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Effect of processing on the beta-glucan physicochemical properties in barley and semolina pasta

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ABSTRACT

A health claim linking the consumption of barley β-glucan and the lowering of blood cholesterol has been allowed in North America and Europe which resulted in increased interest in barley products. Waxy barley flour rich in β-glucan (10% d.b.) was used to produce barley functional spaghetti and compared to semolina spaghetti. The impact of processing (extrusion, drying and cooking) on the physicochemical properties of barley blends and pasta as the molecular characterization of β-glucan were investigated. Pasta processing did not significantly affect the amount of β-glucan, but it impacted the β-glucan physicochemical properties in the end products. In all pasta, extrusion and drying were detrimental to the β-glucan properties, while cooking significantly increased the extractability and molecular weight of β-glucan, and in turn its viscosity, which determines its physiological effectiveness. In general, replacing wheat semolina with barley flour rich in β-glucan resulted in improved barley pasta containing the recommended amount of β-glucan per serving and enhanced β-glucan properties.

1. Introduction

Whole cereal grains, including barley, are an excellent source of bioactive compounds (phytochemicals) such as healthy dietary fiber, particularly β-glucan. Consequently, they are gaining interest as an ingredient in the production of functional foods, such as pasta, bakery products, flakes, snacks, etc (Marconi et al., 2000; Verardo et al., 2011a, 2011b) which are common components of the human diet.

The mixed linkage (1–3, 1–4)-β-D-glucan, commonly referred to as β-glucan, is classified as a soluble dietary fiber and is a major component of the cell walls of barley and oat endosperm. The β-glucan content of cereals ranges from about 5 to 11% in barley and 3–7% in oats, to 2% in rye and <0.5% in wheat grains. Barley and oats are the primary sources of β-glucan in the human diet, but its level can vary dramatically between varieties (Perez Herrera et al., 2016).

β-glucan has been found to be effective in attenuating postprandial blood glucose and insulin, and in lowering blood lipids, especially serum total and LDL-cholesterol (Cavallero et al., 2002; Wolever et al., 2010). The documented relationship between consumption of foods rich in soluble fiber, especially β-glucan, and the reduced risk of heart disease, led to the first health claim for a specific food by the Food and Drug Administration (FDA, 1997). In particular, the physiological role of β-glucan in reducing glycemic responses, has been mostly associated with its capacity to increase viscosity in solution at low concentration in the upper digestive tract, a property of soluble high molecular weight compounds. The viscosity of β-glucan depends on its concentration and molecular weight, which in turn are dependent on its extractability and solubility. Molecular weight and solubility of β-glucan are affected by genotype, environment, agronomic input, with the interactions of these factors with food processing methods (Tiwari and Cummins, 2009). Available literature (Tiwari and Cummins, 2009) reveals that the level of β-glucan in a finished product (e.g. bread, cake, muffins) depends upon several factors in the production chain, whereas food processing operations are mainly affecting molecular weight and solubility of β-glucan (Izydorczyk et al., 2000; Regand et al., 2009).

There has been much speculation and insufficient investigation over the years concerning the effects of processing on the physicochemical characteristics of β-glucan incorporated into food products. This speculation has frequently supposed that processing would be detrimental to bioactivity. Thus, processing may affect the

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molecular (chemical structure and degree of polymerization), structural (molecular interactions) and functional properties (viscosity, water binding capacity and solubility) which, in turn, could affect the sensory, physiological and ultimately the health benefits of β-glucan. Changes in the properties of β-glucan may arise from shearing damage due to mechanical processing, or by excessive heat treatment of food products.

The current study aimed at developing barley pasta rich in β-glucan able to satisfy the health claim requirements of the FDA (0.75 g of β-glucan per serving) (FDA, 2015) and the European Food Safety Authority (EFSA) (≥1 g of β-glucan per quantified portion) (EFSA, 2011) and to meet the needs of North American market. Pasta was made from waxy barley as a rich source of soluble dietary fiber, individually and in blends with semolina. A preliminary study of the pasting properties of barley and semolina blends was carried out in order to understand the contribution of β-glucan to viscosity of raw materials and end products. The health benefits are controlled by the solubility and molecular weight of β-glucan, that in turn affect the final viscosity of the product in the gut.

Thus, the impact of processing (extrusion, drying and cooking) on the concentration and physicochemical properties of the flours and blends, and molecular characterization of β-glucan, as well as viscosity of the developed pasta products was evaluated.

2. Material and methods

2.1. Materials

The two-rowed, hulless, waxy barley cultivar (CDC Fibar) was selected based on its high β-glucan content (Gray et al., 2009) and obtained from the University of Saskatchewan (Saskatoon, Saskatchewan, Canada). The 6 six-rowed, hulled, normal barley cultivar (Celebrity) was provided by a Canadian supplier.

Commercial durum wheat semolina, xanthan gum (El Peto Products), annatto food color (Calico), sea salt (Life stream) were bought from a local store in Guelph (ON, Canada).

