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Structural, functional, and antioxidant properties of water-soluble polysaccharides from potatoes peels

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ABSTRACT

Water-soluble polysaccharides were extracted from potato peel waste (PPW). The structure of the polysaccharides from PPW (PPPW) was examined by means of Fourier transform-infrared spectroscopy (FT-IR) analysis, X-ray diffractometry (XRD) and gas chromatography–mass spectrometry (GC–MS). The results suggest that the extracted polysaccharides form a semi-crystalline polymer constituted essentially of the functional groups CO, CH and OH. Acid hydrolysis of this polymer yielded glucose (76.25%) as the dominant sugar functional properties (water holding capacity: WHC, oil holding capacity: OHC, foaming, and emulsion properties) of this polymer were studied. The PPPW showed interesting water-holding and fat-binding capacities which were 4.097 ± 0.537 g/g and 4.398 ± 0.04 g/g, respectively. In addition, it presented good foaming and emulsion properties. The antioxidant activity of this polymer was also studied and revealed that the polysaccharides showed interesting 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical-scavenging capacity ($IC_{50\ PPPW}$ = 11.578 mg/mL), reducing power and β-carotene bleaching inhibition activities, and also a strong ABTS radical scavenging activity ($IC_{50\ PPPW}$ = 2 mg/mL). Overall, the results suggest that the polysaccharide is a promising source of natural antioxidants and can be used as additive in food, pharmaceutical and cosmetic preparations.

1. Introduction

Potato is the main non-grain food commodity in the world. Its production ranges from 300 to 325 million tons/year (F.A.O., 2012) The problem of the management of potato peel waste (PPW) causes considerable concern to the potato industries in Europe, thus implying the need to identify an integrated, environmentally-friendly solution. While consumption of potatoes has decreased, processed products such as French fries, chips, and puree have experienced growing popularity. Potato peels are part of the production of crisps, instant potatoes and similar products. Potato peel is a zero value waste from potato processing plants. Losses caused by potato peeling range from 15% to 40%, the amount depending on the procedure applied, i.e. steam, abrasion or lye peeling (Scieber, Stintzing, & Carle, 2001). In fact, these peels are rich in substances with high added value (starch, proteins, phenolic compounds, polysaccharides).

The extraction of plant bioactive molecules is the major route of development of agricultural waste, thanks to technological advances in molecular separations and identifications (Wijngaard, Hossain, Rai, & Brunton, 2012). Some bioactive molecules derived from plant extracts (essential oils, polysaccharides, oligopeptides, fibers, ...) have already been used as additives in the formulation of food preparations (Sinha, Sharma, & Sharma, 2008). In addition to their emulsifying and stabilizing activities, some plant extracts have antioxidant and antimicrobial activities (Polya, 2003).

Polysaccharides with high degrees of polymerization are a heterogeneous group of carbohydrates, devoid of sweetness. They have diverse structures and compositions that affect their functional properties. They are constituted by glycosidic linkages between monosaccharides or the configuration α or β (Phillips & Williams, 2000). They have long been used to improve the texture, water retention and stabilization of emulsions and are increasingly

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incorporated into health foods due to their prebiotic effect and the presence of dietary fibers and mimetic fats (Warrand, 2006). These bioactive molecules have been reported to exhibit a variety of biological activities such as anti-tumor (Saima, Das, Sarkar, Sen, & Sur, 2000), immunostimulation (Tzianabos, Wang, & Kasper, 2003), anti-inflammation (Scheppach et al., 2004), anti-coagulation and anti-oxidation activities (Zhao, Kan, Li, & Chen, 2005).

In the present study, we report the extraction and the preliminary characterization of water-soluble polysaccharides from potato peels. The evaluation *in vitro* of the antioxidant activities of the extracted polysaccharides and their functional properties were also investigated.

2. Materials and methods

2.1. Reagents

Chemicals required for the assays including 1,1-diphenyl-2-picrylhydrazyl (DPPH), butylated hydroxyanisole (BHA), β-carotene and L-ascorbic acid were purchased from Sigma Chemical Co. (St. Louis, MO, USA). All other chemicals (potassium ferricyanide, trichloroacetic acid (TCA), ferric–chloride, sodium hydroxide, $FeCl_3$, and other solvents) were of analytical grade.

2.2. Materials

Potato peel waste (PPW) from Spunta variety, was obtained from a local market (Sfax, Tunisia). It was first washed in tap water then in distilled water to remove the adhered surface dust particles. It was finally dried at 50 °C in an oven for 48 h and ground in a mixer grinder (Moulinex). The average particle size of PPW was between 500 and 1000 μm. It was then stored at room temperature (25 ± 5 °C) until use.

