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Physical, sensorial, and antioxidant properties of common wheat pasta enriched with carob fiber

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ABSTRACT

The aim of this study was to evaluate the effect of carob fiber on pasta properties. Common wheat flour was substituted with 0, 1, 2, 3, 4, and 5 g/100 g of carob fiber. Pasta properties including firmness, color, cooking time, sensory analysis, and antioxidant properties were evaluated. The results showed that carob fiber slightly increased the weight increase index and decreased the optimum cooking time. The lightness of pasta strongly decreased with the proportion of carob fiber, from 61.7 to 26.5 and from 55.8 to 38.6 for uncooked and cooked samples, respectively, whereas the total color difference changed from 24.4 to 38.6 and from 9.6 to 17.2, respectively. A linear decrease in pasta cutting force was observed as the proportion of carob fiber increased. The sensory evaluation of pasta showed that the additive decreased scores for pasta smell but increased scores for color evaluation. Carob fiber up to 4 g/100 g of wheat flour had little effect on pasta's overall acceptability and significantly increased total phenolics content and antioxidant activity of samples. Digestion *in vitro* caused an increase in total phenolics content and antioxidant activity.

1. Introduction

Ceratonia siliqua L., commonly known as carob, is a tree belonging to the Leguminosae family. Seeds and pods of carob fruit are used in various industries, such as food, pharmaceutical, and cosmetics (Durazzo et al., 2014). Carob is widely cultivated in the Mediterranean region, especially in Spain, Italy, Portugal, and Morocco (Nasar-Abbas et al., 2016).

Powdered carob seeds are, known as locust bean gum, widely used as a food additive (E-410) (Bouzouita et al., 2007). The separation of seeds results in a significant quantity of de-seeded broken carob pods as by-product, commonly known as kibble (Nasar-Abbas et al., 2016). Carob pods are characterized by low protein (3–4 g/100 g) and lipids (0.4–0.8 g/100 g) and high soluble sugars (40–50 g/100 g, mainly sucrose) contents (Kumazawa et al., 2002). Besides, carob pods are a rich source of valuable compounds such as dietary fiber (Khlifa, Bahloul, & Kitane, 2013) and contain high content of phenolic compounds, especially condensed tannins (Ayaz et al., 2009), minerals, and vitamins (Youssef, El-manfaloty, & Ali, 2013). The seedless pods can be ground into flour and used as a chocolate or cocoa substitute (Durazzo et al., 2014). Carob flour can also be used as a functional additive for food production (Biner, Gubbuk, Karhan, Aksu, & Pekmezci, 2007; Tsatsaragkou, Gounaropoulos, & Mandala, 2014).

Carob fiber (CF), which is a by-product of carob syrup processing, is a predominantly insoluble and nonfermentable dietary fiber. Carob kibble is soaked in water overnight, which dissolves majority of the carbohydrates. Then the water-soluble extract is collected and the resultant material consists of mostly dietary fiber (Nasar-Abbas et al., 2016). CF is unique in its composition due to the presence of high amounts of polyphenols. Most importantly, about 50% of the weight of the carob dietary fiber corresponds to polyphenols (Saura-Calixto, 1988). Carob fiber can be used as a functional food ingredient in a range of food products such as baked goods, extruded products, dairy drinks, health bars, and dietary supplements (Nasar-Abbas et al., 2016).

Pasta is a widely consumed food because of its low cost, easy preparation, and long shelf life. High quality pasta are manufactured using durum wheat semolina because of its very good cooking quality and high consumer acceptance (Kim, Lee, Heo, &

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Moon, 2016). However, in many countries the availability of durum wheat for pasta production is limited and there have been many reports on the partial or complete replacement of semolina with common wheat flour or others flours (Gélinas, Mckinnon, & Gagnon, 2016; Kim et al., 2016; Majzoobi, Ostovan, & Farahnaky, 2011).

In this study, carob fiber was added to common wheat flour with the aim of replacing wheat flour in pasta production. The effects on pasta quality was assessed by evaluating the cooking properties, texture, color, sensory, and antioxidant properties.

2. Materials and methods

2.1. Chemicals

Ferrozine (3-(2-pyridyl)-5,6-bis-(4-phenyl-sulfonic acid)-1,2,4-triazine), ABTS (2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid)), α-amylase, pancreatin, pepsin, bile extract, Folin–Ciocalteau reagent, linoleic acid, and ammonium thiocyanate were purchased from Sigma-Aldrich (Poznan, Poland). All others chemicals were of analytical grade.

2.2. Raw materials and pasta preparation

Common wheat flour (protein 12.5 g/100 g, ash 0.57 g/100 g, moisture 14.1 g/100 g) and CF were used as two main components of pasta. CF was a natural extract from carob kibble, a commercial product available as "Carob fiber" (Carob General Application, Valencia, Spain), with total fiber content 74.6 g/100 g, simple carbohydrates 5.8 g/100 g, fat 0.2 g/100 g, (Gruendel et al., 2006). Blends of flours were prepared by substituting wheat flour with CF flour as 1, 2, 3, 4, and 5 g/100 g (CF1–CF5, respectively). Blends were mixed with water up to a moisture content of 30 g/100 g for 5 min to obtain a homogeneous dough and the dough was fed into a pasta machineMarcato Atlas Wellness 150 Pasta Maker (Marcato, Campodarsego, Italy). Pasta samples (vermicelli about 3.0 mm thickness, 80 mm length) were dried in a laboratory dryer SML30 at 50 °C (POL-EKO-APARATURA, Wodzisław Śląski, Poland) until the moisture of pasta reached about 11 g/100 g (wb). The experiment was performed in triplicate for each blend of flour. The picture of control pasta and pasta with different percentage of CF are presented in Fig. 1.