CDC Fibar grain was ground using a cyclone Sample Mill (UDY Corp., Fort Collins, CO, USA) equipped with a 0.5 mm screen. The barley flour and semolina were refrigerated until pasta preparation.

Microbial α-amylase thermostable (for TDF and Starch Assay; 100 ml; 3.000 U/ml; 45 U/mg) and pancreatin from porcine pancreas was purchased (P7545, activity equiv. 8× USP) from Megazyme International (Ireland) and Sigma-Aldrich (Canada), respectively.

2.2. Pasta preparation

The recipes for making pasta (spaghetti) were chosen to meet the FDA and EFSA health claim requirements and to meet the needs of the North American market.

Barley flour (CDC Fibar) was blended with different amounts of semolina. Four formulations were tested: 1) 100% barley flour; 2) 50% barley flour +50% durum wheat semolina; 3) 30% barley flour +70% durum wheat semolina; 4) 100% durum wheat semolina (pasta control), subsequently referred to as 100% barley flour, 30% barley flour, 50% barley flour and 100% semolina. Salt, xanthan gum and annatto solution were added to flours to improve flavor, texture and color of pasta.

Moisture content of pasta was adjusted during processing on the basis of water absorption of barley blends. Pasta formulations are described in Table 1. The dry ingredients were mixed in a pasta maker (PastaMatic MX700, Simac-Vetrella, Italy) for 3 min. After that, water was added and all ingredients were mixed for 6 min, then the dough was extruded.

The optimum cooking time of pasta (the time necessary to obtain complete gelatinization of starch shown by the disappearance of the white central core of the spaghetti strand) was determined according to the AACCI Method 66–50.01 (AACCI, 2010).

After the extrusion, half of each batch was freeze-dried (e.g. fresh pasta), half was dried at 80 °C in an air oven (Baking Center Duke, Model E101-EV, Duke Manufacturing, St. Louis, MO, USA) for 4 h (e.g. dried pasta). Part of fresh and dried pasta was cooked (e.g. fresh cooked, and dried cooked pasta). Cooked pasta were freeze-dried for chemical assays (Virtis Genesis 25 EL Laboratory Pilot Freeze Dryer, VirTis, Stone Ridge, NY, USA). All samples were ground using a cyclone Sample Mill equipped with a 0.5 mm screen and refrigerated for future analysis.

2.3. Chemical analyses

Moisture content of raw ingredients and pasta was determined according to the standard methods AACCI Method 44–15.02 (AACCI, 2010). Total β-glucan content of samples was determined using the AACCI Method 32–23.01 (AACCI, 2010). For this method, β-glucan is hydrolyzed to D-glucose with lichenase and β-glucosidase.

2.4. Pasting properties of flours

Pasting properties of barley flour, semolina and their blends were measured by means of a Rapid Visco Analyzer (RVA-4) following AACCI Method 76–21.01 (AACCI, 2010) using the RVA General Pasting Method (Newport Scientific Pty. Ltd., Warriewood, Australia). A sample of 3.5 g of flour (14% moisture basis) was transferred into a canister and approximately 25 ± 0.1 mL distilled water was added (correction based on 14% moisture basis). The slurry was heated to 50 °C and stirred at 160 rpm for 10 s for thorough dispersion. The slurry was held at 50 °C for up to 1 min, and then heated to 95 °C over 7.3 min and held at 95 °C for 5 min, and finally cooled to 50 °C over 7.7 min. The pasting temperature (the temperature where viscosity first increases by 25 cP over a 20 s period), peak time (the time at which peak viscosity occurred), peak viscosity (the maximum hot paste viscosity, PV), holding strength or trough viscosity (the trough at the minimum hot paste viscosity, TV), final viscosity (the viscosity at the end of test after cooling to 50 °C and holding at this temperature, FV), breakdown (peak viscosity-holding strength or trough viscosity, BD) and setback (final viscosity-holding strength, SB) were calculated from the pasting curve, using Thermocline version 2.2 software (Newport Scientific Pty. Ltd, Warriewood, Australia). All RVA experiments were run in duplicate and the coefficient of variation of viscosity properties was less than 10% at any value.

2.5. RVA method for viscosity measurement of β-glucan in pasta

An amount of milled pasta sample containing 1.0% β-glucan amount was weighed into an RVA canister to produce slurries. A volume of 20 mM sodium phosphate buffer (pH 6.9) containing 10 mM NaCl, equal to 25 mL minus the moisture present in the sample, was added to the RVA canister. All the digestive enzymes were added to the canister at the beginning of the run in the following amounts: 100 μL of thermostable microbial amylase and 600 μL of pancreatin (0.5 mg/mL in sodium phosphate buffer, pH 6.9), as used in the in vitro digestion protocol (Gamel et al., 2012). The RVA (RVA-4, Newport Scientific, Warriewood, Australia) equipped with Thermocline software version 2.2 for Windows was held constant at 37 °C, and mixing speed was set at 480 rpm for 10 s followed by 2 h at 160 rpm. Viscosity was recorded every 8 s, and the final viscosity was noted at the end of the 2 h, when a plateau of the final segment of viscosity curve was achieved. Viscosity of