, Italy) with a 500-μm sieve. The skins 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-tetramethylchroman-2-carboxylic acid (Trolox), 2,2'-azobis(2-amidinopropane) dihydrochloride (AAPH) and 3',6'-dihydroxyspiro[isobenzofuran-1[3H],9'[9H]-xanthen]-3-one (fluorescein)) and solvents were purchased from Sigma–Aldrich (Milano, Italy). All chemicals were of reagent grade. Ultra-pure water was produced with a Milli-Q System (Millipore, Milan, Italy).

Pasta making and cooking

Ingredients for pasta making such, as soft wheat flour "00" type (12.9 % moisture, 9.8 % protein) (Barilla S.p.A, Parma, Italy) and chicken-pasteurised whole eggs with a content of protein of 12 % and lipid of 11 %, (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, and thickness 1 mm). Control pasta was made using 1 kg of wheat flour "00" type and 400 g of pasteurised eggs, whereas functionalised pasta was made by replacing the wheat flour with ground hazelnut skins at three different levels: 5%, 10%, and 15% (w/w).

Three production batches were done for each type of pasta.

Uncooked pasta was dried at 65 °C in an oven until approximately 5% moisture was reached and then ground with an Ultra Centrifugal Mill ZM 200 (Retsch GmbH, Milano, Italy) with a 500-μm sieve and stored in amber flask at –18 °C.

For the compositional, total phenolic content, antioxidant assays and colour analyses of cooked product, the pasta was cooked in distilled water (ratio pasta:water 1:10) up to the disappearance of the white central core of the pasta, in accordance with the AACC 66-50 method.[27] After cooking, the pasta was immediately cooled in distilled water at room temperature, dried at 65 °C in an oven until approximately 5 % humidity was reached, ground similar 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 liking test, the pasta was cooked in natural unsalted tap water in an approximately 1:10 pasta/water ratio. 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, ashes, proteins and dietary fibre (total, soluble and insoluble) of hazelnut skin and uncooked pasta were determined in accordance with the AOAC Official Methods.[28] The moisture was determined after heating at 103 °C (1 g of samples) in an oven until constant weight. The total protein content (conversion factor 6.25) was estimated by 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, Usmate, Monza-Brianza, Italy) for 6 h using *n*-hexane as the solvent. The ash content was determined in a muffle furnace at 525 ± 25 °C. The carbohydrate value was estimated with the formula [100 – (Moisture + Fat + Protein + Ash + Dietary fibre)]. Dietary fibre (total, soluble and insoluble) was measured using the Megazyme Total Dietary analysis kit (Megazyme International, Bray, Ireland).

Extraction of antioxidant compounds

The extraction of antioxidant compounds from hazelnut skin, uncooked and cooked pasta was performed as reported by Fares, Platani, Baiano and Menga with slight modifications.[29] Briefly, finely ground samples of pasta (1 g of uncooked and cooked) and hazelnut skin (0.25 g) were extracted twice with 20 mL of methanol:water solution acidified with formic acid at pH 2 (80:20 v/v), in dark conditions, with regular shaking, for 2 hours. After centrifugation (15 min, 5 °C, 16800 *g*), the supernatants were collected, filtered (0.45 µm) and stored in amber vials at –18 °C until total phenolic content and antioxidant analyses were performed. The extractions were performed in triplicate.

Total phenolic content assay

The amount of total phenolics (TPC) was assayed spectrophotometrically by means of modified Folin-Ciocalteu method.[30] Briefly, 50 µL of extract were 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 20

% (w/v) aqueous sodium carbonate solution was added. After incubation for 2 hours in the dark at room temperature, the specific absorbance of the mixture at 765 nm was measured with a UV-Visible spectrophotometer (UV-1700 PharmaSpec, Shimadzu, Milano, Italy). A mixture of solvents and reagents were used as a blank. Gallic acid was used as a standard, and the results were expressed as gallic acid equivalents (mg GAE/g sample dry matter basis).