2.3. Color analysis

Color was measured at six points of pasta surface before and after cooking using a colorimeter (Chroma Meter CR-400C, Minolta, Osaka, Color Lab, Japan) The following parameters were recorded: L^*, a^*, b^*. Also, the total color difference (*TDC*) between control pasta and pasta with CF was calculated (Miceli, Francescan, Moschetti, & Settanni, 2015).

2.4. Cooking properties of pasta

For evaluating the cooking properties 100 g of each pasta was cooked in 1 L of boiling distilled water. The optimal cooking time was determined using the method described by Sobota, Rzedzicki, Zarzycki, and Kuzawińska (2015). Cooking loss (g loss/100 g pasta) was measured by evaporating the cooking water to dryness in an oven-dry method 66–50.01 method (AACC, 2011). Absorbed water during cooking was measured as the weight increase of pasta after cooking and the weight increase index was calculated by dividing the weight of pasta after cooking by the weight of uncooked pasta (Bonomi et al., 2012).

2.5. Texture analysis

Texture analysis was performed in a strength tester Z020/TN2S (ZWICK, Ulm-Einsingen, Germany). For every sample of pasta nine repeated measurements were done. Measurements were carried out on cold samples (room temperature), samples were dipped in cool water soon after cooking to stop the cooking process (Larrosa, Lorenzo, Zaritzky, & Califano, 2016). Single samples of pasta were put on the bottom plate of a resistance testing machine (Zwick Z020) and cut with a knife (1 mm thick) at a crosshead speed of 10 mm/min until the distance between the knife and the plate was 0.2 mm. This test was used to determine the maximum force and shear work needed to cut the single cooked pasta sample (Dziki & Laskowski, 2005).

2.6. Sensory evaluation

The 7-point hedonic scale was used for evaluating pasta acceptability (from 1 – extremely dislike to 7 – extremely like). Pasta samples were evaluated by a consumer panel consisting of 67 members (37 males, 30 females, aged 20–52 years). Before testing, all participants were enquired for possible food allergies to wheat flour or CF. Each sample was cooked as per the procedure described in Section 2.4. After cooking, the samples were drained and a portion of approximately 100 g was served to each panelists. Participants were instructed to rinse with water (20 °C) before they began testing and between samples. Pasta samples were evaluated for the strand quality (lack of surface cracks/damages, surface stickiness, and intactness, which indicates the strength to withstand the severity of cooking), color, taste, aroma, texture (firmness of the bite), and overall acceptability (Rekha, Chauhan, Prabhasankar, Ramteke, & Venkateswara Rao, 2013).

2.7. Total phenolics content and antioxidant properties

For buffer (non digested) extract preparation powdered samples (1 g) of dry pasta were extracted for 1 h with 25 mL of phosphate buffered saline (PBS, pH = 7.4) according the procedure described by Gawlik-Dziki et al. (2015). Extracts were combined and stored in darkness at −25 °C until analysis.

To obtain extracts containing potentially bioaccessible compounds, *in vitro* digestion was performed (Gawlik-Dziki et al., 2015). The powdered samples were homogenized with 15 mL of simulated salivary fluid (prepared by (1) dissolving 2.38 g Na_2HPO_4, 0.19 g KH_2PO_4, and 8 g NaCl with 100 mg of mucin in 1 L of distilled water; (2) adjusting to pH = 6.75; and (3) adding α-amylase (E.C. 3.2.1.1) to obtain the final activity of 200 U/mL) in a stomacher laboratory blender 400 (UAC Hos, London, UK) for 1 min to simulate mastication.

For the gastric digestion, the samples were adjusted to pH = 1.2 using 5 mol/L HCl and subsequently 15 mL of simulated gastric fluid was added (300 U/mL of pepsin (from porcine stomach mucosa, pepsin A, EC 3.4.23.1) in 0.03 mol/L NaCl, pH = 1.2). The samples were shaken for 120 min at 37 °C. After digestion with the gastric fluid, the samples were adjusted to pH = 6 with 0.1 mol/L of $NaHCO_3$ and then 15 mL of the mixture of bile extract and pancreatin was added (0.05 g of pancreatin (activity equivalent 4 × USP) and 0.3 g of bile extract in 35 mL 0.1 mol/L $NaHCO_3$). The extracts were adjusted to pH = 7 with 1 mol/L NaOH and finally 5 mL of 120 mmol/L NaCl and 5 mL of mmol/L KCl were added to each sample. The prepared samples were subjected to *in vitro* digestion for 60 min at 37 °C in darkness. Then, the samples were centrifuged and supernatants (extracts after simulated digestion) were used for further analysis.

The amount of total phenolics content (*TPC*) was determined