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Functional, textural and sensory properties of dry pasta supplemented with lyophilized tomato matrix or with durum wheat bran extracts produced by supercritical carbon dioxide or ultrasound

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ABSTRACT

A study was carried out to produce functional pasta by adding bran aqueous extract (BW) and bran oleoresin (BO) obtained using ultrasound and supercritical CO_2, respectively, or a powdery lyophilized tomato matrix (LT). The bioactive compounds, hydrophilic and lipophilic antioxidant activity (HAA and LAA) *in vitro*, were evaluated. BW supplementation did not improve antioxidant activity, whilst LT pasta showed unconventional taste and odor. BO pasta had good levels of tocochromanols (2551 μg/100 g pasta f.w.) and carotenoids (40.2 μg/100 g pasta f.w.), and the highest HAA and LAA. The oleoresin altered starch swelling and gluten network, as evidenced by scanning electron microscopy, therefore BO pasta had structural characteristics poor compared with the control (4.8% vs. 3.2% cooking loss), although this difference did not affect significantly overall sensory judgment (74 vs. 79 for BO and control, respectively). BO supplementation was most effective for increasing antioxidant activity without jeopardizing pasta quality.

1. Introduction

The increasing demand for healthy foods has encouraged food companies to direct new research and development activities towards products providing, beyond basic nutritional functions, beneficial effects for health and/or reducing the risk of chronic diseases, i.e. functional foods (Roberfroid, 2002).

Potentially, pasta is a useful carrier for substances acting as nutrition enhancers or providing specific physiological functions and has, thus, been the object of many functionalization strategies (Li, Zhu, Guo, Brijs, & Zhou, 2014). To improve protein content and essential amino acid profile, pasta has been supplemented with flour made from split pea and faba bean (Petitot, Boyer, Minier, & Micard, 2010), common bean (Gallegos-Infante et al., 2010), lupin (Doxastakis et al., 2007), and chickpea and lentil (Zhao, Manthey, Chang, Hou, & Yuan, 2005). Other supplements aimed to increase omega-3 polyunsaturated fatty acid content to prevent/ reduce cardiovascular diseases. For this purpose, functional ingredients of marine origin, such as seaweeds, have been exploited (Prabhasankar, Ganesan, & Bhaskar, 2009). Microencapsulated fish oil, rich in long chain omega-3 polyunsaturated fatty acids, was proposed by Iafelice et al. (2008). Other pasta formulations, supplemented with carrot and oregano leaf powders (Boroski et al., 2011), black carrot concentrate (Day, Seymour, Pitts, Konczak, & Lundin, 2009), carob flour (Sęczyk, Świeca, & Gawlik-Dziki, 2016) or germinated pigeon pea seeds (Torres, Frias, Granito, & Vidal-Valverde, 2007) showed higher antioxidant activity *in vitro* as well as increased levels of phenolic compounds than unsupplemented controls.

Tomato and durum wheat are among the major food crops in the Mediterranean area and there is huge economic interest in evaluating alternative uses for these crops, including products, by-products and waste derived from their industrial processing. Food industry by-products and waste, as well as cultivars specifically selected for the high content of a specific bioactive

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compound, are potentially valuable sources of functional ingredients suitable for incorporation into pasta.

The outermost layers of wheat caryopsis constitute bran, an abundant by-product of the milling industry. Destined mainly for animal feed, bran contains antioxidants including phenolics (Yu, 2008), carotenoids, and tocochromanols (Durante, Lenucci, Rescio, Mita, & Caretto, 2012). Wheat bran extracts, obtained by preliminary KOH-induced hydrolysis, have been used in fresh pasta in a previous study (Delvecchio & Pasqualone, 2013). However, addition of the extract reduced dough machinability and affected the sensory properties of the end product, due to salts derived from KOH neutralization. Ultrasound-assisted and supercritical carbon dioxide (SC-CO_2) technologies represent effective and non-toxic systems for extracting nutraceuticals (Wang & Weller, 2006), which can be exploited to recover bioactive compounds from bran without the need for chemical pretreatments.

Rich in antioxidant molecules, such as lycopene, ascorbic acid, vitamin E, carotenoids, flavonoids, and phenolic compounds (Raffo et al., 2002), tomato has undergone intense breeding, especially in regard to lycopene content. As a result, a number of high lycopene hybrids, with good agronomic and biochemical traits, have been introduced to the global market (Ilahy, Hdider, Lenucci, Tlili, & Dalessandro, 2011; Ilahy et al., 2016) and, recently, used to produce antioxidant enriched lyophilized powders suitable for addition to innovative functional foods (Lenucci et al., 2010, 2015).

Until now, there have been no reports about either the addition to pasta of functional extracts from bran, obtained by ultrasound-assisted and SC-CO_2 technologies, or lyophilized matrices from high lycopene tomatoes. Further, there are no comparative studies on the properties of pasta made with aqueous, oleaginous or powdery supplements. These materials, although similar in terms of antioxidant activity, are very different in composition, and could have different effects on the pasta-making process. The aim of this study was to explore the feasibility of producing functional pasta, with quality characteristics similar to conventional pasta, by adding antioxidant extracts or powdery matrices derived from food industry by-products or specifically selected cultivars. In particular, supplementation was realized by addition to the semolina: (i) a bran aqueous extract obtained using ultrasound-assisted technology; (ii) a bran oleaginous extract (oleoresin) prepared using SC-CO_2; (iii) a powdery lyophilized tomato matrix with high lycopene content. Functional, textural, and sensory properties of the supplemented pasta were evaluated.

