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Cereal foods fortified with by-products from the olive oil industry

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ABSTRACT

The oil industry produces large volume of waste, olive mill waste water (OMWW) and olive paste (OP), which represents a disposal and a potential environmental pollution problem. They are also promising sources of valuable compounds that can be recovered and used. The effects of OMWW and OP addition to bread and pasta, separately and combined, were studied. Both sensory and chemical properties as related to phenols content and antioxidant activity of raw materials, and fortified bread and pasta were evaluated. Results suggested that the enrichment of bread and pasta with OMWW slightly improved the chemical quality without compromising the sensory properties. While, foods enrichment with OP had considerably improved chemical quality, the sensory acceptability was worse due to the bitter and spicy taste of OP. To choose the best cereal food between bread and pasta to be enriched, a mathematical model, the whole quality index (WQI), was used. Bread was better than pasta for re-using olive oil by-products. Between OMWW and OP, the latter was more suitable for food fortification, despite the sensory problems of the enriched product. Also, when the two by-products were combined, the best product continued to be the bread.

1. Introduction

Italy is the second largest European olive oil producer with about 6–7 million tonnes of oil/yr (Caporaso, Formisano, & Genovese, 2017). From the olive oil extraction process three different by-products, olive paste (OP), olive pomace and olive mill waste water (OMWW) are obtained in considerable amounts. In particular, the OP and olive pomace are generally re-used as fuel and an ingredient for compost production or as fertilizer for agricultural soils. The OMWW is characterized by its strong undesirable smell, an intense brown to dark color, a pH between 3 and 6 and a highly diverse organic pollutant load. Generally, OMWW is a problem because of the large volume of concentrated liquid that needs to be disposed of by Italian crushers. Membrane filtration has recently been proposed to transform this waste into a source of bioactive compounds (D'Antuono et al., 2014). This system, through the use of selective membranes with different pore size, microfiltration (cut-off of 100,000 Da), ultrafiltration (cut-off of 5000 Da) or nanofiltration (cut-off of 200 Da), has the dual purpose of recovering substances with high added value, like polyphenols (to be used in various fields such as food) and a much cleaner water steam that is less environmentally harmful (D'Antuono et al., 2014).

The olive oil by-products are rich in bioactive compounds, such as polyphenols (0.5–24 g/l), with potential health-benefits (Obied et al., 2005). Specifically, the main phenolic compounds of OMWW are hydroxytyrosol, tyrosol, caffeic acid, p-coumaric acid, vanillic acid, syringic acid, gallic acid, luteolin, quercetin, cyanidin, verbascoside and some polymeric compounds (D'Antuono et al., 2014; Obied, Prenzler, Konczak, Rehman, & Robards, 2009). For OP, polyphenols such as caffeic, vanillic and coumaric acids, and fatty acids such as oleic, palmitic and linoleic acids were the main compounds identified (Padalino et al., 2018). These by-products can be recognized as potentially low-cost starting materials to extract antioxidant compounds for food, nutraceutical or cosmetic applications (De Marco, Savarese, Paduano, & Sacchi, 2007; El-Abbassi, Kiai, & Hafidi, 2012; Obied, Prenzler, & Robards, 2008). Moreover, many scientific articles are available on the biological activity of polyphenols from olive oil by-products (Cicerale, Lucas, & Keast, 2010), these waste may be a suitable source of valuable compounds that could be used to transform an agro-industrial waste stream into useful and relevant ingredients (Moure et al., 2001; Obied et al., 2009). The potential incorporation of fruit and vegetable by-products in food could alter the sensory and technological properties, thus suggesting the need to carefully select the amount to be added (Marinelli, Padalino, Nardiello, Del Nobile, & Conte, 2015; Spinelli, Conte, Lecce, Incoronato, & Del Nobile, 2015). This difficulty may

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considerably limit oil by-products for food fortification (Cedola, Cardinali, Del Nobile, & Conte, 2017; Padalino et al., 2018).

Considering that cereal products are consumed daily around the world, they could be important carriers of bioactive substance from olive oil by-products (Duranti & Morazzoni, 2011). Therefore, OMWW and OP were used to fortify two different cereal-based foods, bread and pasta.

