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Physical quality of snacks and technological properties of pre-gelatinized flours formulated with cassava starch and dehydrated cassava bagasse as a function of extrusion variables

Fernanda Assumpção Fiorda [a], Manoel Soares Soares Jr. [a], Flávio Alves da Silva [a], Camila Melo Araújo de Moura [a], Maria Victoria Eiras Grossmann [b, *]

[a] Escola de Agronomia e Engenharia de Alimentos, Universidade Federal de Goiás, Campus Samambaia, Rod. Goiânia/ Nova Veneza, KM 0, CP 131, Goiânia, CEP 74690-900, GO, Brazil
[b] Departamento de Ciência e Tecnologia de Alimentos, Universidade Estadual de Londrina, Rod. Celso Garcia, KM 380, CP 6001, Londrina, CEP86055-900, PR, Brazil

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ABSTRACT

In cassava industrialization, starch is produced, but residues are generated, including bagasse, which has high moisture content and is generally not availed, creating a serious environmental problem. The objective of this work was to study the effects of moisture (12–20 g 100 g^{-1}) and extrusion temperature (61.7–118.3 °C) on the expansion and color of snacks, and on functional properties of pre-gelatinized flours formulated with cassava starch and dehydrated cassava bagasse (70:30), to verify the possibility of extending the application of this co-product. Response surface methodology and analysis of variance were applied. The moisture of the mixture and the extrusion temperature significantly affected physical properties of snacks and functional properties of pre-gelatinized flours. Snacks lighter and yellowish with larger expansion index and intermediate specific volume were obtained at the extrusion temperature of 104.1 °C and moisture of 16 g 100 g^{-1}. Pre-gelatinized flour with high absorption rates, solubility in water and oil absorption were obtained at extrusion temperatures of 90 °C and moisture of 16 g 100 g^{-1}. It is viable to use the dehydrated cassava bagasse and cassava starch (30:70) in the production of snacks and pre-gelatinized flours.

1. Introduction

Cassava starch (*Manihot esculenta* Crantz) producers generate large amounts of residues that are harmful to the environment, mainly the peel, wastewater and cassava bagasse. Cassava bagasse is the main solid residue produced by cassava starch industry and it is thrown into water courses or left in ditches which over flows and carry much of the organic load towards them. The high moisture content, around 85 g 100 g^{-1}, impairs the use of cassava bagasse by the starch industry, because there is a strong possibility of microbial contamination of the product, causing undesirable fermentation. In this sense, for the effective utilization of cassava bagasse, drying simultaneously to production is essential. However, for the drying process becomes economically interesting for entrepreneurs, alternatives for using this product are necessary, including its destination for human consumption.

Numerous studies using industrial residue from food processing have been conducted in order to develop new products. Thus, it minimizes the environmental impact of these types of industries in the regions where they are located and add value to residues. Studies have been performed to develop technologies for using dehydrated cassava bagasse (CB) as a fiber enriching ingredient in various food products such as breads, cakes, cookies and pasta (Fiorda, Soares, Silva, Grossmann, & Souto, 2013a, b, c; Shittu, Dixon, Awonorin, Sanni, & Maziya-Dixon, 2008). Another possible application for CB is its mixture with cassava starch (CS) for production of snacks and pre-gelatinized flours (PGFs), applying the extrusion technology.

The thermoplastic extrusion is a continuous process in which the raw material is forced through a die or mold, under heating conditions, pressure and molecular friction. Such conditions lead to gelatinization of starch, denaturation of proteins and rupture of

* Corresponding author. Tel.: +55 43 33714080.
E-mail address: victoria@uel.br (M.V.E. Grossmann).

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hydrogen bonds, causing cooking, mixing, sterilization, drying, restructuring of the raw material and creating new textures and shapes.

The physical quality of the extruded snacks is dependent on the raw materials used in its formulation (composition, particle size, moisture), as well as on the processing variables (temperature, pressure, screw speed) and all the equipment variables, such as the mechanical conformation, screw configuration, type and dimensions of the die (Day & Swanson, 2013). On the other hand, the extrusion conditions may cause hydrolysis or gelatinization of the starch molecule, which can modify its ability to interact with water molecules, interfering with its hydration capacity and water solubility. These are important defining parameters for applications of pre-gelatinized flour as an ingredient (Altan, Mcarthy, & Maskan, 2009). The extrusion-cooking has been applied to raw materials with different compositions (Alonso, Orúe, Zabalza, Grant, & Marzo, 2000; De Pilli, Carbone, Derossi, Fiore, Severini, 2008; De Pilli, Derossi, Talja, Jouppila, Severini, 2011; De Pilli, Giuliani, Carbone, Derossi, & Severini, 2005; De Pilli, Jouppila, et al., 2008, 2012; Ding, Ainsworth, Tucker, & Marson, 2005; Dust et al., 2004) becoming an interesting process for the alternative application of dehydrated cassava bagasse.