DPPH radical scavenging capacity assay

The free radical scavenging capacity (RSC) of the extracts was determined according to the procedure reported by von Gadow, Joubert and Hansamann using the stable 2,2-diphenyl-1-picryhydrazyl radical ($DPPH^{\bullet}$).[31] Briefly, 75 µL of sample extract were added to 3 mL of 6.1 x 10^{-5} M $DPPH^{\bullet}$ methanol solution and incubated for 1 h, at room temperature, in the dark. After this time, the decrease of absorbance at 515 nm was recorded using a methanol as a control and a methanol solution of $DPPH^{\bullet}$ as a blank. The inhibition percentage (IP) of the $DPPH^{\bullet}$ by the antioxidant extracts was calculated according to the following formula:

$$IP = [(A_{0min} – A_{60min})/A_{0min}] \times 100$$

where A_{0min} is the absorbance of the blank at t = 0 min, and A_{60min} is the absorbance of the samples at 60 min. The results were expressed as µM Trolox equivalents per gram of sample (dry basis) by means of a dose-response curve for Trolox (0-350 µM).

Trolox equivalent antioxidant capacity assay

The Trolox equivalent antioxidant capacity (TEAC) was determined according to the original analytical procedure described by Re, Pellegrini, Proteggente, Pannala, Yang and Rice-Evans.[32] The 2,2'-azinobis-(3-ethylbenzthiazoline-6-sulphonate) radical cation ($ABTS^{\bullet+}$) was prepared by reacting 7 mM ABTS stock solution with 2.45 mM potassium persulphate (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 solutions (or standard) (30 µL) were mixed with $ABTS^{\bullet+}$ solution (3 mL). Absorbance readings were

taken at 30 °C exactly 6 min later than the initial mixing. An appropriate solvent blank was obtained by mixing extraction solvent (30 µL) with $ABTS^{\bullet+}$ solution (3 mL), and absolute ethanol was used as a control. The $ABTS^{\bullet+}$ scavenging effect (% Inhibition) was calculated by the equation

$$\% \text{ Inhibition} = [(A_{734blank} - A_{734sample})/A_{734blank}] \times 100$$

where $A_{734blank}$ and $A_{734sample}$ are the absorbances of $ABTS^{\bullet+}$ solution at 734 nm before and after samples addition. The results were expressed as µM Trolox equivalents per gram of sample (dry basis) by means of a dose-response curve for Trolox (0-350 µM).

Oxygen radical absorbance capacity assay

An oxygen radical absorbance capacity (ORAC) assay was performed with a PerkinElmer 2030 Multilabel Reader (Perkin Elmer, Milano, Italy) with 96-well black plates. The reaction was performed in 75 mM potassium phosphate buffer (pH 7.4) used as a blank and different Trolox solutions, ranging from 0.25 to 6 µM, were used as standards.[33] The sample solutions were prepared by diluting antioxidant extracts with phosphate buffer. To start the incubation, aliquots of fluorescein (3',6'-dihydroxyspiro[isobenzofuran-1[3H],9'[9H]-xanthen]-3-one) solution (150 µL of a 48 nM solution 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 (2,2'-azobis(2-amidinopropane) dihydrochloride) solution (133 mM in phosphate buffer) were added, and the reaction started when the plate was reinserted into the reader at 37 °C. All fluorescence measurements were expressed relative to the initial reading of the fluorescence signal and were repeated every minute for 35 min at the 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 from the AUC either of the standard or of the sample. The Trolox equivalent molar concentrations of the samples were calculated using a linear regression equation between the Trolox concentration and corresponding net AUC. To compare the antioxidant activity of the extracts, the relative ORAC values were calculated as Trolox equivalent micromoles present in 1 g of extracted matrix.

Texture analysis

Texture analysis was performed only for cooked pasta with a TAxT2i Texture Analyser (Stable Micro Systems, Godalming, U.K.) fitted with a Perspex cutting probe of 1 mm of thickness according to AACC 66-50 method.[27] The crosshead speed was 10 mm/s; 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 for a distance of 5 mm to stop at 0.5 mm from the base plate then returned to the start position. The cutting-shear test was performed on one "tagliatelle strand" for the time placed on the HDP/90 instrument platform perpendicular to the base of the knife. Five strands for each cooked batch were analysed.

The Texture Export Exceed software rel. 2.54 (Stable Micro Systems, Godalming, U.K.) 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. For the analyses, 5 grams of powdered samples were put into a 5.5 cm diameter petri dish and a thickness of 5 mm was obtained. For each sample, five measures were performed.

Liking test

To evaluate pasta quality, 82 consumers (45% male and 55% female, age between 26 and 65 years) were recruited to conduct acceptance testing. Criteria for recruitment of the participants were that they ate pasta at least three times per week and had no food allergies.

The test was performed inside a heated/air conditioned meeting room with white light. The temperature was approximately 21°C, and the RH was approximately 50%. Tests were performed from 11 a.m. over 3 days.