2. Materials and methods

2.1. Raw materials

The fresh OMWW, from the *Coratina* cultivar, were collected from an olive oil manufacturer (Andria, Italy). It was processed with a laboratory-scale system (Permeare s.r.l., Milano, Italy) in the laboratory of the Institute of Sciences of Food Production, National Research Council of Bari (Bari, Italy). This system used a continuous parallel flow, consisting of a series of membranes with different porosity (from 0.1 to 0.005 μm) to give 3 types of permeate fractions: micro- (MF, above 5000 Da), ultra- (UF, from 5000 to 200 Da), and nano-filtrates (NF, below 200 Da) (D'Antuono et al., 2014). The UF fraction, that represented the best compromise between polyphenols content and degree of purification was stored at 4 °C until used (maximum of 1 wk).

The OP was obtained from a local olive mill (Bisceglie, Bari, Italy), in the last wk of November, from the *Cellina* cultivar and milled using a two-phase decanter (Pieralisi Leopard, Jesi, Ancona, Italy) with a multiphase decanter (DMP). It is a two-phase decanter that extracted without the addition of water. This new technology produced a dehydrated husk similar to the one coming from a three phases decanter but without any traces of pit. The fresh OP was dried at 35 °C in a dryer (SG600, Namad, Rome, Italy) for 72 h. The dry OP was reduced to a fine powder (< 500 μm) using an hammer mill (16/BV-Beccaria s.r.l., Cuneo, Italy) and stored a maximum of 1 wk at 4 °C.

2.2. Chemicals

Gallic acid monohydrate, Folin-Ciocalteu reagent, Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), ABTS (2,2-azinobis(3-ethylbenzothiazoline-6-sulfonic acid diammonium salt), potassium persulfate, iron (III) chloride, 2,4,6-Tris(2-pyridyl)-s-triazine, aluminum chloride, sodium nitrite, sodium hydroxide solution (1 mol/l), methanol, ethanol and quercetin were supplied by Sigma-Aldrich (Milan, Italy). Anhydrous sodium carbonate was supplied by Carlo Erba (Milan, Italy). For the preparation of the phosphate buffered saline (PBS), the following salts were used: sodium phosphate dibasic heptahydrate (1.340 g) and sodium phosphate monobasic monohydrate (0.276 g). These were purchased from Sigma-Aldrich. All reagents were of analytical grade and purchased from Sigma-Aldrich.

2.3. Bread-making process

The bread making was done using the method of Saccotelli et al. (2017) using laboratory-scale equipment at the University of Foggia (Foggia, Italy). Briefly, wheat dough was used as the reference sample (B-CTR), was prepared with 1500 g wheat flour (grade 00, a flour indicated for the production of bread and pasta) acquired from the Agostini mill (Montefiore dell'Aso, Ascoli Piceno, Italy), 900 g of water, 45 g of compressed fresh yeast (Lievital, Sissa Trecasali, Parma, Italia, acquired at a local market), 15 g of sugar and 30 g of salt. Other ingredients were purchased from a local market (Foggia, Italy). The wheat flour, compressed fresh yeast and sugar were mixed with half of water in a mixer (Spiral Mixers Kg. 20/30, Conti Impastatrici, Verona, Italy) for 10 min at a speed of 200 rpm. Then the rest of the water, with salt previously dissolved, was slowly added and mixed at a speed of 110 rpm for 15 min. Once a homogeneous mixture was obtained, dough portions of 800 g were manually rounded and placed in a thermostatic proofing oven (Thermogel, Varese, Italy) for about 70 min at 30 °C and relative humidity of 85%. The enriched sample, B-OMWW, was prepared using the same procedure, but using UF-OMWW instead of water (900 ml) and half the amount of the common wheat flour was replaced with a stronger flour, Manitoba flour (Lo Conte, Avellino, Italy), purchased from a local market (Foggia, Italy), that had a bread making capacity index (W) equal to 390. The experimental sample B-OP was prepared using the same procedure, but adding 10% (w/w) of dry OP pre-treated with milk (fat% = 1.6), as described by Cedola et al. (2017), in place of part of the wheat flour. Specially, the dry OP was hydrated with milk with an OP/liquid ratio of 1:1 for 1 h and the excess liquid was drained. Finally, the sample B-OMWW-OP was prepared using the same ingredients as the last sample (B-OP), but using UF-OMWW in place of water. Finally, all samples were baked on aluminum baking pans in an electric oven (Europa Forni, Vicenza, Italy) at 230 °C for 15 min, followed by 35 min at 200 °C.

