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Quality of wholemeal pasta made with pigmented and ancient wheats

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ABSTRACT

Pigmented and ancient wheats are receiving increasing attention in food applications as they well reflect consumers' request for new sensory experiences, positive nutritional quality, and environmental sustainability. In this study, pigmented and ancient wheats were used in wholemeal pastas that were analysed considering their consumers' acceptability and preference, cooking, physical and nutritional quality. Pigmented and ancient wholemeal pastas were well accepted by consumers with liking scores >7 (1–9 hedonic scale) for overall liking, appearance, odour, taste, and texture. Pigmented wheat pasta was preferred (63%) over ancient wheat pasta (37%) due to its peculiar color and more complex aromatic profile that triggered consumers' interest. Both pastas can be considered "high quality" due to their low cooking losses, and comparable physical properties to semolina pasta. Pigmented wheat conferred products total phenolic content and antioxidant activity significantly higher than ancient and durum wheat semolina, that were also partially preserved during cooking. Results suggested that both grains can be promising materials for producing wholegrain pasta, especially pigmented wheat which also delivered new sensory experience and potential health impacts to consumers.

1. Introduction

Pasta is one of the most consumed foods worldwide due to its low cost, nutritional composition, versatility, easy preparation and storage, extended shelf life as well as desirable sensory attributes. Traditional pasta is a very simple product consisting of only two ingredients: semolina and water. The pasta world has been subjected in recent years to an important revitalization of its ingredients to respond to the market requests for food products that are healthy, sustainable, and able to provide "new flavours and experiences" (Bresciani et al., 2022; IPO report, 2022; EIT Food report, 2021).

In the past two decades, much effort has been given to innovation in pasta formulation primarily to improve its nutritional profile and/or its health impact, and to meet the consumers' request for new eating experiences (Romano et al., 2021; Conte et al., 2021). A large variety of alternative ingredients have been considered, including cereals other than wheat (Durazzo et al., 2013), legumes (Laleg et al., 2016), vegetables (Oliviero and Fogliano, 2016), insects (Çabuk and Yılmaz, 2020), fish (Devi et al., 2013), algae (Ribeiro et al., 2022), dietary fibre (Foschia et al., 2015), resistant starches (Gelencsér et al., 2008), amongothers. The substitution of wheat with other ingredients causes important changes in the quality attributes of pasta primarily due to the reduced/nulled presence of the gluten network that requires modification of the production process and/or limits the level of alternative ingredient inclusion in product's formulation.

Large interest in pasta innovation has also been devoted to the use of ancient wheat varieties that favour high product quality (warranted by the presence of gluten), higher environmental sustainability and biodiversity preservation (Zingale et al., 2022; Recchia et al., 2019). Ancient wheat was also suggested to have interesting nutritional (e.g. reduced starch digestibility, Acquistucci et al., 2020; higher vitamins, mineral and nutraceutical compounds content, Kohajdová and Karovicova, 2008, Hidalgo and Brandolini, 2012) and health (reduced cardio-metabolic risk factors, Dinu et al., 2018; reduced non-celiac gluten sensitivity gastronintestinal symptoms, Ianiro et al., 2019) benefits.

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More recently, food industry has also shifted its attention towards the utilization of coloured wheat varieties that owe their colour to their richness in natural pigments (e.g. anthocyanins). The high level of coloured bioactive compounds naturally present in pigmented wheat provides the simultaneous positive effect of delivering new sensory attributes to the product, and of promoting health and preventing diseases (Saini et al., 2021; Gupta et al., 2021). Coloured pasta has been an object of large interest in industry and research and has been often produced by including coloured ingredients, extracts or concentrates into pasta formulation (e.g. purple wheat bran, Zanoletti et al., 2017; oregano and carrot leaf, Boroski et al., 2011; elderberry juice concentrate, Sun-Waterhouse et al., 2013; red sorghum flour, Khan et al., 2013; spirulina, De Marco et al., 2014). Problems of using coloured ingredients or concentrates are related to a diluted protein network and structural stability, increased cooking loss, texture (Sun-Waterhouse et al., 2013; De Marco et al., 2014). The use of pigmented wheat varieties could be a natural and an effective tool to produce coloured pasta without a negative effect on protein network, as suggested by Ficco et al. (2016) that used purple durum wheat for pasta production and reported improved nutritional quality (i.e. higher presence of bioactive compounds) and preservation of sensory attributes as compared with commercial pasta.

The objective of this study was to investigate consumer's acceptability, bioactive compounds and antioxidant activity and physical quality of wholemeal pasta made with two different wheat varieties: an ancient wheat, called Senatore Cappelli (SC), and a pigmented wheat, named Grano Mischio (GM).

2. Materials and methods

2.1. Pasta samples

Wholemeal pasta (paccheri shaped) produced using ancient wheat (Senatore Cappelli - **SC**) and pigmented (Grano Mischio - **GM**) was acquired from Pastificio Marella (Pastificio Marella S.r.l, Gioia del Colle, Bari, Italy). Two pasta products were also referred to as "**ancient**" and "**pigmented**" pasta, respectively in the manuscript.