For each session, five samples of pasta (about 30 g for each sample) were presented in completely randomized and balanced order. The samples were offered to the consumers in coded opaque white plastic

cup hermetically sealed with a plastic lid without dressing. Plastic forks, napkins and bottled water were provided to each participant.

Consumers rated appearance, texture and overall liking impression for each pasta sample on a nine-point hedonic category scale ranging from 'dislike extremely' (1) to 'like extremely' (9). A 5 min gap between each sample was enforced. Consumers were required to rinse their mouth with still water during the gap 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 statistical software (Release 7.0; StatSoft Inc., Tulsa, OK, USA).

RESULTS AND DISCUSSION

Hazelnut skins

The proximate composition of hazelnut skins is reported in Table 1. According to the results reported by Anil[35] and Montella et al.[5], the total dietary fibre was the major component, with a range between 51.07% to 54.40% with significant differences among the cultivars. A mean 86% of the total dietary fibre was constituted by insoluble fibre with values also significantly different among the cultivars. The second most abundant component was carbohydrates (ranging from 17.23% to 18.60%) except for Tombul hazelnut skin (2.34%). It is important to also underline content of lipids that ranges from 10.51% to 27.71%.

Recent studies have shown that hazelnut skins are also rich in phenolic compounds and possess stronger antioxidant activity than those of their kernel and other tree nut by-products.[36] As reported by Schmitzer,

Slatnar, Veberic, Stampar and Solar[37] a significant decrease in individual phenolics, resulting in lower total phenolic content and antioxidant potential was detected after the skin removal in different hazelnut cultivars.

The TPC and the antioxidant capacity (AC) values, assessed in hazelnut skin extracts and expressed on dry basis, significantly characterised the cultivars. The highest values were always measured in Georgia skin extracts and the lowest in Tombul skin extracts. The TGT and San Giovanni results were always similar. The TPC ranged from 102.2 to 195.8 mg GAE/g dry matter. The use of different extraction methods and/or different data expression methods prevent the comparison of our results with those published by other authors. In a previous work[4] a TPC of 116.5 mg GAE per gram of dry TGT hazelnut skin extracted with 80% ethanol was detected. For the same cultivar, Del Rio et al.[3] reported a TPC of 111 mg of polyphenol per gram of hazelnut skin extracted with 1% aqueous formic acid, whereas Monagas et al.[38] assessed, in acidified methanol extract of Giresun hazelnut skin, a TPC of 107 mg GAE/g of skin.

The results of RSC, TEAC and ORAC assays revealed the same trend as the TPC, with the highest values reported for the Georgia sample, followed by San Giovanni, TGT, and Tombul. All assays were able to significantly discriminate the cultivars, with less efficacy with the ORAC assay. 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 μM TE/g in Oregon and Turkish roasted hazelnut skin, 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 the other parameters significantly increased ($p < 0.001$), as expected, for all cultivars according to the level of fortification.

Moisture, lipid and carbohydrate differences among the cultivars were also observed. In particular, for lipids, significant differences ($p < 0.001$) were observed for all the addition levels, and the Tombul cultivar displayed the highest values for all levels.

The addition of hazelnut skin substantially changed the colour of the uncooked pasta samples, and significant differences were observed for L*, a* and b* colour coordinates among the percentage of fortification but also among the hazelnut varieties.

In regards to the L* parameter, the use of hazelnut skin resulted in an increase in sample darkness with the amount of fortification independently of the type of hazelnut skin used for pasta fortification.

With 5% addition, no differences were observed among fresh pasta fortified with hazelnut skin of different varieties, whereas at the 10% level, the lowest values were observed for pasta fortified with San Giovanni and Georgia skin. At 15%, the lowest values were instead observed for pasta fortified with San Giovanni and TGT skin.

In regards to the a* parameter, generally, lower values were observed for pasta with Tombul skin, whereas higher values were observed for pasta with Georgia skin.

For the b* parameter, only the 10% and 15% addition levels displayed significant differences among hazelnut varieties, with generally lower values for San Giovanni.