2.4. Spaghetti preparation

Commercial durum wheat semolina (grade 00) was purchased from Agostini Mill. Semolina was mixed with water at room temperature (T = 22–24 °C; 30% w/w) (for samples S-CTR and S-OP) or UF-OMWW (same quantity) (for S-OMWW and S-OMWW-OP) with a rotary shaft mixer (9700 series, Namad, Rome, Italy) at 25 °C for 20 min at 20 rpm. The formulations with OP (10% w/w) (S-OP and S-OMWW-OP) had 0.6% transglutaminase Activa WM (TG, Perrins Chemical, Triggiano, Italy) was added and mixed how to uniformly distribute the liquid throughout the semolina particles (Padalino et al., 2018). The dough was extruded with a twin-screw extruder (60VR, Namad), dried in a dryer (SG600, Namad). The drier conditions used were according to Padalino et al. (2018): 1st step, 60 °C for 20 min and 65% moisture (external drying phase); 2nd step, 90 °C for 130 min and 79% moisture (wrapping phase); 3rd step, 75 °C for 150 min and 78% moisture (drying phase); 4th step, 45 °C for 160 min and 63% moisture and, finally, 5th step, 50 °C for 17.3 h and 50% moisture (cooling phases). The spaghetti (30 g) were cooked in 10 times greater boiling water (300 g) than their weight for the optimal cooking time (Padalino et al., 2014). Specially, the optimal cooking time was evaluated every 30 s during cooking by observing of disappearance of the core of the spaghetti by squeezing it between two transparent glass slides according to the AACC 66–50 approved method (2003). The time at which the core completely disappeared was taken as the optimal cooking time.

2.5. Sensory analysis

The samples were submitted to a panel of 12 trained tasters (women, between 27 and 45 years) from the packaging laboratory of the University of Foggia (Foggia, Italy) to evaluate the sensory attributes of samples. The panelists had at least several years of experience in sensory evaluation; however, they were retrained in a session of 2 h to be experienced with the product and terminology. Appropriate descriptive terms for sensory evaluation were decided during the retraining sessions. After retraining, experienced panelists were able to evaluate color and resistance to break of uncooked spaghetti and elasticity, firmness, bulkiness, adhesiveness, color, odor and taste of cooked spaghetti (cooking time: 10 min for S-CTRL samples and 8 min for S-OP, S-OMWW and S-OMWW-OP samples). The elasticity is the measure of the degree of extension of the spaghetti before the break and it is evaluated on a single sample using a slight pull at two points at a distance of ~10 cm. The firmness is the resistance of cooked pasta to the compression by teeth and it is measured by compressing the spaghetti strand against the palate with the tongue. The bulkiness, which is the degree of adhesion of pasta strands after cooking, is evaluated by placing two spaghetti strands together and determining the force required for detachment. The adhesiveness is related to the formation of a surface coating made of amylose. It is evaluated by placing the spaghetti in the mouth, pressing it against the palate, and determining the force required to remove it with the tongue. The panelists were asked to evaluate the color, odor, taste, crust and crumb firmness, presence of large bubbles and overall quality of bread samples. All the instructions were given to panelists before evaluation. The panelists were also trained in sensory vocabulary and identification of attributes by evaluating a durum wheat commercial bread (durum wheat loaf, purchased at local market) (Saccotelli et al., 2017). Before sensory analysis, bread samples were sliced with an electric slicing knife (thickness ~15 mm) (Atlantic; Calenzano, Firenze, Italy) without removing the crust and immediately placed in plastic bags. Each bag was codified with three digits random numbers. Two slices of different bread samples were served twice on a white plastic dish. Panelists were also supplied with water for mouth rinsing between samples. Breads were evaluated (on a scale of 1–9), for 6 quality parameters: color (dark to light); odor and taste intensity (not intense until acute); crust and crumb firmness and large bubbles (1 corresponded to *extremely unpleasant*, 9 to *extremely pleasant*, and 5 as the *threshold of acceptability*). Also, the overall quality was obtained for an overall assessment of the samples analyzed.

