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Physical characteristics of extrudates from corn flour and dehulled carioca bean flour blend

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ABSTRACT

Extruded products were prepared from a corn flour and dehulled carioca bean (*Phaseolus vulgaris*, L.) flour blend using a single-screw extruder. A central composite rotate design was used to evaluate the effects of extrusion process variables: screw speed (318.9–392.9 rpm), feed moisture (10.9–21.0 g/100 g) and bean flour level (4.8–55.2 g/100 g) on the specific mechanical energy (SME), sectional expansion index (SEI), longitudinal expansion index (LEI), volumetric expansion index (VEI) and density (*D*) of the extrudates. The instrumental texture was also analyzed. The independent variables had significant effects on the physical properties (SEI, VEI and density) of extrudates, with the exception of SME and LEI. SEI increased with increasing screw speed, but a higher moisture and bean flour content resulted in decreasing SEI and VEI. The increase of moisture and bean flour increased the density of extrudates. According to texture analysis, some treatments with 30 and 45 g/100 g bean flour did not show significant differences when compared to commercial brand snacks. However, when combined with higher moisture content (≥19 g/100 g) and lower screw speed (≤333 rpm), the results of the expanded product were not satisfactory.

1. Introduction

Aside from soybean (*Glycine max*), dry edible beans, or common beans (*Phaseolus vulgaris*, L. of the Fabaceae family), are the legume with the highest economic value in the world. Dry beans contain, on a 100 kcal basis, 80% less total fat than lean ground beef, and they are low in sodium, cholesterol free and high in protein and soluble fiber content (Berrios, 2006). In addition to these nutritional benefits, beans are also gluten-free, so products made from bean flours provide alternatives to wheat flour based products (Siddiq, Kelkar, Harte, Dolan, & Nyombaire, 2013). Additionally, they are a main source of protein for low-income populations (Nyombaire, Siddiq, & Dolan, 2011). Beans are usually purchased dry and raw; preparation is time consuming, which makes them less competitive than semi-ready or ready products (Gomes, Silva, Costa, & Pirozi, 2006).

Currently, the yearly consumption of beans in Brazil is approximately 3.5 million tons (CONAB, 2010). Carioca beans occupy more than 85% of the national market, while black beans corresponds to 10% of sales. Moreover, the carioca bean is cheaper and is emerging in biofortification food programs in the context of conventional crossing of cultivars with high levels of iron and zinc. This cultivar's resistance to drought is a positive factor for productivity, especially in the Northeast area of Brazil.

Snack foods have become a significant part of the diet of many individuals, particularly children, and can influence overall nutrition (Meng, Threinen, Hansen, & Driedger, 2010). The most widely consumed extruded snacks are made primarily with cereals/grains due to their good expansion characteristics; however, they tend to be low in protein and many other nutrients. As a result, demand from consumers for more nutritious snacks has been increasing (Giménez et al., 2012).

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Corn flour is widely used to elaborate expanded extrudates. However, as with other cereals, corn flour's nutritional value does not satisfy the needs of health-conscious consumers (Rampersad, Badrie, & Comissiong, 2003). It is well known that the addition of legumes to cereals produces an increase in both the amount and the quality of the protein mix (Anton, Fulcher, & Artnfield, 2009; Chillo et al., 2010; Pérez et al., 2008). Extruded legumes have been reported to have good expansion and are regarded as highly feasible for the development of value-added high nutrition, low calorie snacks (Berrios, 2006; Berrios, Camara, Torija, & Alonso, 2002; Berrios, Morales, Camara, & Sanchez-Mata, 2010; Berrios, Wood, Whitehand, & Pan, 2004).

The main objectives of this study were as follows: (a) to optimize extrusion processing conditions for production of extruded snacks from corn flour and carioca bean flour; (b) to determine the effect of extrusion variables such as screw speed, feed moisture content and bean content on physical properties of the extrudates; and (c) to evaluate the texture properties of the products on select extrudates.

2. Material and methods

2.1. Material

Corn flour (degermed) was obtained from the local market (Rio de Janeiro, RJ, Brazil). Carioca beans (*P. vulgaris*, L. (BRS Pontal)) were provided by Embrapa Rice and Bean (Goiânia, GO, Brazil).

The carioca beans were dehulled in order to promote the expansion of the snack. First, the bean grains were submersed in warm water (four times their weight) at 40 °C for 4 h. They were then dried in a forced-air drier (model Fabbe-Primar, Sao Paulo, SP, Brazil) at 100 °C for 1 h. The hulls were separated from the seeds by passing them through two rotating stone discs, followed by sieving. The dehulled seeds were milled into flour on a disc mill in order to obtain most particles between 853 and 1200 μm in size, similar to those of corn flour (Perten, Laboratory Mill 3600, Hägersten, Sweden).