A paccheri shaped pasta sample from the same manufacturer made with common semolina was also used as **control** for comparison in the analysis of pasta cooking quality and nutritional evaluation.

2.2. Pasta characterization

2.2.1. Sensory analysis and consumers' preference

Ancient (Senatore Cappelli, SC) and pigmented (Grano Mischio, GM) pastas were subjected to sensory evaluation using a 65-member panel enrolled among Italian consumers located in central Italy. All panel members were usual pasta consumers, and the test was run in a home setting. All members gave their informed consent to this study. Each panel member was given two 400 g labelled pasta boxes (ancient-SC and pigmented-GM) together with two 10 ml extra-virgin olive oil single portion bottles (Olearia Clemente S.r.l., Manfredonia FG), white plastic plates, and printed detailed instructions on how to perform the test.

In particular, panel members were instructed to analyse the pasta samples following the order indicated: cook 15 pasta pieces (= 90 g) in 3 L boiling water (with 10 g of salt) for 14 min (optimal cooking time suggested by manufacturer), to drain pasta using a colander, to shake the product in the colander for three times and place it on a white plate, and add one portion olive oil. This procedure replicates typical handling of cooked pasta. Panel members were asked to cleanse mouth with water between samples. Samples were tested in a randomized monadic sequence to balance their order of analysis. A QR-code was then provided to bring panel members to the questionnaire form.

Questionnaire was structured in 3 sections focusing on:

1) Information about panel member sex, age, habits about pasta consumption, and attitude/knowledge about ancient and pigmented grains;
2) Sensory evaluation of pasta samples. Panel members were at first asked to evaluate cooking water clarity (an aliquot of the cooking water was placed clear glass and observed), and then to proceed to the evaluation of the pasta. In particular, panel members were asked to evaluate, for each pasta sample, acceptability of pasta attributes (appearance, colour, texture, flavour, overall perception) using a "1–9 hedonic scale" (1 extremely dislike to 9 like extremely), and a "just about right" from 1 (too weak), 3 (just about right), to 5 (too strong). Check all that apply (CATA) questions were also used to deepen the understanding of consumers' perception of appearance, flavour, texture, and two open questions ("what did you particularly like of the sample" and "what did you particularly dislike of the sample") were also asked;
3) Preference of pasta sample, and reasons for preference (open question).

2.2.2. Pasta cooking quality

<u>*Pasta cooking procedure*</u>: Cooking procedure was carried out according to Morreale et al. (2019) with some modification. Pastas were cooked in boiling water, using a pasta to water ratio of 1–30 with no salt, for 14 min (optimal cooking time suggested by the producer). Cooked pasta and cooking water were quickly separated using a colander. Pasta was cooled at room temperature in a sealed container, for 5 min, to prevent moisture loss, and was then used to determine pasta cooking quality indicators and nutritional composition. Three cooking batches for each pasta were analysed and results were reported as the average of three replicates.

<u>*Cooking loss*</u>: cooking loss into cooking water was determined according to AACC official method 16–50 and was expressed as g solids/100 g raw pasta.

<u>*Moisture content*</u>: moisture content of cooked pasta was measured by weight loss by drying at 105 °C to constant weight and reported as percentage moisture lost (%) with respect to original cooked pasta weight as described in Suo et al. (2022).

<u>*Dimensional changes*</u>: length and thickness of raw and cooked pasta were measured using a caliper. Dimensional changes in length and thickness of cooked pasta were expressed as percentage increase (%) with respect to the original dimensions of raw pasta pieces. At least ten pieces from each cooking batch were measured.

<u>*Texture*</u>: texture of cooked pasta (three batches for sample) was measured using a Food Texture Analyzer (TA1 Texture Analyzer, AMETEK, USA) equipped with a 100N load cell. Hardness (N) was evaluated with a cutting test (at 2 mm/s) using a flat blade (stainless steel blade: 6.4 × 11 × 0.1 cm) and was measured as the maximum force at brake point. Adhesiveness was evaluated as previously reported (Suo et al., 2022). Briefly, cooked samples were opened along the main axis, and compressed with a cylinder probe (25mm × 100 mm) to 50N at 1 mm/s, held for 10 s, and then the probe was released at 1 mm/s. Adhesiveness (J) was recorded as the work to separate the sample from the probe. Ten replicates of each cooking batch were evaluated for each sample.

2.2.3. Pasta bioactive compounds and antioxidant activity evaluation

2.2.3.1. Extraction of bioactive compounds. Bioactive compounds were extracted from 2 g of pasta (raw and cooked) that was mixed with 10 mL of ethanol (70%); the mixture was then subjected to homogenization with Ultra-Turrax S18 N-10G homogenizer (IKA-Werke Gmbh & Co., Germany) for 2 min, then sonicated (40 KHz, room temperature, for 60 min) in a FALC ultrasonic bath (Treviglio, Italy). Extraction solutions were then centrifuged (Thermo Scientific IEC CL10 Centrifuge, Chateau-Gontier, France) at 5000 rpm for 10 min. The sample solutions were filtered through Whatman no. 1 filter paper. All extracts were kept at −18 °C until performing all the subsequent analyses.