The objective of this work was to study the effects of moisture and extrusion temperature on the expansion and color of snacks, and on the technological properties of PGFs formulated with CS and CB (70:30), to verify the possibility of extending the application of this co-product.

2. Material and methods

2.1. Material

Cassava starch (CS) and cassava bagasse (CB) samples were donated by Fecularia Bela Vista Ltda., located in Bela Vista de Goiás, Goiás, Brazil. CB was collected at the entrance of the storage silo, dried in an oven with air circulation at 55 °C for 24 h, and ground in a mill rotor equipped with a 30-mesh sieve.

2.2. Extrusion

In the extrusion experiment it was used a crude mixture (CM) of SC and CB (70:30), obtained in a Y-type homogenizer mixer (Tecnal, TE 201/05, Piracicaba, Brazil) for 15 min. The mixture was stored in nylon bags in different moisture levels, according to the values set in the experimental design, and kept under refrigeration, 24 h before use.

The thermoplastic extrusion was performed on equipment with single screw (Inbramaq, PQ-30, Ribeirão Preto, Brazil). The fixed processing parameters were: screw speed of 250 rpm (60 Hz), circular die opening of 4 mm diameter, pre-die with 22 holes, screw of 300 mm length with compression ratio of 3:1, helical barrel design, feed rate of 350 g min^{-1}; and temperature in the first and second heating zones of 50 °C and 57 °C, respectively. The heating system is done by electrical resistors independents for each zone and the cooling is done with cold water. The temperature control involves a programming system and thermocouples; when the temperature increases above the programmed value, a solenoid valve is open, and begins pumping cold water until the temperature decrease, then closing. The variables processing parameters were the temperature of the third heating zone (61.7–118.3 °C) and the moisture of the material (12–20 g 100 g^{-1}). After extrusion, the snacks were dried at 100 °C for 15 min in an oven with air circulation, to reduce the moisture content to values around 3%. The snacks were stored in nylon bags.

2.3. Analysis

2.3.1. Chemical compositions

The mixtures were evaluated with respect to their moisture, ash and dietary fiber (total, soluble and insoluble) contents using methods 925.09, 923.03 and 985.29, respectively, (AOAC, 1997); for protein using method 960.52 (AOAC, 1990) and lipids by method 920.39C (AACC, 2000).

2.3.2. Structural analysis

The volume of snacks was evaluated after extrusion and before drying process, by displacement of millet seeds, with 16 replicates per experimental unit. The mass was evaluated in semi-analytical scale. The specific volume (SV) was calculated by the ratio between the average volume and mass of snacks. The expansion index (EI) was determined by the ratio between the diameter of the extrudate and the diameter of the output hole of the extruder (4 mm). A digital caliper was used for measuring the diameter of the extrudate, and the arithmetic mean was calculated from 10 randomly chosen snacks per experiment.

2.3.3. Instrumental color parameters

The snacks also were evaluated for instrumental parameters of color, according to the Cielab system obtaining the values L* (luminosity), a* (red-green component) and b* (yellow-blue component) in colorimeter (Color Quest, XE, Reston, EUA). Observation angle of 10° and standard illuminant D65 were fixed, corresponding to natural daylight. The color difference (ΔE*) between the CM and PGF was also obtained (Eq. (1)). Analyses were performed in triplicate.

$$\Delta E^* = \left(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}\right)^{1/2} \quad (1)$$

where, $\Delta L^* = L_o$ (CM luminosity) − L_e (PGF luminosity); $\Delta a^* = a_o$ (CM a* value) − a_e (PGF a* value); $\Delta b^* = b_o$ (CM b* value) − b_e (PGF b* value).

2.3.4. Water absorption index (WAI), water solubility index (WSI) and oil absorption index (OAI)

The PGF and CM were evaluated as for water absorption index (WAI) and water solubility index (WSI) according to the method of Anderson, Conway, Pfeifer, and Griffin (1969). About 2.5 g (db) of the ground extrudate was suspended in 30 mL of water at room temperature for 30 min gently stirred during this period, and then centrifuged at 3000 × g for 15 min. The supernatant was decanted into an evaporating dish of known weight. The WSI is the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample. The WAI is the weight of gel obtained after removal of the supernatant per unit weight of original dry solids.

For the determination of oil absorption index (OAI) the same WAI methodology adapted was used, but the water was replaced by soya oil. All analyses were performed in triplicate.

2.3.5. Scanning electron microscopy

Micrographs of CM and fractured PGF samples (center point) with magnification of ×1600 were performed in a scanning electron microscope (FEI Quanta-200, Hillsboro, USA). The samples were completely dried at 105 °C for 24 h, remaining in a desiccator until the time of its preparation. The time of deposition of gold in the samples was 98 s, representing 15 nm layer of material.