2.2. Proximate composition and particle size distribution

The proximate composition of each raw material was determined according to AOAC (2000) standards: moisture (method 930.15), protein (method 990.03), fat (method 920.39), ash (method 942.05) and crude fiber (method 962.09). Carbohydrates were calculated by difference (100−moisture + protein + fat + ash + crude fiber). Calories were calculated with the following formula: (carbohydrates × 4 kcal) + (protein × 4 kcal) + (fat × 9 kcal). The particle size distribution of each raw material was determined by sifting 100 g of flour per 10 min through a plan sifter equipped with seven sieves with different opening sizes (1200, 1000, 853, 710, 422, 354 and 297 μm), according to ASAE Standards method S319.2 (1995).

2.3. Blend preparation

The two raw materials were mixed in proportions established by the experimental design. Bean flour was mixed with corn flour in proportions of 4.8–55.2 g/100 g. The appropriate amount of water was added to adjust the flour moisture content of the blend to the required level of 10.9–21 g/100 g. Then, the moisture of the blend was equilibrated overnight under refrigerated conditions to guarantee homogeneity and dispersion of the water throughout the dough before extrusion.

2.4. Extrusion processing

Extrusion was performed on an Inbra RX50 single screw extruder (Ribeirão Preto, São Paulo, Brazil) equipped with a circular die of 3.0 mm. The corn/bean flour blend was fed into the extruder operating at a screw speed of 318–393 rpm. A production rate of 50 kg/hr and die cutting knife rotation of 33 rpm were used as constant extrusion parameters. The extrudates were collected 5 min after the process was stable. The extrudates were immediately dried at 52 °C overnight in a forced-air drier. The final dried samples, containing approximately 5 g/100 g (wb) moisture, were stored in polyethylene bags at room temperature for further analysis.

2.5. Physical extrusion properties

Specific mechanical energy (SME) was calculated following the methodology described by Mesa et al. (2009) using the following equation:

$$\mathrm{SME} = \frac{\frac{\tau-\tau 0}{100} \times P_{\mathrm{rated}} \times \frac{N}{N_{\mathrm{rated}}}}{m} \tag{1}$$

Eqn. (1). Specific mechanical energy.

where τ is the measured torque, $\tau 0$is the no-load torque (assumed to be 0%), P_{rated} is the rated power for the extruder (7.5 kJ/s), N is the measured extruder screw speed in rpm, N_{rated} is the rated extruder screw speed and m is the mass flow rate.

The sectional expansion index (SEI), longitudinal expansion index (LEI) and volumetric expansion index (VEI) were determined using the proposed methodology of Alvarez-Martinez, Kondury, and Harper (1988). Triplicate measurements were made on 10 randomly chosen pieces of extrudates from each run to calculate these indexes. For each test, the diameter of the extrudates was measured with a vernier caliper.

Density (ρ_e) was evaluated using the method described by Fan, Mitchell, and Blanshard (1996). Equations for the calculation of the different expansion indices and density are presented below:

$$\mathrm{SEI} = \left[\frac{D}{D_o}\right]^2 \tag{2}$$

Eqn. (2). Sectional expansion index (SEI).

$$\mathrm{LEI} = \left[\frac{\rho_d}{\rho_e}\right]\left[\frac{1}{\mathrm{SEI}}\right]\left[\frac{1-M_d}{1-M_e}\right] \tag{3}$$

Eqn. (3). Longitudinal expansion index (LEI).

$$\mathrm{VEI} = \mathrm{SEI}{*}\mathrm{LEI} \tag{4}$$

Eqn. (4). Volumetric expansion index (VEI).

$$\mathrm{Density}(\rho_e) = \frac{4m}{\pi D^2 L} \tag{5}$$

Eqn. (5). Density (ρ_e).

where m is the mass of a length L of extrudates with diameter D after cooling and D_o is the diameter of the die. Bulk density of the dough (ρ_d) behind the die was considered to be 1400 kg m^{-3} and ρ_e is the density of the extrudates. The moisture content (M_e, wb) of the extrudates and the moisture content of the dough inside the extruder (M_d, wb) were measured by drying 2–3 g samples in a forced-air drier at 105 °C until constant weight was reached. An average of three measurements was used in all calculations.

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