EXTRUDABILITY OF CASSAVA FLOUR, WATER AND BY-PRODUCTS OF RENEWABLE FUELS INDUSTRY TO PRODUCE BIOPLASTIC

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Abstract: This work describes the evaluation of operating parameters of cassava flour extrusion with different concentrations of micronized castor cake and sunflower cake powder, water and glycerol. Based on screw dimensions and speed, the nominal shear rate was estimated to vary from 492.1 to 2,416.6 s-1. The shear rate and screw speed change did not influence the functional properties of extrudates but have directly correlation between outer pressure and production. The experimental data showed that the extrusion cassava flour outflow rate increased with the addition both micronized castor bean and sunflower cakes, therefore the production of biomaterials can be optimized with the addition of reinforcing biomaterials from the renewable fuel industry.

Keywords: Extrusion, byproducts, biodegradable composites

INTRODUCTION

As environmental consciousness increases due to pollution caused mainly by non biodegradable polymers, it has been observed a considerable increase of studies dealing with the use of material with fast biological degradation. The biodegradable packing from renewed resources, such us proteins and carbohydrates seems to be an alternative to petroleum based polymer, although its high water affinity and low mechanical resistance need considerable improvement.

There is a global concern in searching packaging materials which properly protect food products and causes little impact in the environment. Among raw materials starchy flours (cereals, tubers and roots sources), plasticizers (glycerol and water) and fiber/protein rich by-products from renewable fuels industry present great potential to replace petroleum based packing materials. Cassava is a root found in tropical regions. In order to be stored it usually is processed into starch and flour otherwise it perishes quickly. For cassava flour, some fibers and proteins are kept in the final product, when compared to the starch form.

Extrusion technology has been widely used to produce a large variety of starch bio-plastics. This process combines heat, shearing and pressure to convert granular starch and to denature protein, it involves the formation of complexes among starch, lipids and proteins (Camire et al., 1990).

Considering the importance of varying the composition (reinforce material content) in order to improve the extruder´s capacity and the commercial value of extruded bioplastics, this work studies the extrudability (outer pressure and flow production) of cassava flour with different concentration of micronized castor bean cake and sunflower cake powder (0, 0.5, 1, 2, 2.5, 5 and 10%) at 28% water content and 8% glycerol.

MATERIALS AND METHODS

Materials

Cassava flour was donated by Embrapa Genetic Resources and Biotechnology (Brazil) and was used as starch source. The chemical composition of the cassava flour was 88.75% carbohydrates, 0.9% proteins, 0.56% fat, 3.48% ash, and 6.31% moisture.

The micronized castor bean cake and sunflower cake was supplied by Embrapa Agroenergy, Brazil. Both materials were finely ground in a planetary ball mill Fritsch (Idar-Oberstein, Germany) for 60 minutes to produce micronized powder of average particle size of 20 µm. The chemical composition of the micronized castor bean cake was 44.76% carbohydrates, 36.18% proteins, 2.75% fat, 9.77% ash, and 6.54% moisture.

Preparation of extruded bioplastics

The sample of cassava flour with different concentration of micronized castor cake and sunflower cake powder was equilibrated to 28% of moisture and 8% of glycerol.

Moisture content of samples was calculated in terms of the initial moisture of the mixture. Each sample, 2g, was weighted in an infrared balance (MOC 120H, Shimadzu, Japan) and dried at 105° C until constant weight (Instituto Adolfo Lutz, 1985). The amount of water to be added was calculated according to Equation 1:

$$Y = \left[\frac{(Xf - Xi).W}{100 - Xf}\right] \quad (1)$$

Where:

Y = amount of water to be added (ml)

X_f = final moisture content of the sample (%)

X_i = initial moisture of the sample (%)

W = weight of sample (g)

After adjusting moisture, the samples were homogenized manually, and then stored in plastic bags for for 24 h at approximately 18°C to allow the uniform distribution of water. Only after this conditioning period, each batch (500g) was submitted to the extrusion process.

Extrusion

Cassava flour added with different contents of castor bean cake and sunflower cake (from 0, 0.5, 1, 2, 2.5, 5 and 10%) and glycerol (8%) was submitted to a Brabender DSE 20 (Duisburg, Germany) single screw extruder (Figure 1). The process was kept at the same operational parameters: temperatures at the 1st, 2nd and 3rd heating zone (50º, 80º and 100ºC respectively), screw compression ratio (3:1), inner flat die of 1 mm and rotational speed of screw (180 rpm).

At the outlet, close to the die, a pressure transducer was fitted in order to register the static pressure (Figure 2).

The extrudates were collected after 3 minutes or until low torque fluctuation was observed (less than 5%) and then one sample was collected each 30 s completing three replicates.

Figure 1. Photography of the single screw extruder.

Extrudability

This variable is defined as the result of the interaction between different components of the mixture added into the extruder cylinder. It is transformed into a new product flowing and changing in accordance with established different variables in a given extruder (temperature, screw configuration, die size and format, melt viscosity, etc). The pressure and flow production were determined in triplicate to characterize each treatment as described by Ortiz (2009).

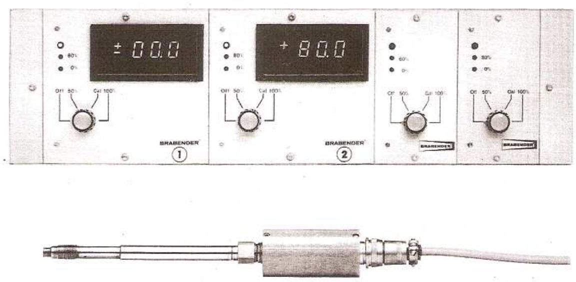

Figure 2. Calibration section of pressure measuring and pressure transducer of 2.75 MPa.