Finally, the whole quality index (WQI) was proposed to assess which cereal product, between bread and pasta, was the best food to be fortified with by-products from the olive oil industry (Spinelli, Padalino, Costa, Del Nobile, & Conte, 2019):

$$WQI = (|CFA - CFC|/CFC) \cdot ((SQF - SQ_{min})/(SQC - SQ_{min})) \qquad (1)$$

where: CFA is the phenolic content of samples; CFC is the phenolic content of the control sample (food product without by-products); SQF is sensory quality, expressed as overall acceptability, of fortified sample; SQC is the sensory quality, expressed as overall acceptability, of the control sample (food product without by-products); SQ_{min} is the sensory threshold for product acceptability set equal to 5 (Mastromatteo et al., 2013).

2.6. Total phenolic compounds and antioxidant activity

To determine total phenols and antioxidant activity, the extraction from bread and spaghetti was evaluated as described by Biney and Beta (2014). Briefly, bread (without crust) and spaghetti samples were dried in a ventilated stove (Binder GmbH, Tuttlingen, Germany) at 35 °C and milled to obtain a powder. The extractions were done as reported in Marinelli et al. (2015). For the extraction, 1 g of dried sample (both for bread and spaghetti samples) was mixed with 10 ml of acidified methanol (H_2O:MeOH, 20:80 acidified with 1% of HCl). The mixtures were included in 50 ml centrifuge tubes and shaken at room temperature in the dark for 2 h at 300 rpm using an orbital shaker (HS 260 BASIC, IKA, Staufen, Germany). Next, the samples were centrifuged at 5 °C for 15 min at 10,000 g (5804R, Eppendorf, Milan, Italy) and supernatant was collected and filtered with PTFE 0.45 μm (Sigma-Aldrich, Milan, Italy) prior to the analytical determinations. Triplicate extractions were made for each sample.

Total phenolic compounds in spaghetti and bread samples were determined using the UV-vis spectrophotometer (UV1800; Shimadzu, Milan, Italia s.r.l), using the Folin-Ciocalteu method. The method of Spinelli et al. (2015) was used. Briefly, 0.5 ml of bread and spaghetti sample extracts was mixed with 2.5 ml of Folin-Ciocalteu reagent and, after 5 min, 2 ml of Na_2CO_3 (75 g/l) was added. The sample was kept in darkness at room temperature for 2 h. The absorbance was measured at 740 nm. Total phenolic compounds were quantified using a calibration curve (3.12–100 mg/l; $R^2 = 0.9988$) using standard solution of gallic acid, and the total phenolic content was expressed as mg gallic acid equivalence/g of dried sample. Total phenolic compounds were also measured in OMWW and dry OP.

The antioxidant activity of OMWW, OP and all the food with and without by-products was assessed using ABTS assay, using the method of Re et al. (1999), and by the ferric reducing ability of plasma (FRAP) using a method described by Mohd Salleh and Faraniza (2013) with slight modifications. The ABTS assay is based on the ability of antioxidants to interact with the $ABTS^{+}$ inhibiting its absorption at 734 nm. Sample extract (300 µl) was added to 2.2 ml of $ABTS^{\cdot +}$ diluted solution and after 6 min at room temperature the mixture was measured at 734 nm. The calibration curve used Trolox as a standard, at concentrations between 1.56 and 50 mg/l ($R^2 = 0.999$) and the antioxidant activity was expressed as mg Trolox equivalents/g of dried sample.

For the FRAP assay, 200 µl of extract was mixed with 3 ml FRAP reagent and incubated in water bath for 30 min at 37 °C and the absorbance was determined against blank at 593 nm. The calibration curve used an aqueous solution of $FeSO_4 \cdot 7H_2O$ as the standard, at concentrations between 12.5 and 600 µM ($R^2 = 0.9999$) and the antioxidant activity was expressed as µM of ferrous equivalent Fe (III)/g of dried sample. All tests were carried out in triplicate.

2.7. Statistical analysis

Experimental data were compared using a one-way analysis of variance (ANOVA). Duncan's multiple range test, with the option of homogeneous groups ($p < 0.05$), was carried out to determine significant differences between the samples. STATISTICA 7.1 for Windows (StatSoft, Inc., Tulsa, OK, USA) was used.

3. Results and discussion

The optimization of cereal-based products enriched with olive oil by-products is proposed as balance between chemical and sensory quality. In particular, OMWW and OP were chosen to increase the polyphenols content of bread and pasta. Therefore, these two aspects of food quality will be discussed separately.