2.3. Extraction of water-soluble polysaccharides

Polysaccharides of potato peels were extracted according to the protocol described by Ding, Zhu, and Gao (2012) with some modifications. Flour peels (20 g) were mixed with 500 ml of distilled water in a 1 L flask, and boiled under reflux with a heating mantle. After 4 h, the solution was filtered and recovered. The extraction was performed twice to ensure complete extraction of polysaccharides. The filtrates obtained were combined and concentrated 20-fold by means of a rotary evaporator maintained at 50 °C under vacuum. Recovery of the polysaccharides was performed by ethanol precipitation for one night at −20 °C, followed by centrifugation for 15 min at 5300×*g*. The next step was to re-solubilize the polysaccharides in distilled water. A dialysis step against double-distilled water was carried out for 3 days to remove inorganic salts, prior to freeze-drying for three days to obtain water-soluble polysaccharides.

2.4. Determination of chemical composition

Total nitrogen, lipid, moisture and ash contents of the potato peels polysaccharide were analyzed according to the American Association of Cereal Chemists 2000 standard methods 46-30, 30-10, 44-19 and 08-01, respectively (AACC, 2000). Crude protein was estimated by multiplying total nitrogen content by the factor 6.25. Total carbohydrates were determined by the phenol–sulphuric acid method (Dubois, Gilles, Hamilton, Rebers, & Smith, 1956). Total glycoalkaloids content was carried out using the method of Harborne (1973). All measurements were performed in duplicate.

2.5. Determination of water activity

The measurement of the water activity (AW) was conducted using the apparatus AW SPRINT TH-500 brand Novasina (Switzerland). The measurement consists in filling a plastic capsule with lyophilized polysaccharides followed by measuring the water activity at 25 °C. Reading the AW is done after stabilization of reading.

2.6. Color test

Color parameters were measured with a tristimulus colorimeter (model DP-400 with chroma meter model CR-400, Konica Minolta Sensing, Inc., Osaka, Japan). The color was expressed with L^* (100 = white, 0 = black), a^* (positive = redness, negative = greenness), and b^* (positive = yellowness, negative = blueness values. A standard white plate with reflectance values of $L^* = 93.68$, $a^* = -0.69$, $b^* = -0.88$, was used as reference. Color analyses were performed on samples treated three times using the same processing conditions and the mean values together with the standard deviations are reported.

2.7. Infra-red spectroscopic analysis

The absorption spectra of the samples were obtained using FTIR spectroscopy (Analect Instruments fx-6 160). The FTIR spectra of the materials prepared were recorded between 400 and 4000 cm^{-1} in a NICOET spectrometer. The absorption spectra of the samples were recorded using the KBr pallet containing 0.1% sample.

2.8. X-ray diffraction (XRD)

The X-ray diffractograms were acquired at room temperature (20 ± 1 °C) on an X-ray diffractometer (Bruker; Type: D8 ADVANCE; Germany; Type RX: Copper). The patterns were collected in the 2θ ranges of 5–60° with a step size of 0.02° and a speed of 1 s/step

2.9. Determination of the monosaccharide composition

The elemental monosaccharide composition (molar ratios) of the polysaccharide extracted from potato peels was determined using a modified method of Kamerling, Gerwig, Vliegenthart, and Clamp (1975). 50 μg myo-inositol, used as internal standard, was added to 500 μg lyophilized polysaccharide. The mixture was hydrolyzed for 4 h at 100 °C, in screw glass tube, using 500 μL methanolic HCl (3 N). After cooling to room temperature, all solutions were neutralized with 10 mg silver carbonate. The generated methyl glycosides were then converted to their corresponding volatile trimethylsilyl derivatives. The reaction took place by adding 100 μL pyridine and 100 μL derivatization reagent; Bis (trimethylsilyl) trifluoroacetamide (BSTFA) + 1% trimethylchlorosilane (TMCS) (Supelco), incubated for 25 min at 80 °C. After solvent evaporation under nitrogen flow, the generated per-O-trimethylsilylmethyl glycosides were resuspended in 500 μL dichloromethane, and analyzed by gas chromatography-flame ionization detector (GC-FID). An Agilent GC 6850A instrument equipped with HP-5MScapillary column (30 m length, 0.25 mm diameter and 0.25 μm film thickness) was used. The GC oven temperature was set to 120 °C, increased first to 180 °C at 3 °C/min, then increased to 200 °C at 2 °C/min and held for 5 min. The helium carrier gas flow was set at 1.5 mL/min and the injection volume was 0.1 μL.