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The physicochemical properties of fibrous residues from the agro industry

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ABSTRACT

The objectives of this work were to determine some of the physicochemical properties of four agro-industrial residues, namely malt bagasse, oat hulls, rice hulls and fibrous residue from banana pseudo-stems (FRBPS). Oat hulls contained the highest dietary fiber content (89.08 g/100 g), followed by malt bagasse (63.84 g/100 g), rice hulls (56.26 g/100 g) and FRBPS (47.99 g/100 g). The insoluble fiber in all residues formed the major fraction of the fiber contents, ranging from 43.79 (FRBPS) to 88.0 g/100 g (oat hulls). FRBPS exhibited the highest soluble fiber content (4.44 g/100 g), water (4.71 g/g) and oil-holding capacity (2.68 g/g). Only malt bagasse and FRBPS exhibited emulsifying capacity, which was 59.83 and 8.28 mL oil/g, respectively. As demonstrated by water sorption isotherms, rice hulls were less hygroscopic and FRBPS were more hygroscopic.

1. Introduction

Dietary fiber is a class of compounds that includes a mixture of plant carbohydrate polymers, both oligosaccharides and polysaccharides, e.g., cellulose, hemicelluloses, pectic substances, and gums that may be associated with lignin and other non-carbohydrate components (e.g., polyphenols, waxes, saponins, cutin, phytates, and resistant protein) (Elleuch et al., 2011).

Fibers extracted from some grains and seeds present physical and functional properties that make them useful for the food industry, which encourages researchers to search for novel raw materials that meet the needs of these areas, with a particular focus on food industry residues, such as malt bagasse, oat and rice hulls, or on residues from agriculture, such as the fibrous residue of banana pseudo-stems (FRBPS). These materials are used as bedding for animals and livestock feeding, burned in the fields, added into soil as green fertilizer, or used as soil conditioners or fertilizers, biofuels, thermoplastics, activated charcoal, and components of other composite materials. However, the potential of these agro-industrial residues as a source of food dietary fiber has not been fully examined (Kuan & Liong, 2008).

Brazil is the third largest beer producer in the world, with a production of 12.6 ML, trailing only China (40 ML) and the United States (35 ML) (Mardegan et al., 2013). According to Cordeiro, El-Aouar, and Araújo (2013), malt bagasse is a byproduct of beer brewing, and it is a component of the solid material produced from wort filtration before boiling. This solid byproduct primarily consists of the leftover peels and pulp of malt and grains and also some additives, such as rice, corn, and wheat. Crushed malt makes up 85% of the total product generated by the brewing industry and is thus considered to be the most important byproduct of this process.

Oat hulls are a poorly used byproduct of oat groat milling and are discarded during processing, making them an environmental pollutant. Oat hulls are approximately 90 g/100 g fiber, which is higher than that of wheat (47 g/100 g) or corn bran (62 g/100 g) (Galdeano & Grossmann, 2006), and they are an interesting raw material for use as a source of insoluble fiber.

Every year, billions of pounds of rice hulls are generated by rice-producing countries and most are thrown away as a waste byproduct. Rice hulls represent approximately 20% of the dry weight of the rice harvest (Dagnino, Chamorro, Romano, Felissia, & Area, 2013). Rice hulls consist in 36–40 g/100 g cellulose and 12–19 g/100 g hemicelluloses (Banerjee et al., 2009), and they also

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contain fats, gums, alkaloids, resins, essential oils and other cytoplasmic components (extractives), and with an ash composition of approximately 12 g/100 g, which are made primarily of silica (80–90 g/100 g) (Dagnino et al., 2013). Due to the high silica content present rice hulls have not yet been exploited in the food and feed industry, but the removal of silica can be an alternative to convert this residue in a suitable fiber-rich food ingredient (Nenadis, Kyriakoudi, & Tsimidou, 2013).

Brazil is the fifth largest banana producer in the world with a production of 7.3 million tons, which follows India, China, the Philippines and Ecuador (FAO, 2013). Fibrous residue from banana pseudo-stems (FRBPS) is pre-consumption waste that is generated during the production phase. According to Saraiva et al. (2012), the current destination of pre-consumption residues in South America is not well documented in the scientific literature; however, the pseudo-stems produced in China and India are normally cut and usually abandoned in the plantation to become organic waste and cause environmental pollution after harvesting banana bunches.

Thus, as part of an effort to determine the potential application for four agro-industrial residues (malt bagasse, oat hulls, rice hulls and fibrous residue from banana pseudo-stems), the objectives of this work were to determine some selected physicochemical properties of these residues.