As expected, with the increased levels of fortification, the amount of total phenolic compounds and the antioxidant capacity (AC) increased accordingly. Similarly, for each skin addition level, the behaviour of the cultivars was significantly different but did not follow a uniform trend. We observed different trends for the different assays and for the different levels of addition. At 15% fortification, when the effect of skin addition was most sizable, the 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. The extracts of pasta containing hazelnut skins exhibited higher phenolic content and antioxidants compared with the control; however, low levels of TPC (1.65 mg GAE/g dry matter) and AC (3.21, 0.63, and 15.47 μM TE/g dry matter for RSC, TEAC and ORAC assays) were found also in the control sample. 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 level of phytochemicals that include 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]

Cooked pasta

The TPC and the antioxidant indices of cooked pasta fortified with hazelnut skins and cooking water are summarised in Table 3 and Table 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, whereas the average TPC decrease in fortified pasta samples ranged between 54% and 60% (Table 5). The 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 the different antioxidant assays. Nevertheless, the Tombul skin addition having the lowest efficacy was confirmed. This could be due to the leaching of phenolic compounds into the cooking medium that, however, had poor phenol content (0.01 – 0.11 mg GAE/mL) and AC values (TEAC ranged between 0.01 and 0.99 μM TE/mL). Similarly, Hirawan, Yuin Ser, Arntfield and Beta[42] reported a 40% reduction in the total phenolic content of both regular and whole wheat spaghetti after cooking.

In regards to the L* parameter, the control pasta presented the highest brightness value followed by the pasta with added Tombul skin for all percentages used.

The decreased of redness degree (a* value) was lowest for the pasta fortified with Georgia skin at 15%. Instead, the highest decrease was observed for pasta samples at 5 % with Georgia skin.

The yellowness parameter (b* value) was the one most affected by the cooking process. The decrease of the yellowness degree was lowest for the samples of pasta with TGT skin at 15%, and the highest decrease was observed for the control pasta samples followed by the pasta samples with Georgia skin at 5%.

For cooked pasta, we also evaluated the texture properties that are generally recognised as the most important parameters in evaluating its overall quality playing a determinant role in consumer acceptability.[34, 43] Thus, any addition made should not preclude its commercial value.

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

With only a few exceptions, an increase of the percentage of skin used was generally associated with a decrease of the values of maximum cutting force, though this 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 a 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 among the products. Pasta fortified with Georgia, Tombul and TGT skins displayed a decrease of the values with an increase of the percentage of skin used. Only in pasta with Tombul skin the control samples were characterised by higher values with respect to the fortified samples. In contrast, in pasta with added San Giovanni hazelnut skins, the 10% and 15% addition levels displayed higher values respect to 5 % and control (> 0.70 mJ). Higher cut energy was detected for pasta with 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 very scarce, and some studies have reported rheological and physico-mechanical information only for fresh “tagliatelle” products.[21]

The first textural characteristics of cooked “tagliatelle” pasta were described by a Texture Profile Analysis test, involving subjecting the strand to two complete cycles of compression-relaxation-tension.[44] In another study the same authors reported data on cooked “tagliatelle” that was derived differently 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 Ltd), our data cannot be compared with their results. As in this study, a 1-mm thick blade cutting probe was used, a probe largely 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 results of consumer tests showed that consumers liked pasta with 5% of hazelnut skin the best and reported means higher than 7 (“like moderately”) or 8 (“like very much”).

Pasta with 10% or 15% of hazelnut skin was rated significantly differently and lower than pasta with 5%. Generally, the mean value for pasta with 10% skin addition is 6 (“like slightly”) and 5 (“neither like nor dislike”) or 4 (“dislike slightly”) for pasta with 15% skin addition.

In regards to the appearance of pasta, the hedonic rating is related to the hazelnut variety used for fortification. Lower ratings were obtained by pasta fortified with TGT and Georgia skin, whereas higher

ratings were associated to the pasta with added Tombul skin. The consumer rating for this product is even higher than those 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 is only 7 (“like moderately”) and 8 (“like very much”) for pasta with Tombul or San Giovanni skins.

The mean ratings of the overall liking are similar to those obtained for texture. Pasta fortified with Tombul and San Giovanni skins obtained the higher rating, whereas products with TGT and Georgia skins achieved lower values. The control pasta had intermediate mean ratings.

CONCLUSIONS

In 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 (compositional, texture and sensory) of obtained pasta are strictly correlated to the hazelnut varieties used for skin production and, of course, to the percentage of addition. Consumer liking is an important parameter to determine. The preliminary results obtained in this study revealed a positive effect on consumer liking of pasta obtained with the addition a low quantity (approximately 5%) of hazelnut skin. Higher quantity reduces the product acceptability independently of the skin origin.

Future studies are necessary to define the effect of other hazelnut varieties and roasting methods on the chemical-physical characteristics of functionalised pasta and its shelf-life.

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