2.2.3.2. Total polyphenols contents. Total polyphenols contents (TPCs) were determined using Folin-Ciocalteu method spectrophotometrically (Agilent Technologies, Cary 8454 UV-Vis) according to Mustafa et al. (2016) method with some modifications. Briefly, 0.5 mL of extracts solution was introduced into test tubes, then 2.5 mL of Folin-Ciocalteu reagent solution and 7 mL of Na_2CO_3 (7.5% w/w in water) solution were added. The reaction mixture was allowed to stand at room temperature in the dark for 120 min and absorption was measured at 765 nm against blank. The blank was prepared using 0.5 mL of ethanol 70% instead of the extract. TPC was expressed as mg of gallic acid equivalents (GAE) per 100 g of dry weight (DW) pasta using gallic acid calibration curve. The concentrations used for construction of calibration curve were 100, 200, 400, 600 and 800 ppm.

2.2.3.3. Antioxidant activity. Antioxidant activity (AOA) was determined using the 1, 1-diphenyl- 2-picrylhydrazyl (DPPH %) method according to Mustafa et al. (2022) with some modifications using the Cary 8454 UV-Vis (Agilent Technologies). An aliquot of 0.5 mL of the extract solution was mixed with 4.5 mL of ethanolic solution of DPPH (0.1 mM). The mixture was shaken vigorously and kept in darkness for 30 min at room temperature. Absorbance was measured spectrophotometrically at 517 nm. Trolox was used as the reference antioxidant and the results were expressed as mg trolox equivalent (TE)/100 g dry weight (DW). Solution of 100, 200 400, 600, 800 and 1000 ppm of Trolox standard was used for calibration curve.

2.2.3.4. Polyphenols characterization by HPLC-MS/MS. Polyphenols were then quantified by HPLC-MS/MS (Agilent 1290 Infinity series and a Triple Quadrupole 6420 Agilent Technology, Santa Clara CA, USA), and linked to an electrospray ionization (ESI) source that operated in negative and positive ionization modes, following the method of Mustafa et al. (2022) with some modifications. Prior to being injected into the HPLC-MS/MS system, the extract solutions were filtered using a 0.2 m syringeless filter. Using Optimizer Software, the MS/MS parameters of each standard were optimized using flow injection analysis (FIA). Bioactive compounds were separated in gradient elution mode on a Phenomenex SynergiPolar–RP C18 column (250 mm × 4.6 mm, 4 μm) using a mixture of water and methanol as solvents A and B, respectively, both with 0.1%, formic acid. For column protection, a Polar RP security guard cartridge preceded the column (4 mm × 3 mm ID). The mobile phase composition was made up of the following components: 0–1 min, isocratic condition, 20% B; 1–25 min, 20–85% B; 25–26 min, isocratic condition, 85% B; 26–32 min, 85–20% B. A 0.2 μm polyamide filter was used to filter all solutions and solvents. The injection volume was 2 μL and the flow rate was kept at 0.8 mL min^{-1}. The temperature of the column was set to 30 °C, and the drying gas temperature in the ionization source was set to 350 °C. The flow rate of the gas was set to 12 L/min, the capillary voltage was 4000 V, and the nebulizer pressure was 55 psi. The peak areas were integrated for quantitation after detection in the dynamic-multiple reaction monitoring (dynamic-MRM) mode. Each analyte's most abundant product ion was employed for quantification, while the other ions were used for qualitative analysis.

2.3. Statistical analysis

Data were subjected to statistical analysis using IBM SPSS Statistics 22 (IBM Corporation, New York, USA). Significant differences of each parameter between samples were identified by means of one-way Analysis of Variance (ANOVA, $p < 0.05$) with Duncan's test.

3. Results and discussion

3.1. Sensory analysis and consumer preference

The 65-member panel was composed of 58% women and 42% men with 51%, 46% and 3% of the panel of 18–34, 35–64, and >65 years of age, respectively. All individuals were Italian, living in the Marche region (central Italy), and were usual pasta consumers. The 75% of panels indicated that they were aware of the existence of "ancient grains" while only 23% indicated that they had previously heard of "pigmented grains" (Fig. 1A). Panel members perceived ancient grains as healthy (30% of respondent), easy to digest (18%), better than a common product (30%), high quality (58%), typical product (34%) and expensive (47%; Fig. 1B). Pigmented grains were perceived better than a common product (30%), high quality (58%), typical product (37%), and expensive (30%; Fig. 1B).

Evaluation of the cooking water indicated that cooking water was perceived as "turbid" or "very turbid" by >80% of the panel with pigmented pasta slightly more skewed toward "very turbid" than ancient pasta. It is interesting to note that cooking water was described as "yellowish" for both samples, suggesting that the pigments released in the cooking water were not those associated to the "purplish" color of pigmented pasta.