3.1. Chemical quality

The two by-products (OMWW and OP) used to fortified bread and pasta were rich in phenolic compounds (Fig. 1). It is important to underline that OP phenolic compounds are more than 4 times higher than OMWW. For the antioxidant activity a similar trend was observed. The OP had higher values of antioxidant activity than OMWW for both by-products for ABTS and FRAP.

Table 1 (first column) shows the theoretical polyphenols content (ThPC) in the fortified foods, obtained from mass balance calculations assuming the contributions were additive and the temperature abuse during processing was neglected. Furthermore, in the case of spaghetti samples, the ThPC was calculated also supposing that polyphenols did not leached out during cooking. As expected, the ThPC of OMWW, for both bread (B-OMWW) and spaghetti (S-OMWW), was higher than that for OP products (B-OP and S-OP), due to the high amount of OMWW compared to the small quantity of OP in both foods. The ThPC of B-OMWW was 5.97, about 1.4 times higher than the B-OP (4.25). A similar trend was measured for spaghetti samples where the ThPC of S-OMWW is about 2.82 times higher than in S-OP sample. The phenolic compounds recovered in the enriched samples after processing and cooking were considerably lower than those expected. These results were in agreement with other studies that suggested that phenolic are unstable to heat and this is why the polyphenols are lower than predicted (Leenhardt et al., 2006; Visioli, Wolfram, Richard, Abdullah, & Crea, 2009). Vogrinčič, Timoracka, Melichacova, Vollmannova, & Kreft (2010) also studied the impact of bread making and baking on rutin, quercetin and polyphenol concentrations as well as the antioxidant activity of tartary buckwheat bread. They showed a decrease in polyphenols concentrations as a result of baking. Delgado-Andrade, Conde-Aguilera, Haro, Pastoriza de la Cueva, & Rufián-Henares (2010) showed that baking involved thermal and moisture conditions that facilitate the Maillard reaction and, at the same time, the destruction of labile

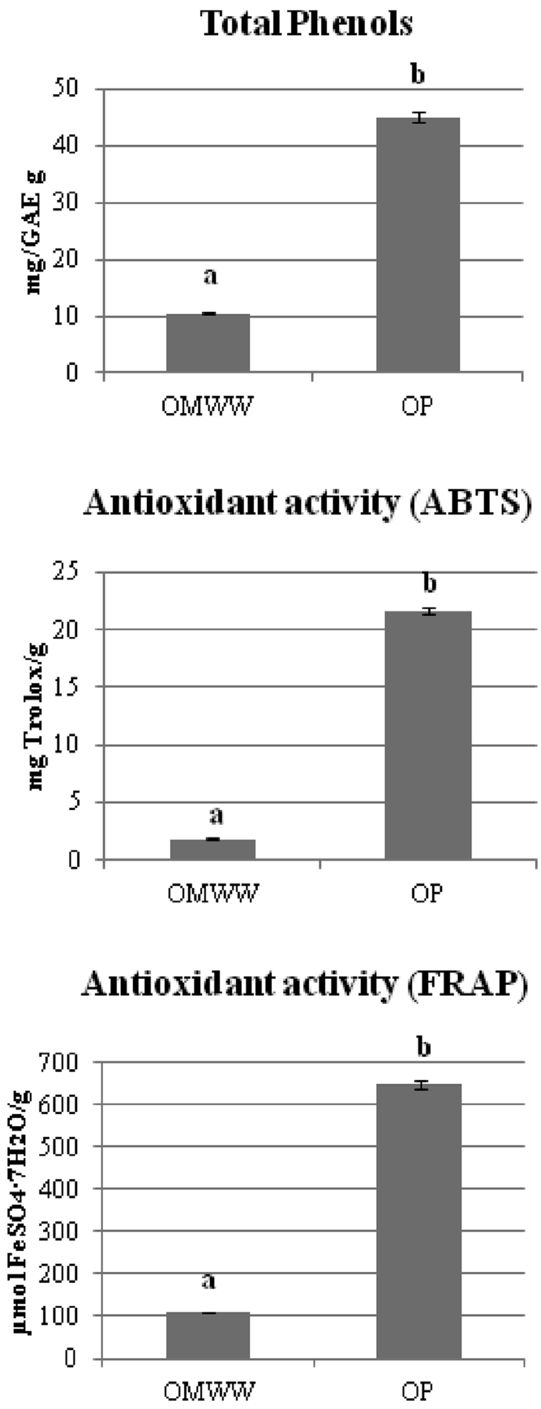

Fig. 1. Total phenols, ABTS antioxidant capacity and FRAP antioxidant capacity of OMWW and OP used to fortify bread and pasta. OMWW: olive mill waste water; OP: olive paste. ^{a,b}Data with different superscripts are significantly different ($p < 0.05$).

