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Physicochemical properties of expanded extrudates from colored sorghum genotypes

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ABSTRACT

The diversity of sorghum grains is related to their intrinsic properties, which include starch type, non-starch components and phenolic compounds. The latter are genotype dependent and affect the pericarp characteristics such as color and presence of a pigmented testa. This diversity can be valuable for developing new food products by thermoplastic extrusion intended for human consumption. Flours from sorghum grains from the genotypes of varied pericarp color: white (CMSXS180; 9010032), red (BRS 310; BRS 308) and light brown (BRS 305; 9929034) were processed in a co-rotating twin-screw extruder. Changes promoted by extrusion cooking were evaluated via specific mechanical energy (SME), die pressure, apparent density, sectional expansion index (SEI), water absorption index (WAI) and water solubility index (WSI). Pericarp color affected die pressure, apparent density and WSI values of extrudates. Light brown genotypes, rich in tannin and fiber content, generated the lowest die pressure and SEI values. Red genotypes presented the lowest SME and the highest WAI values. White genotypes presented intermediate SME and the highest die pressure values. These results reflect differences in starch conversion induced by the pericarp type. These results further suggest the potential use of pigmented sorghum extrudates for human consumption.

1. Introduction

The production of sorghum in Brazil reached 1.93 million tons in 2011 (FAOSTAT, 2013). Despite the noticeable production of this grain, it is not included directly in the Brazilian diet, but is used for animal feeding. In Brazil, it is believed that sorghum is not consumed due to sensorial reasons (Vázquez-Araújo, Chambers Iv, & Cherdchu, 2012). Although, the consumption of whole sorghum flour would bring health benefits, because it contains bioactive compounds such as high fiber content and phenolic compounds (phenolic acids, flavonoids and condensed tannins) (Awika & Rooney, 2004; Dykes & Rooney, 2006).

In recent years, sorghum was studied for human consumption using mainly thermal process (Al-Rabadi, Torley, Williams, Bryden, & Gidley, 2011a,b; Mahasukhonthachat, Sopade, & Gidley, 2010; Meera, Bhashyam, & Ali, 2011; Méndez-Albores, Veles-Medina, Urbina-Álvarez, Martínez-Bustos, & Moreno-Martínez, 2009; Moraes et al., 2012; Wu, Huang, Qin, & Ren, 2012) compared to non-thermal processing (Mukisa et al., 2012). Extrusion cooking is a continuous process in one-step that combines shear forces, high pressure and high temperature in a short time (Berk, 2009). The food material is plasticized with water to achieve fluidity and continuously cooked while traversing through a cylindrical barrel (Berrios, Ascheri, & Losso, 2013). All granular material loses their native and organized structure to form a continuous viscoelastic mass. These order–disorder transitions result in size and shape modifications. Thus, simultaneously, starch granules and protein bodies are disrupted with fibrous material rearranged between them, which affect the functional properties of the extrudate (de Mesa-Stonestreet, Alavi, & Gwirtz, 2012; Lai & Kokini, 1991).

Most of the previous studies with regard to the sorghum extrusion were carried out with flours from decorticated grains of low-tannin genotypes and processed in single screw extruders (Anderson & Jones, 1999; Falcone & Phillips, 1988; Fapojuwo, Maga, & Jansen, 1987), whereas sorghum of low and high-tannin contents was also processed (Youssef et al., 1990), as well as sorghum with varied amylose and moisture content (Gomez, Waniska, Rooney, & Lusas, 1988).

The pericarp of sorghum grains differ in color, thickness, presence of a pigmented testa and affects the phenolic composition (Dykes, Seitz, Rooney, & Rooney, 2009). Phenolic compounds may be present in free

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or esterified/etherified soluble form as well as in insoluble form, bound to cell wall constituents such as carbohydrates, proteins and fibers (Arranz & Saura Calixto, 2010). This natural arrangement in sorghum genotypes could influence in melt crystalline polymers/glass transition amorphous polymers and consequently on the functional properties of extruded products.

The objective of this study was to compare the extrusion performance of six sorghum genotypes of differentiated pericarps and evaluate their physical chemical attributes.

2. Materials and methods

2.1. Sample preparation and characterization

Sorghum cultivars were supplied by Embrapa Maize and Sorghum (Sete Lagoas, MG, Brazil): CMSXS180 and 9010032 (white pericarp, without testa); BRS 310 and BRS 308 (red pericarp, without testa); BRS 305 and 9929034 (light brown pericarp, with testa). Whole grains of each genotype were manually cleaned to remove foreign particles, and then milled using a disc mill (DM) LM3600 (Perten Instruments AB, Huddinge, Sweden) set to aperture 2. The moisture content (MC) of each flour was determined by drying at 105 °C in a moisture balance MOC-120H (Shimadzu Corporation, Kyoto, Japan) and dried until attained a remaining moisture less than 0.05% (wet basis).

2.1.1. Particle size distribution

The particle size distribution measurement of the milled grains was carried out in a ROTAP sieve shaker RX-29-10 (W.S. Tyler, St. Albans, WV, USA) in duplicate. Seven screen sieve sizes (Newark, USA) were selected (1.68, 1.4, 1.18, 1, 0.71, 0.3 and 0.106 mm) and a pan, in order to obtain a normal distribution of particles from 100 g of sample sieved for 10 min.