Sensory evaluation of the two whole meal pastas (ancient, SC, and pigmented, GM) indicated that both samples were well received by consumers not only for overall liking but also for all key performance indicators (appearance, odour, taste, and texture) with scores >7 (no significant differences; Fig. 2A).

Color and **appearance** of the two pastas (Fig. 2B) were perceived differently by consumers with a marked preference for the pigmented pasta (GM) whose color was indicated "as I like it" by 77% of the panel (as compared to 46% for ancient SC pasta). This experimental evidence suggests that color of the pigmented pasta has a very important role in pasta characterization, and it rises interest in the product probably due to its novel and unconventional appearance. Both pastas were described as having a rough surface (60% and 80% for SC and GM, respectively), uniform color (40% and 68% for ancient SC and pigmented GM, respectively), and being opaque (20% and 40% for ancient SC and pigmented GM, respectively). Moreover, SC was indicated as being pale (52%) and GM dark (18%). **Odour** perception was similar between the two pastas with approximately 40% of the panel that described it "as I like it" and 40% "not very intense", as reflected also in the 9-point liking scale that was skewed towards higher liking (6–9) for both samples. Similarly, **taste** of pastas was perceived "as I like it" and "not very intense" by 40% of the panel. Both pastas were described as "tasty" (68% and 42% for ancient SC and pigmented GM, respectively), while pigmented pasta was also described as having an "intense" (20%) and "vegetable" (18%) taste. As regard to **texture**, ancient pasta was considered "too hard" by 12% while pigmented by 3% of the panel, and "quite hard" by 53% vs 42% (pigmented, GM) of the panel. Both samples were described as "al dente" (about 50% of panel), and pigmented (GM) also "floury" (20%) and "fibrous" (15%). Overall pasta preference indicated a marked preference of the pigmented pasta (preferred by 63% of the panel) as compared to the product made with ancient grain (Fig. 3). This finding is probably related to the marked novelty of the product due to its peculiar color and more complex aromatic profile that might have triggered panel's interest. The panel commented on the pigmented product as "has more personality", "it is more peculiar", "it is interesting", "it is not a common product", "it is more authentic", suggesting that the pigmented product was perceived as novel product and its characteristics aroused interest in the consumers. Many panel members indicated that they liked "the color", "the flavor (more intense, peculiar, more persistent …)", and the texture (better, rough texture)" of the pigmented product. Ancient pasta, on the contrary, was described as "less fibrous", "more similar to normal pasta", "good texture", "good flavor".

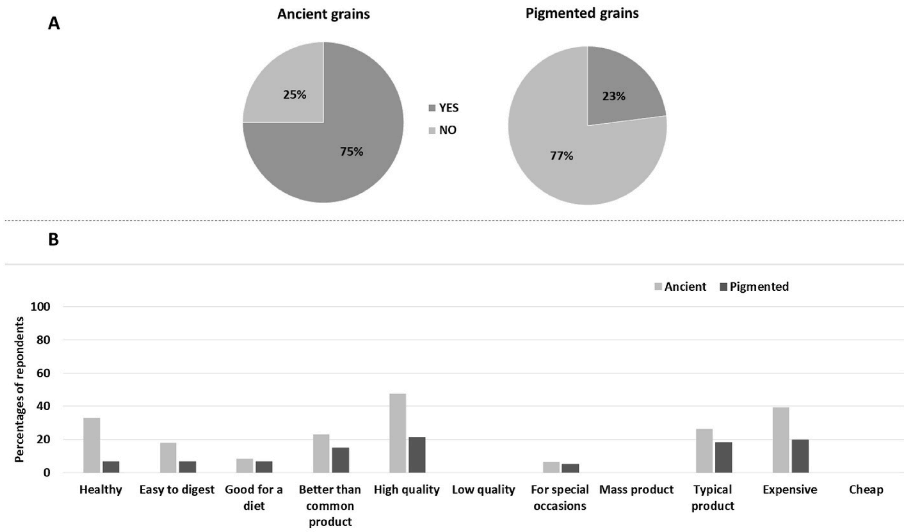

Fig. 1. Attitude/knowledge of the consumers' panel about ancient and pigmented grains: A- Awareness/knowledge (YES- panels know this grain; NO- panels don't know this grains); B - perception.

3.2. Pasta cooking quality

Ancient and pigmented wholegrain pasta cooking quality was evaluated and compared also with a traditional semolina pasta (control). All pastas had a low cooking loss during cooking to their optimal cooking time below 6 g solids/100 g raw pasta (Table 1), indicating that all products can be considered "high quality" (Diamante et al., 2019). The presence of fibre did not affect cooking quality, indicating proper processing conditions during pasta production and drying (Mefleh et al., 2019).

Dimensional increase of pasta pieces during cooking was more significant in control and ancient wheat pasta than pigmented pasta both for length and thickness suggesting a lower elasticity of gluten network of this product (Table 1). It is well known that polyphenols form complexes with gluten proteins that lead to structural and functional changes of this network possibly reducing elasticity, therefore, limiting expansion upon cooking (Krekora et al., 2021; Welc et al., 2022).