antioxidant compounds. The high temperature reached during drying and cooking of spaghetti may be the responsible for phenolic degradation (Hirawan, Ser, Arntfield, & Beta, 2010). Verardo, Caravaca, Messia, Marconi, & Caboni (2011) also studied the effects of the pasta-making and boiling processes, showing a decrease of ~53% of total phenolic compounds in the cooked spaghetti, due to the solubility of phenolic compounds in the cooking water. The same losses were also confirmed in bread and pasta enriched with both types of by-products with values of 1.75 and 0.98 mg GAE/g for B-OMWW-OP and S-OMWW-OP, respectively.

Table 1
Theoretical polyphenols content (ThPC) of enriched products and their chemical characteristics.

Sample	ThPC (mg GAE/g dm)	Total phenols (mg GAE/g dw) ± SD	Antioxidant activity (mg Trolox/g dw) ± SD	Antioxidant activity (μmol $FeSO_4.7H_2O$/g dw) ± SD
B-CTR	-	0.14 ± 0.01^{a}	0.046 ± 0.003^{a,b}	1.8 ± 0.1^{a}
B-OMWW	6.0	0.49 ± 0.01^{c}	0.08 ± 0.01^{c}	5.6 ± 0.4^{d}
B-OP	4.3	1.33 ± 0.04^{f}	0.42 ± 0.02^{f}	17 ± 1^{e}
B-OMWW-OP	10.2	1.8 ± 0.1^{g}	0.67 ± 0.02^{g}	25.3 ± 0.4^{f}
S-CTR	-	0.11 ± 0.01^{a}	0.043 ± 0.002^{a}	0.68 ± 0.03^{a}
S-OMWW	3.2	0.24 ± 0.02^{b}	0.071 ± 0.002^{b,c}	2.2 ± 0.1^{c}
S-OP	1.1	0.76 ± 0.04^{d}	0.28 ± 0.01^{d}	13 ± 0.5^{b}
S-OMWW-OP	7.7	0.98 ± 0.07^{e}	0.30 ± 0.03^{e}	13 ± 0.2^{b}

The second column of Table 1 shows the opposite situation between OMWW and OP in the two cereal products. Samples with OMWW had a concentration of phenolic compounds lower than samples enriched with OP, contrary to what was expected using the theoretical approach. Abdel-Aal and Rabalski (2013) also suggested that the decrease in bioactive compounds depends on the type of product, on the recipe and processing conditions but mainly on the type of phenolic compounds. The characterization of OMWW and OP underlined a different phenolic composition, with the OP rich in oleuropein and triterpenic acids (oleanolic and maslinic acids) present in the epicarp, endocarp, wood shell and seeds of olives (D'Antuono et al., 2014; Padalino et al., 2018). The antioxidant activity of the cereal products was in agreement with the total phenolic content (Gregoris & Stevanato, 2010; Swieca, Seczyk, Gawlik-Dziki, & Dziki, 2014). Therefore, the enrichment with only OMWW for both bread and spaghetti did not lead to a significant increase in the antioxidant activity ($p \geq 0.05$), whereas, the OP enrichment considerably improved the antioxidant activity of the two cereal products.