2. Materials and methods

2.1. Wheat bran oleoresin production

Durum wheat (*Triticum durum*, Desf.) bran was provided by Tomasello s.p.a. milling industry (Casteldaccia, Palermo, Italy) and processed into a dehydrated matrix accordingly to Durante, Lenucci, Laddomada, Mita, and Caretto (2012). Briefly, wheat bran was oven dehydrated at 60 °C to a residual moisture content of 3%. The dehydrated material (with an average granulometry of ~600 μm) was used directly for SC-CO_2 oleoresin extraction. The matrix was vacuum-packaged in food grade oxygen impermeable plastic bags and stored in a freezer at −20 °C until SC-CO_2 extraction. SC-CO_2 extractions were performed in the pilot plant described by Vasapollo, Longo, Rescio, and Ciurlia (2004). Aliquots (3 kg) of the wheat bran matrix were packed into a 5 L stainless-steel extraction vessel and extracted dynamically for 3 h using CO_2 at a rate of 18–20 kg/h. The other operative parameters were pressure = 35 MPa and temperature = 60 °C. The obtained oleoresin was stored at −20 °C in a food-grade polyethylene terephthalate (PET) bottle until use.

2.2. Wheat bran aqueous extract production

Durum wheat bran (3.5 kg) was mixed with tap water (35 L) (pH 7.6, Maximum Contaminant Levels 315 mg/L, hardness 20 °fH, conductibility 451 μS/cm at 20 °C). The suspension was subjected to ultrasound-assisted extraction at 20 °C for 25 min by means of a pilot plant assembled by Weal (Milano, Italy), consisting of a stainless steel cylindrical extraction chamber (32-cm diameter, 102-cm height) equipped with a Sonic Digital LC 1000 SD 25-P Premium ultrasound generator (Weber Ultrasonics, Karlsbad-Ittersbach, Germany), and a Sonopush Mono titanium alloy transducer bar (Weber Ultrasonics, Karlsbad-Ittersbach). A centrifugal electrical-pump allowed recirculation of the suspension of water and bran into the extraction chamber, with the aim of ensuring homogeneous cavitation in the mass to be extracted. Thirty-second recirculation steps were carried out every 5 min during ultrasonic treatment. Finally, the suspension was filtered through a metal grid with 1 mm holes to recover the liquid phase. The extract obtained, with a total phenolic concentration of 1.30 g/L expressed as ferulic acid equivalents (FAE), was stored at −20 °C until use.

2.3. Lyophilized tomato matrix production

Open field grown red-ripe tomatoes (*Solanum lycopersicum* L.), high lycopene HLY 18 cultivar, were processed in a dehydrated matrix as described by Lenucci et al. (2010). Briefly, tomatoes were blanched in water at 70 °C for 5 min, crushed and sieved using a Reber 9004 N tomato squeezer (Reber, Luzzara, Italy) to obtain a tomato purée free from skins, seeds and vascular tissues. The purée was centrifuged at 27000×*g* for 10 min to remove water-soluble substances. The pellet was dehydrated to a constant weight using a Christ ALPHA 2-4 LSC freeze-dryer (Martin Christ Gefriertrocknungsanlagen GmbH, Osterode am Harz, Germany). The lyophilized tomato pellet was ground in a laboratory ultracentrifugal mill (ZM200, Retsch GmbH, Haan, Germany) through a 35-mesh (500 μm) sieve. The powdered matrix obtained was vacuum-packaged in food grade oxygen impermeable plastic bags and stored in a freezer at −20 °C until use.

2.4. Pasta production

Durum wheat (*Triticum durum* Desf.) cv. 'Vertola' was used to perform all the experimental work. This cultivar, released in 2003, was developed by the Agricultural and Forest Sciences Department of the University of Palermo (Italy). It is characterized by good agronomic features (short plant stature, early heading and maturity, high yield potential). Sowing was carried out during the first week of December 2013 and production of the grain was conducted under rain-fed conditions at the Pietranera farm (Santo Stefano Quisquina, Italy; 37° 30′ N, 13° 31′ E), located in a hilly area of Sicily. It has a semiarid Mediterranean climate with a mean annual rainfall of 552 mm, most of which falls in the autumn/winter (74%) and spring (18%). There is a dry period from May to September. The mean air temperature is 15.9 °C in autumn, 9.8 °C in winter, and 16.5 °C in spring. The average minimum and maximum annual temperatures are 10.0 °C and 23.3 °C, respectively. The weather data were collected from a weather station located within 500 m of the experimental site. Grains were harvested at full ripening stage during the first week of July 2014. Grains were milled to semolina by means of MLU 202 mill (Buhler, Uzwil, Switzerland), after conditioning at 17.5% moisture, the semolina was used to produce five types of pasta: (i) control pasta; (ii) pasta containing bran