Moisture content of the cooked products was in the expected range and slightly higher in pigmented sample as compared to control and ancient products (Table 1). Wholegrain ancient pasta was reported to absorb less water with respect to durum wheat semolina pasta (Acquistucci et al., 2020; Padalino et al., 2015) which is contributed by the competition of fiber with starch for absorbing water. A relative lower moisture absorption for ancient product was also observed in the current study, as compared to the control pasta. Ancient pasta was found to be significantly harder than the other products (pigmented and control; Table 1), confirming sensory analysis while all samples had comparable adhesiveness (Table 1). The wholegrain pasta made with the same ancient wheat Sanatori Cappelli was found being harder than other wholegrain pasta (Padalino et al., 2015) which due to its lower fiber content. No significant difference was also observed between commercial durum wheat pasta and coloured pasta which were produced from purple and yellow wheat (Ficco et al., 2016), meaning no effect of pigments on hardness and adhesiveness properties.

3.3. Pasta bioactive compounds and antioxidant activity evaluation

3.3.1. Total polyphenol contents (TPCs) and antioxidant activity (AOA) of pasta determined by spectrophotometry

Phenolic acids content could be altered during processing or cooking (De Paula et al., 2017; Fares et al., 2010). Processing of cereals may positively or negatively affect the content of phenolic compounds which possibly impacts their bioactive properties and health benefits. In particular, the literature showed that pasta production and cooking may increase or decrease phenolic acids content and its antioxidant activity (Verardo et al., 2011). Considering nutritional evaluation, the main focus was given to TPCs and AOA in this study as they are important indicators of anti-inflammation and anti-carcinogenesis (De Paula et al., 2017). TPCs and AOA of raw and cooked pastas were measured and reported in Table 2. The highest TPCs and AOA were detected in raw pigmented pasta (87.18 ± 2.08 mg GAE/100 g DW and 81.67 ± 0.96 mg TE/100 g DW, followed by ancient pasta (42.95 ± 0.84 mg GAE/100g DW and 31.78 ± 1.49 mg TE/100 g DW), while the lowest contents were detected in the control pasta (37.18 ± 9.75 mg GAE/100g DW and 31.39 ± 0.75 mg TE/100 g DW).

The results showed that cooking decreased the TPCs and AOA in all types of pasta. The percentages of loss of TPCs upon cooking were 24.68%, 33.49% and 38.85% in control, ancient, and pigmented pastas, respectively, while the corresponding percentages of loss of AOA were 59.23%, 59.68% and 2.45%. The obtained results are in a good accordance with literature, for example, Hirawan et al. (2010) reported that the amount of TPC of commercial spaghetti was negatively affected by the cooking process, with a decrease ranged from 57% to 68%.

Overall, raw and cooked pigmented pasta had the highest levels of TPCs and the highest AOA. Conversely, control pasta demonstrated the lowest amounts of TPCs and antiradical property, and the ancient pasta was in between. Therefore, higher TPCs in pastas contributed to higher antioxidant activity (Mustafa et al., 2022).

3.3.2. Phenolic compounds of pasta determined by HPLC-MS/MS

Polyphenols, including phenolic acids and flavonoids, could play significant roles in human nutrition and health due to their antioxidant, anti-inflammatory and anti-carcinogenic effects (De Paula et al., 2017). Phenolic acids are the main phenolic compounds in cereal grains, such as wheat and barley with antioxidant effects on humans (Abdel-Aal et al., 2012; Călinoiu and Vodnar, 2018), and they are present in free and bound forms primarily in the outer layers of the cereal kernels. To better understand individual bioactive compounds of the three types of pasta, HPLC-MS/MS analysis was applied to three products and the results are shown in Table 3. The phenolic profiles indicated that phenolic acids were the most frequent class of phenolics, followed by flavonoids (Table 3). Ferulic, followed by p-coumaric, p-hydroxybenzoic and vanillic acids, were the most abundant phenolic acids that are in good agreement with previous literature (Abdel-Aal et al., 2012; De Paula