3.2. Sensory quality

Table 2a shows that the sensory quality of bread decreased due to the addition of by-products; however, all the fortified bread samples remained acceptable above the sensory threshold. The enrichment of bread with alternative ingredients to dough generally decreases the sensory quality of bread because alter the network formation and destabilizes the gas cells, causing low gas retention (Hemdane et al., 2015; Saccotelli et al., 2017). This effect was more evident when OMWW was added to the dough (B-OMWW), thus leading to a worsening of crumb firmness and large bubbles. When OP was included in the bread formulation (B-OP), the attributes that mainly affect sensory quality were color and taste, highly compromised by the bitter and spicy taste of OP phenols (Padalino et al., 2018). When both by-products were used (B-OMWW-OP) the texture defects (crumb firmness and large bubbles) were more accentuated. All the fortified bread were considered without significant differences among them. In Table 2b the sensory characterization of spaghetti with and without by-products is shown. Results showed that the overall quality of both uncooked and cooked control samples (S-CTR) was higher than spaghetti supplemented with by-products. The attributes that mainly compromised spaghetti acceptability were linked to the strength of gluten network, such as elasticity, firmness and bulkiness, as well as those linked to the aesthetical aspect, such as adhesiveness and color. Odor and taste decreased mostly when both by-products were combined. In addition, elasticity and firmness were found to be very low in the cooked spaghetti with olive paste. Most probably, this was due to the inclusion of fibers from oil by-products that promoted the formation of discontinuities or cracks in the pasta strand, thus weakening its structure (Lončarić, ković, Marko, Žaneta, & Pilizota, 2014).Color of the enriched spaghetti with colorless OMWW was not significantly altered. On

Table 2a

Sensory characteristics of bread samples.

Sample	Color	Odor	Taste	Crust firmness	Crumb firmness	Large bubbles	Overall quality
B-CTR	8.1 ± 0.2^{a}	8.2 ± 0.3^{a}	7.9 ± 0.3^{a}	7.9 ± 0.2^{a}	7.8 ± 0.3^{a}	7.8 ± 0.3^{a}	7.8 ± 0.3^{a}
B-OMWW	7.3 ± 0.3^{b}	7.7 ± 0.3^{b}	$7.3 \pm 0.4^{a,b}$	$6.8 \pm 0.3^{b,c}$	5.9 ± 0.2^{c}	$6.2 \pm 0.4^{b,c}$	6.4 ± 0.2^{b}
B-OP	6.5 ± 0.4^{c}	7.8 ± 0.3^{b}	$6.8 \pm 0.4^{b,c}$	7.2 ± 0.3^{b}	6.7 ± 0.3^{b}	6.6 ± 0.2^{c}	6.8 ± 0.3^{b}
B-OMWW-OP	6.8 ± 0.3^{c}	7.3 ± 0.2^{b}	6.9 ± 0.5^{c}	6.4 ± 0.4^{c}	5.6 ± 0.4^{c}	5.8 ± 0.3^{b}	6.3 ± 0.3^{b}

B-CTR: control bread; B-OMWW: bread with olive mill waste water; B-OP: bread with olive paste; B-OMWW-OP: bread with olive mill waste water and olive paste. ^{a,c}Data in columns with different superscripts are significantly different ($p < 0.05$).

Table 2b

Sensory characteristics of spaghetti samples.

Sample	Uncooked sample			Cooked sample							
	Color	Odor	Overall quality	Color	Odor	Taste	Elasticity	Firmness	Bulkiness	Adhesiveness	Overall quality
S-CTR	7.6 ± 0.4^{a}	7.1 ± 0.2^{a}	7.1 ± 0.2^{a}	7.6 ± 0.3^{a}	7.1 ± 0.2^{a}	7.1 ± 0.2^{a}	7.2 ± 0.4^{a}	7.3 ± 0.5^{a}	6.3 ± 0.3^{a}	6.6 ± 0.2^{a}	7.3 ± 0.3^{a}
S-OMWW	7.6 ± 0.2^{a}	6.9 ± 0.2^{a}	7.0 ± 0.3^{a}	7.4 ± 0.2^{a}	7.1 ± 0.2^{a}	7.0 ± 0.3^{a}	7.1 ± 0.2^{a}	7.1 ± 0.2^{a}	6.3 ± 0.3^{a}	6.6 ± 0.2^{a}	6.9 ± 0.2^{a}
S-OP	6.2 ± 0.3^{b}	6.8 ± 0.3^{a}	6.2 ± 0.3^{b}	6.8 ± 0.3^{b}	6.8 ± 0.3^{a}	6.3 ± 0.3^{b}	5.9 ± 0.2^{c}	6.2 ± 0.3^{b}	5.7 ± 0.3^{b}	5.8 ± 0.3^{a}	6.3 ± 0.3^{b}
S-OMWW-OP	6.3 ± 0.3^{b}	6.9 ± 0.2^{a}	6.3 ± 0.3^{b}	6.8 ± 0.3^{b}	6.7 ± 0.4^{a}	6.2 ± 0.3^{b}	5.3 ± 0.3^{b}	6.1 ± 0.2^{b}	5.6 ± 0.2^{b}	5.6 ± 0.2^{a}	6.0 ± 0.3^{b}