2. Material and methods

2.1. Materials

Malt bagasse was kindly provided by Microcervejaria Fábrica 1 (Londrina, Paraná, Brazil). Oat and rice hulls were kindly supplied by SL-Alimentos (Mauá da Serra, PR, Brazil) and HT-Nutri (Camaquã, RS, Brazil), respectively. FRBPS from the Nanica cultivar (*Musa cavendishii*) was collected at the Technological Federal University of Paraná, and the pseudo-stems were manually defibrillated and dried at room conditions (at approximately 25 °C and 70% relative humidity). After the residues were obtained, all of them were dried (12–14 h) at 45 °C in air circulation oven (Marconi MA 415 – Piracicaba-Brazil) and milled (IKA-A 11 Basic Mill - Germany) to yield particles < 0.30 mm.

2.2. Chemical composition

The centesimal composition of the residues (proteins, lipids, moisture and ash) was determined by following Association of Official Analytical Chemists (AOAC) methods (2003), and the total carbohydrates were calculated by taking the difference. All determinations were run in triplicate.

The total dietary fiber and soluble and insoluble fractions were determined according to AACC methods (AACC method 32-07, 1990). Cellulose was determined by the Updegraff (1969) method, and the lignin content was determined by the Technical Association of the Pulp and Paper Industry (TAPPI T222 om-88) method (TAPPI, 1999). Because the insoluble dietary fiber (IDF) fraction in cereals is made of cellulose, hemicelluloses and lignin (Chawla & Patil, 2010), the hemicelluloses were calculated by taking the IDF minus cellulose plus lignin contents.

2.3. Fourier transform–Infrared spectroscopy (FT–IR)

The samples were dried and compressed into tablets with potassium bromide. The FT–IR analyses were performed with a Shimadzu FT–IR 8300 (Shimadzu, Japan), which has a spectral resolution of 4 cm^{-1} and a spectral range of 4000–500 cm^{-1}.

2.4. Scanning electron microscopy (SEM)

The dried samples were mounted on bronze stubs using double-sided tape, and their surfaces were coated with a thin gold layer (40–50 nm). The analyses were performed with an FEI Quanta 200 microscope (Oregon, USA) using an accelerating voltage of 30 kV.

2.5. X-ray diffraction

The samples were finely powdered (particles < 0.149 mm) and the analysis was performed by using a PANalytical X'Pert PRO MPD diffractometer (Almelo, The Netherlands) according to Matsuda, Vercelheze, Carvalho, Yamashita, and Mali (2013). The relative crystallinity index (CI) was calculated by Ruland method (1961) as follows: $CI = ((A_c)/(A_c + A_a))^*100$, where A_c is the crystalline area and A_a is the amorphous area.

2.6. Water-holding (WHC) and oil-holding capacity (OHC)

Both capacities were determined according to Chau, Cheung, and Wong (1997) with modifications. Each sample (2.00 g) was weighed and then stirred into 20 mL of distilled water or soybean oil for 30 min at 200 rpm in a shaker (Quimis Q 225M, Brazil). These fibrous suspensions were centrifuged (Centrifugal Boeco U-32, Germany) at 2200 × *g* for 30 min and the supernatant volumes were measured. The water-holding capacity was expressed as g of water held per g of sample, and the oil-holding capacity was expressed as g of oil held per g of fiber. All tests were conducted in triplicate.

2.7. Emulsifying capacity

The emulsifying capacity was determined according to Seibel and Beléia (2009). Each sample (1.00 g) was weighed, stirred into 50 mL of distilled water and homogenized for 30 s. Soybean oil was then added to the mixture at a rate of 10 mL/min and mixed at 300 rpm in a shaker (Quimis Q 225M, Brazil). The emulsifying capacity was calculated as the amount of oil emulsified by each gram of sample. All tests were conducted in triplicate.

2.8. Swelling

The swelling capacity was determined according to Robertson et al. (2000). One gram of each sample was mixed with 20 mL of distilled water in a 100 mL graduated cylinder. The suspension was intermittently stirred for 2 h and then allowed to stand for 18 h to achieve complete hydration and sedimentation equilibrium. The bulk volume was recorded and the swelling capacity was expressed as the volume occupied by the sample per gram of original sample dry weight. All tests were conducted in triplicate.

2.9. Moisture sorption isotherms

Samples of the residues (0.5 g) were dried for 15 d over anhydrous calcium chloride. The samples were then were placed over saturated salt solutions in separate desiccators, each with a specific level of relative humidity (RH) (11, 33, 43, 58, 75 and 90%) and held at 25 °C. Each sample was weighed at regular intervals, and when two equal consecutive measurements had been recorded, it was assumed that the equilibrium weight had been reached. The equilibrium moisture content was calculated as the mass increase of the dried sample at equilibration for each RH. The GAB (Guggenheim–Anderson–de Boer) model was used to fit the data from the sorption isotherms, and monolayer values were calculated