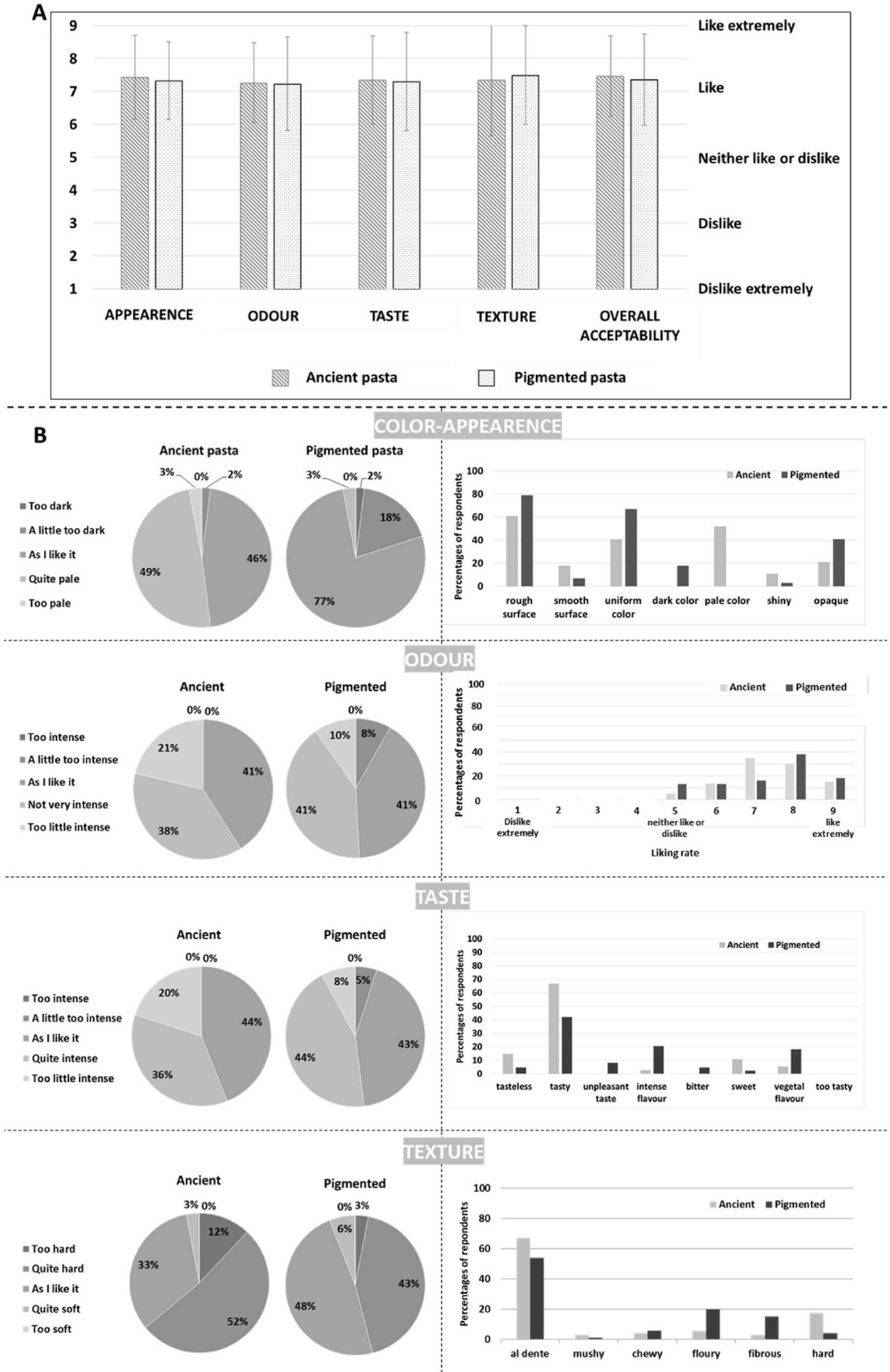

Fig. 2. Sensory analysis and consumers' preference of pasta made with ancient and pigmented grains: A- Acceptability/liking of appearance, odour, taste, texture and overall on the hedonic scale (1–9); B- Frequency distribution of liking ratings and percentages of selections of descriptors associated with the perceptual description of colour, appearance, odour, taste and texture (check all that apply).

et al., 2017).

Flavonoids in wheat are yellow pigments (or colourless) divided into four groups: flavones, flavonols, flavanones and flavans which include flavan-3-ols (flavanols), flavan-4-ols and flavan-3, 4-diols. Interestingly, anthocyanins were found only in the pigmented pasta (Table 3); they are a subclass of flavonoids which give rise to pigmented grains, which vary widely in shade, and the combination of genes for different colours leads to very dark colour which is reported as "black colour". Moreover, it was observed that total flavonoid content was slightly decreased in pigmented pasta, while it was slightly increased in the case of ancient and control pasta upon cooking. Similar to results of Table 2, cooking decreased TPCs of all pasta samples considering HPLC-MS/MS analysis. This drastic decrease in TPCs was attributed to the high losses in the ferulic, p-coumaric, 4-hydroxybenzoic and vanillic acids contents upon cooking which is in line with previous study (Verardo et al., 2011). Other studies also observed that cooking caused a decrease of hydrophilic antioxidant activity (Pasqualone et al., 2016) and a decrease of free phenolic acids content (Khan et al., 2013) in pasta samples. Free

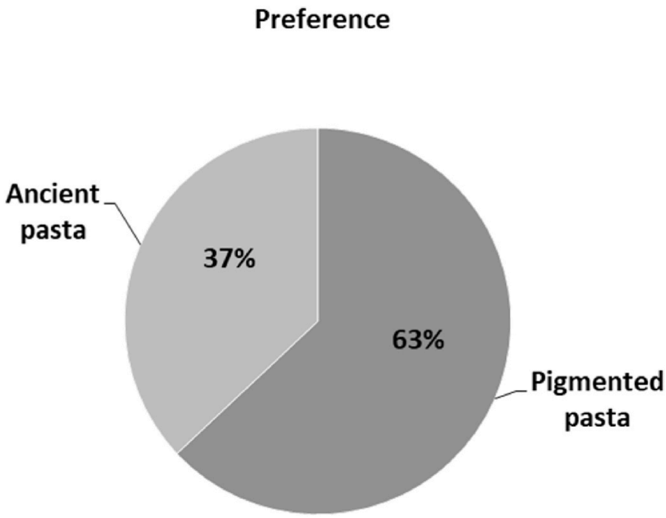

Fig. 3. Pasta overall preference by consumers' panel.

phenolic acids are not physically trapped in protein network (Naczk et al., 2011), therefore the cooking process could have resulted in leaching of these compounds into the cooking water (Verardo et al., 2011).