2.1.2. Chemical composition analysis, neutral detergent fiber and phytates content

The whole sorghum grains were grounded using a DM followed by a hammer-mill (HM) LM3100 (Perten Instruments AB, Huddinge, Sweden) fitted with a 0.8 mm sieve aperture. The proximate composition, neutral detergent fiber and phytates content of milled samples were determined according to the official methods of analysis of AOAC (2005), in duplicate measurements: moisture content (Method 925.09), total nitrogen (Method 2001.11, a conversion factor of 5.75 was used to convert total nitrogen to protein content), fat content (Method 945.38), ash content (Method 923.03), neutral detergent fiber (Method 2002.04) and phytates content (Method 986.11).

2.1.3. Condensed tannins

Condensed tannins were determined via the modified vanillin assay as described by Burns (1971) and Deshpande and Cheryan (1985) with modifications. Milled samples were defatted with petroleum ether in a disperser device T25 basic Ultra-Turrax (Ika® Werke, Staufen, Germany) at 9500 rpm for 3 min. The extraction was performed using 1–6 g of defatted sample, according to genotype, with 15 mL of 10% HCl/methanol (v/v) in a vortex shaker (Genie 2 Scientific Industries, Bohemia, NY, USA) for 1 min and then in ultrasound water bath Branson 2210 (VWR Scientific, Bridgeport, NJ, USA) for 10 min. The mixture was kept at 4 °C for 8 h and then filtered. An aliquot of filtered extract was added to solutions of 4% vanillin and 10% HCl/methanol (blank). After 20 min of reaction, the resultant colors were read on a spectrophotometer UV-1800 (Shimadzu Corporation, Kyoto, Japan) at 500 nm. Condensed tannins were quantified using a calibration curve of catechin and results were expressed as milligram of catechin per gram of sample.

2.2. Extrusion conditions and responses

The extrusion was conducted using a Clextral Evolum HT25 co-rotating, intermeshing twin-screw extruder (Clextral Inc., Firminy, France) with screw diameter of 25 mm, length:diameter ratio of 40:1 and ten temperature zones. The screw speed (600 rpm), screw configuration and temperature profile were kept constant and are depicted in Fig. 1.

The front plate assembly (die) consisted of three parts: central manifold plate, distributor plate and holder-inserts plate (Fig. 1). Die pressure was measured with a pressure transducer fitted at the central manifold plate (Dynisco Instruments, Franklin, MA, USA). The holder-inserts plate had four holes, each of 3.8 mm in diameter and 14 mm in length.

Whole sorghum flours were fed into the feeding zone by a twin-screw, loss-in-weight gravimetric feeder model GRMD15 (Schenck Process, Darmstadt, Germany) at rate of 9 kg/h and were monitored by Schenck Process Easy Serve software (Schenck Process, Darmstadt, Germany). Distilled water was injected between the first and second modular zones through a port with 5.25 mm internal diameter using a plunger metering pump model J-X 8/1 (AILIPU Pump Co. Ltd., China) set to compensate moisture differences in the samples and provide a final 14% MC. The water flow of pump was calibrated prior to extrusion runs. Extrusion variables such as motor torque, die pressure, screw speed, water feed rate and temperature of the modules were recorded by a computer using the software FITSYS Plus (Clextral Inc., Firminy, France). Data was recorded after a minimum variation of torque and pressure at the die. The samples were collected over 15–20 min, placed in plastic trays and dried in a fan oven (60 °C for 4 h). After drying, they were sealed into plastic bags and stored at 7 °C pending further analysis.

Specific mechanical energy (SME, kJ/kg) was calculated according to Fan, Mitchell, and Blanshard (1996) using Eq. (1).

$$SME = (T \times 2\pi f \times n)/(S + W) \quad (1)$$

Where T is the screw torque in kJ (given in % by the software FITSYS Plus and converted to kJ multiplying to 0.1076, provided by the manufacturer), f is the screw rotation frequency in s^{-1}, n is the number of screws, S is the dry feed rate in kg/s and W is the liquid feed rate in kg/s.

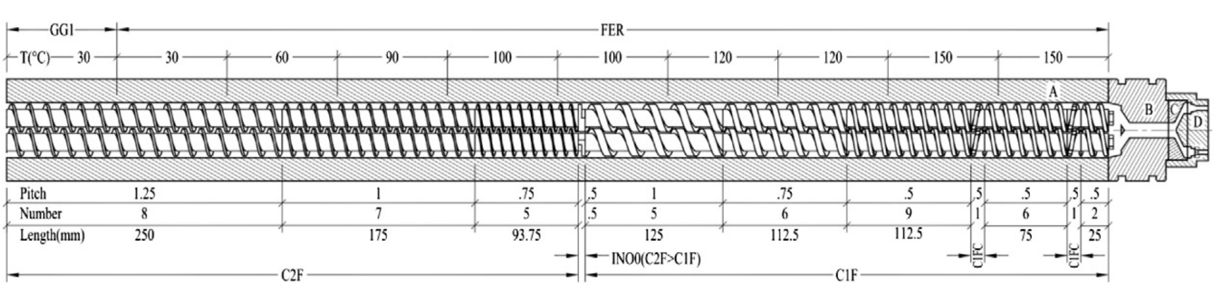

Fig. 1. Schematic representation of the top view (in mm) of the barrel, screws and front plate assembly (die) of the Clextral Evolum HT25 extruder: A, the barrel; B, the central manifold plate; C, the distributor plate; D, the holder-inserts plate; E, the insert hole; T, module temperature; GG1, feeding module; FER, closed modules; C1F/C2F, conveyor screw of single/double pitch; INO0, interface screw for transition between screws of single and double pitch; and C1FC, reverse screw of single pitch, slotted.