Afterwards, the flow production of each sample was calculated from triplicates to characterize their extruded production in kg/h.

RESULTS AND DISCUSSIONS

In accordance with the concept of equivalent energy (ZHENG e WANG, 1994), heat and shear are responsible for the molecular transformation of the raw material during extrusion. The shearing causes disruption of the starch structure reducing it to granules smaller than 5 μm (ZHENG et al., 1995).

Frahia et al. (1997) observed that the static pressure is influenced by the interaction between die configuration, mass temperature and shear rate and can be manipulated by die configuration changes.

Figures 3 and Figure 4 show the effect of the castor cake and sunflower cake addition on pressure. By increasing either sunflower or castor bean cake content lead to a reduction of pressure and a stable flow output.
The addition of castor bean cake content decreased the top pressure of 5500 kPa down to 4800 kPa, indicating a considerable reduction in shear strength.

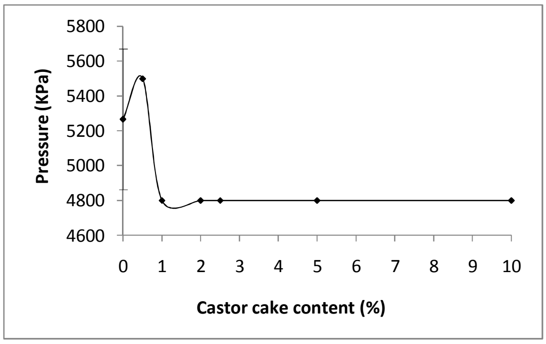

Figure 3. Relationship between pressure and castor bean cake content.

Similarly, Figure 4 shows that by increasing sunflower cake content, the pressure also dropped however of lower magnitude when compared to castor bean cake addition.

In terms of production, Figure 5 and Figure 6 demonstrate that the increase of both cakes conducted to slight variation of flow production during the extrusion demonstrating that starch matrix (cassava flour) prevailed as the main component which influences this variable.

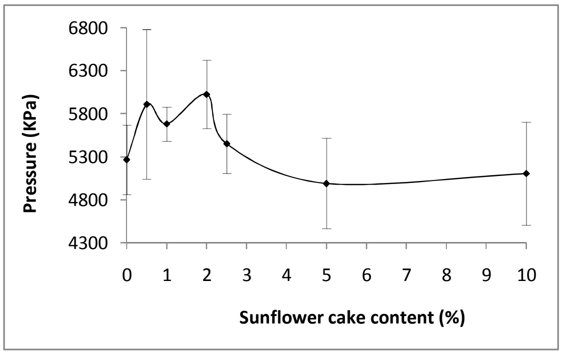

Figure 4. Die pressure output of extrusion processing of cassava flour added of sunflower cake.

Comparing the flow productions, castor bean cake presented a higher value compared to sunflower cake, consequently showed the highest extrudability process.

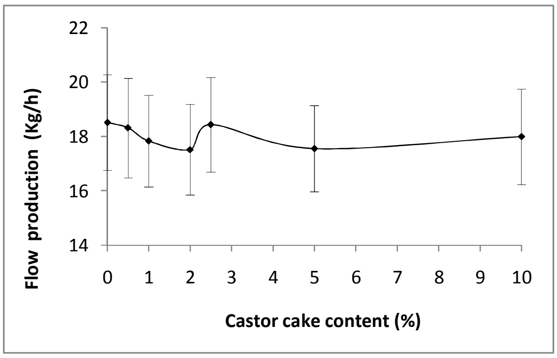

Figure 5. Mass flow rate of cassava flour added of micronized castor bean cake .

Sunflower cake (Figure 6) shows greater standard deviation of flow production than castor cake that leads to a reduction of 10X in their yield production.

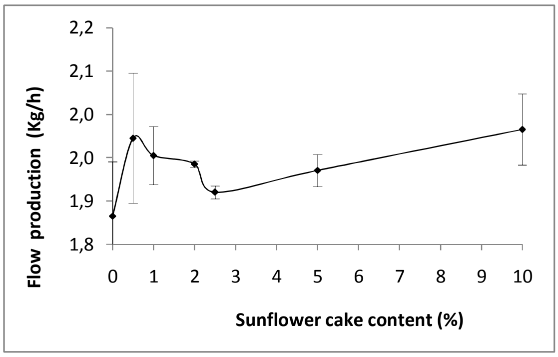

Figure 6. Relation between sunflower cake content and flow production.

CONCLUSIONS

The degree of production was found as a result of shear and compression rates during extrusion process. The shear rate and screw speed changes did not influence the functional properties at the same water content of extrudates but have directly correlation between outer pressure and flow production. Sunflower cake presented a reduction of tenfold in their yield production if compared to castor cake. The experimental data showed that the extruded bio-plastics elaborated with both castor and sunflower cakes presented higher production than cassava flour only. The production of biodegradable packing from renewed resources constitutes an alternative to produce continuously polymer matrices for bioplastic industry.

NOMENCLATURE

Y amount of water to be added

X_f final moisture content of the sample

X_i initial moisture of the sample

W weight of sample

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