Considering the sum of the phenolic compounds, raw and cooked pigmented pasta showed the highest TPCs (42.19, 21.49 mg/kg DW), followed by ancient pasta (11.54, 7.54 mg/kg DW) and the lowest content was detected in the control pasta (9.48, 7.00 mg/kg DW). TPCs measured by HPLC-MS/MS confirmed the results obtained spectroscopically, with TPCs that followed the same order in the three pastas considered in this study: pigmented > ancient > control pastas (Table 3). Furthermore, the results showed that cooking decreased TPC in all types of pasta, and the percentages of loss of TPCs upon cooking were 26.21, 34.68 and 49.07% in control, ancient and pigmented, respectively. These results obtained were also consistent with spectrophotometrical analyses using Folin-Ciocalteu method, suggesting that pigmented pasta is potentially the healthiest product even after cooking as it retained more phenolic content and higher antioxidant activity.

4. Conclusions

In this study, two innovative wholegrain commercial pasta were produced using ancient and pigmented wheats, and their consumers' acceptability and cooking, textural, bioactive compounds and antioxidant activity, as well as the effect of cooking on bioactive compounds were investigated.

Results indicated a well acceptance of consumers to both products for overall liking and all key performance indicators, with more liking to pigmented pasta due to its peculiar color and more complex aromatic profile that might have triggered panel's interest. Both products presented good cooking quality and comparable textural property as compared to semolina pasta. Given the advantages of nutrition profiles of pasta produced from ancient and pigmented grains, we conclude that pigmented wheat favors pasta more total phenolic contents and higher antioxidant activity even after cooking, followed by ancient wheat, as compared with commercial durum semolina wheat. The consumption of wholegrain wheat products is associated with a number of health benefits, owing to their promising nutritional profiles. Current study suggests that innovating pasta products by using pigment wheat could be a promising avenue since their positive influence to sensory acceptance, cooking quality and antioxidant activity. The marked preference of consumers for the pigmented grain pasta could be a good drive for its consumption and, hopefully, might have a positive effect of consumers' health and wellbeing.

Author statement

Xinying Suo: Data curation, Formal analysis, Writing - original draft.
Francesca Pompei: Conceptualization, Data curation, Formal analysis, Writing - original draft.
Matteo Bonfini: Conceptualization, Writing - review & editing.
Ahmed M. Mustafa: Data curation, Formal analysis, Writing - original draft.
Gianni Sagratini: Supervision, Writing - review & editing.
Zhangcun Wang: Supervision, Writing - review & editing.
Elena Vittadini: Conceptualization, Funding acquisition, Project administration, Supervision, Writing - review & editing.

Implications for gastronomy

Consumers are increasingly searching for food able to provide new sensory experiences, positive nutritional quality, and environmental sustainability. Pigmented and ancient wheats might provide an answer

Table 2
Total polyphenol contents (TPCs) and antioxidant activity (AOA) of raw and cooked pastas (control, ancient, and pigmented).

	TPCs	TPCs reduction upon cooking	AOA	AOA reduction upon cooking
	(mg GAE/ 100g DW)	(%)	(mg TE/ 100 g DW)	(%)
Control raw	37.18 ± 9.75b***	–	31.39 ± 0.75b***	–
Control cooked	28.01 ± 3.39B	24.68	12.78 ± 6.15B	59.23
Ancient raw	42.95 ± 0.84b***	–	31.78 ± 1.49b***	–
Ancient cooked	28.59 ± 1.26B	33.49	12.81 ± 8.10B	59.68
Pigmented raw	87.18 ± 2.08a***	–	81.67 ± 0.96a	–
Pigmented cooked	53.32 ± 0.99A	38.85	79.67 ± 0.99A	2.45

GAE: gallic acid equivalents; DW: dry weight; TE: trolox equivalent.
Data are presented as mean ± SD of three replicates.
Different letters following values indicate significant difference ($p < 0.05$) among control, ancient and pigmented pastas (small letters = raw samples, capital letters = cooked samples).
Asterisks (***: p < 0 0.001) indicate differences between raw and cooked pasta of the same composition.

Table 1
Cooking quality (cooking loss and dimensional changes), moisture content, and texture (hardness and adhesiveness) of the control, ancient and pigmented pasta.