S-CTR: control spaghetti; S-OMWW: spaghetti with olive mill waste water; S-OP: spaghetti with olive paste; S-OMWW-OP: spaghetti with olive mill waste water and olive paste. ^{a,c}Data in columns with different superscripts are significantly different ($p < 0.05$).

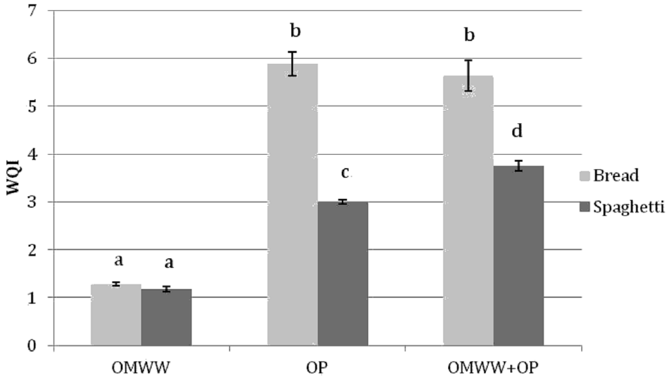

Fig. 2. Whole quality index of bread and spaghetti enriched with OMWW and/or OP.WQI: Whole quality index; OMWW: olive mill waste water; OP: olive paste. ^{a,d}Data with different superscripts are significantly different ($p < 0.05$).

the other hand, the use of olive paste (S-OP and S-OMWW-OP) led to a quality decrease due to the OP dark green color. As happened for bread, the various fortified pasta samples were found to be similar, with score values from 6 to 6.94.

3.3. *Whole quality index*

Fig. 2 shows the WQI of bread and spaghetti, as a function of the different by-products used for their fortification, individually or combined. This index is given by the product of two terms: the former takes into account the nutritional quality of fortified sample (it increases with by-products addition with respect to the control sample), the latter is related to the sensory quality of the sample (it decreases with the increase of by-products addition). As can be seen in the figure, the WQI for both bread and spaghetti is much lower when OMWW was used for the enrichment. During the production process the phenols were strongly reduced due to the high cooking temperature (Abdel-Aal & Rabalski, 2013). When OP was used for the enrichment, instead, the WQI was lower for the spaghetti respect to the bread samples. Probably, the boiling process induced the leaching of most OP phenolic compounds into the cooking water, causing a significant loss in pasta samples. When the two by-products were combined the best product continued to be the bread, with a final WQI not statistically different from the value when the sole OP was used. Therefore, the WQI shows that OP is the best ingredient to enrich cereal products and among them, bread is better than pasta.

4. Conclusions

The impact of olive oil by-products addition as OMWW and OP on both chemical and sensory characteristics of bread and pasta was evaluated. In addition, the WQI was calculated to assess which by-product was the best for food fortification. Results showed that the enrichment of bread and pasta with OMWW slightly improved the chemical quality of samples whereas the OP enrichment considerably improved both phenolic contents and antioxidant activity. The OP, in particular, negatively influenced the sensory properties, due to a very bitter and spicy taste. The WQI was higher for bread than spaghetti when both OMWW and OP were used. Furthermore, the WQI showed that the OP was the best by-product for bread fortification. The current study will hopefully benefit the olive oil industry by indicating uses for these by-products for the production of new healthy foods.

Declaration of competing interest

The authors confirm that they have no conflicts of interest with respect to the work described in this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.fbio.2019.100490.

B-CTR: bread control; B-OMWW: bread with olive mill waste water; B-OP: bread with olive paste; B-OMWW-OP: bread with olive mill waste water and olive paste; S-CTR: Spaghetti control; S-OMWW: spaghetti with olive mill waste water; S-OP: spaghetti with olive paste; S-OMWW-OP: spaghetti with olive mill waste water and olive paste. ^{a,g}Data in columns with different superscripts are significantly different ($p < 0.05$). GAE: gallic acid equivalents.

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