Sample	Cooking loss	Length gain	Thickness gain	Moisture content	Hardness	Adhesiveness
	(g solids/100g raw pasta)	(%)	(%)	(g H_2O/100g cooked pasta)	(N)	($J \times 10^{-3}$)
Control	5.57 ± 0.11b	10.87 ± 0.78a	54.40 ± 3.39a	49.99 ± 0.09b	32.84 ± 2.41b	2.61 ± 0.53a
Ancient	5.00 ± 0.25c	12.94 ± 3.20a	44.46 ± 7.28b	48.91 ± 0.44c	35.32 ± 2.46a	2.70 ± 1.39a
Pigmented	5.91 ± 0.05a	5.82 ± 1.00b	24.58 ± 1.30c	51.78 ± 0.47a	31.51 ± 2.22b	2.32 ± 1.03a

Data are presented as mean ± SD of three replicates. Different letters following values indicate significant difference ($p < 0.05$) among three pastas.

Table 3
Bioactive compounds content (mg kg^{-1} of dry weight) in raw and cooked pastas (control, ancient and pigmented) analysed by HPLC-MS/MS; Relative standard deviations ranged from 1.46 to 7.54%.

Bioactive compounds	Control		Ancient		Pigmented	
(mg kg^{-1} of dry weight)	raw	cooked	raw	cooked	raw	cooked
Phenolic acids						
Gallic acid	n.d.	n.d.	0.1	0.12	0.11	0.15
Neochlorogenic acid	0	0.01	0.02	0.04	0.02	0.05
Chlorogenic acid	0.02	0.11	0.03	0.17	0.15	0.23
p-Hydroxybenzoic acid	2.27	1.66	3.22	2.09	7.64	4.12
3-Hydroxy benzoic acid	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Caffeic acid	n.d.	n.d.	n.d.	n.d.	0.51	0.44
Vanillic acid	1.04	0.32	0.64	0.24	6.33	2.65
Syringic acid	0.32	0.32	0.32	0.11	2.06	0.79
p-Coumaric acid	0.6	0.43	1.01	0.43	9.53	4.9
Ferulic acid	4.19	2.87	4.94	2.95	12.56	5.47
3,5-Dicaffeoylquinic acid	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ellagic acid	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Flavonoids						
A) Anthocyanins						
Delphinidin 3,5 diglucoside	n.d.	n.d.	n.d.	n.d.	0.04	0.04
Delphinidin3-galactoside	n.d.	n.d.	n.d.	n.d.	0.4	0.38
Cyanidin-3-glucoside	n.d.	n.d.	n.d.	n.d.	1.12	0.89
Petunidin-3-glucoside	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Pelargonidin-3-rutinoside	n.d.	n.d.	n.d.	n.d.	0.02	0.01
Pelargonidin-3-glucoside	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Malvidin-3-galactoside	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
B) Flavonols						
Rutin	0.06	0.04	0.07	0.05	0.46	0.31
Isoquercitrin	0.04	0.03	0.03	0.07	0.06	0.07
Quercitrin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Myricetin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Kaempferol-3-glucoside	n.d.	n.d.	0.01	0.02	0.03	0.04
Quercetin	n.d.	0.03	0.01	0.03	0.07	0.07
Isorhamnetin	n.d.	0.01	n.d.	n.d.	0.04	0.04
Hyperoside	0.02	0.03	0.02	0.07	0.04	0.07
Kaempferol	n.d.	n.d.	0.02	0.01	0.02	0.02
C) Flavan-3-ols						
Catechin	0.11	0.11	0.17	n.d.	0.36	0.31
Epicatechin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Procyanidin B2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Procyanidin A2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
D) Dihydrochalcones						
Phloridzin	n.d.	n.d.	n.d.	n.d.	0.01	0.01
Phloretin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
E) Flavanones						
Hesperidin	0.81	1.04	0.93	1.13	0.61	0.44
Naringin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Non-phenolic acids						
Trans-cinnamic acid	n.d.	n.d.	0.11	0.08	0.28	0.21
Total phenolic acid content	8.44	5.71	10.27	6.15	38.91	18.79
Total anthocyanin content	0	0	0	0	1.59	1.32
Total flavonoid content	1.04	1.29	1.27	1.39	3.28	2.69
Total phenolic content	9.48	7.00	11.54	7.54	42.19	21.49

n.d.: not detectable.

to this request, but their effect on consumers' acceptability and products' quality (technological and nutritional) should be evaluated.

The aim of this study was, therefore, to evaluate consumer's acceptability/preference and quality of wholegrain pasta produced with a pigmented (Granomischio) and ancient (Senatore Cappelli) wheats.

Results shown that products produced from ancient and pigmented wheat were well accepted by consumers with higher preference to pigmented wheat pasta because of its new sensory experiences (peculiar color and more complex aromatic profile). Pigmented wheat product presented the highest total phenolic contents and antioxidant activity even after cooking. A low cooking loss and comparable textural quality to semolina pasta of both wholegrain products indicated the successful production by using the two wheats which allows pasta manufactures to broaden their formulations. A higher interest of consumers to pigmented wheat pasta and its higher antioxidant activity over ancient and semolina pasta suggested a promising marketing of pigmented-grain food as well as its potential positive effect on consumers' health.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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