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BEHAVIOR OF FLOW IN STEADY STATE OF MIXING RICE AND BREWER'S SPENT GRAIN FLOUR EXTRUDED

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1 Introduction

Extrusion process can be used to produce foods that are nutritionally fortified. The use of a co-product from beer industries (brewer's spent grain – BSG), in combination with rice flour, can provide not only a useful alternative to highly nutritious food (Hagenimana et al. 2007), but may also contribute to decrease environmental impact, reducing waste products with high nutritional value and adding value to them.

The rheological properties of extruded blend water/milk dispersions, which influence the process of porridge making, are of great importance for several reasons such as sensory evaluation, quality control, new product development and process optimization. Numerous studies have been conducted on the rheological properties of dispersions of various foods evaluating the behavior of the flow of suspensions and suitability of rheological model (Baby Latha et al., 2002). However, very few studies have been conducted to investigate thoroughly on dynamic rheological properties of extruded product pastes (Wu et al., 2008).

The aim this study was at investigating the rheological properties of extruded dispersions (rice flour/brewers spent grain) in terms of a steady state flow behavior.

2 Materials

A co-product of beer industry (BSG) was produced locally in Rio de Janeiro by the microbrewery Imperial Premium Bier Ltda (Petrópolis, RJ, Brazil). Broken rice was donated by the rice processing company Josapar (Pelotas, RS, Brazil).

3 Methods

The rheological properties of dispersions extruded (rice flour/BSG) were investigated using oscillatory rheometer according to the methodology described by Wu et al. (2008).

The effects of BSG concentration (0%, 15%, 30%) and temperature (100, 130, 160ºC) on the dispersion viscosity were investigated according to a factorial design 2^2 with two central points.

All rheological measurements were performed in triplicate and the Ostwald-de-Waele model was used to model the data, by using the software provided by the manufacturer of the oscillatory rheometer Mars (Thermo Haake, Karlsruhe, Germany). Rheological tests were conducted at a shear rate range of 0 to 50 s^{-1}, with acquisition time of 3 min. The geometry used was parallel plate-plate PP35Ti. All analyzes were conducted at 25ºC. About 1 g of sample was mixed with water (1:10) to forma a paste, left to equilibrate for 10 min prior to the analysis.

4 Results and Discussion

Table 1 presents the design matrix, along with the experimental results of the rheological parameters (κ and *n*) obtained from the software.

Table 1. Design matrix and rheological parameters of Ostwald-de Waele Model

Sample	Temperature (°C)	% BSG	k (O-W)	*n* (O-W)
T1	100	0	6.42	0.6039
T2	160	0	26.56	0.4586
T3	100	30	53.16	0.0494
T4	160	30	72.62	0.2189
PC1	130	15	42.67	0.3308
PC2	130	15	49.26	0.3145

Figure 1 shows the viscosity curves for all formulations proposed herein, where the pseudoplastic behavior is clear. Among the existing mathematical models, one of the most frequently applied to food systems, particularly for starch mixtures, is the Ostwald-de-Waelle (Power Law), that was used to fit the data presented at Figure 1. The parameters were estimated by the software from the rheometer.

This pseudoplastic behavior observed suggests that all starch granules were sufficiently damaged due to the combination of shear and heating caused by the extrusion process, which can be deformed under applied shear force (Hagenimana et al. 2007).

The effect of temperature and BSG on the viscosity at shear rate of 20 s^{-1}, decreasing curve, and at 50 s^{-1}, the end of the curve, can be seen in the Pareto chart, Figures 2a and 2b, respectively. It is noticed that, for the ranges chosen herein, only BSG content was important at 20 s^{-1}, considering 5% of significance level. Temperature and the interaction effect were marginally significant ($0.05 < p$). The curvature was not important, which means that for this range of BSG content, the viscosity did not have a maximum value.

For shear rate of 50 s^{-1}, no factor was statistically significant, which could be explained by the structure rupture of the pastes at higher shearing.

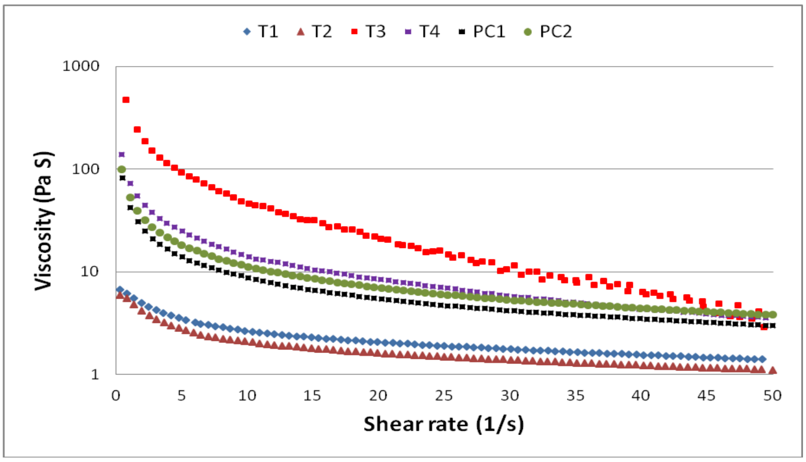
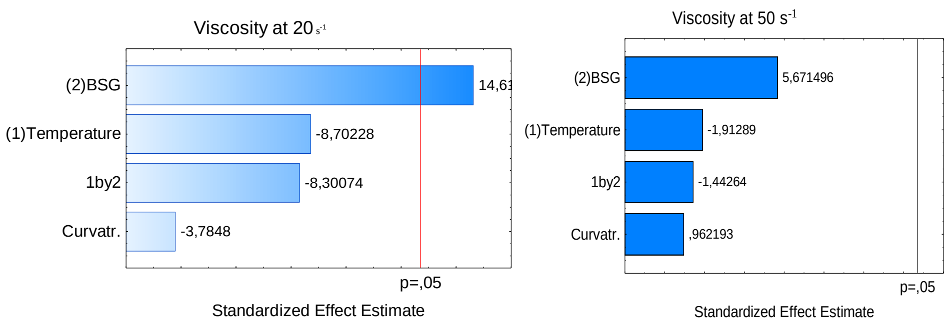


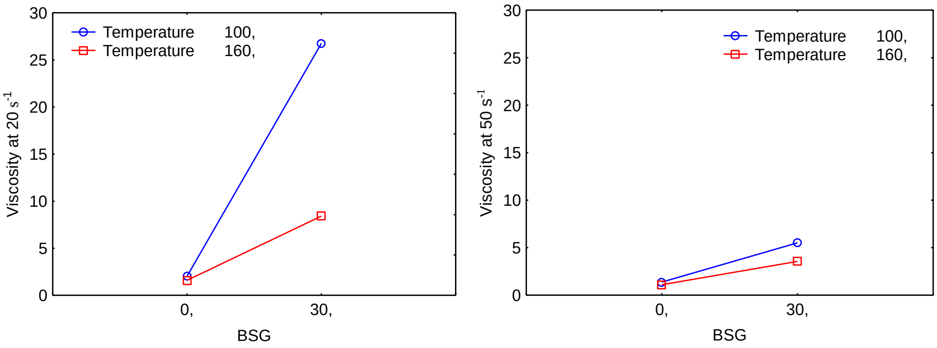
Figure 1. Steady-shear viscosity as a function of shear rate for different BSG contents.



(a) (b)

Figure 2. Pareto chart of steady-shear viscosity at shear rates of 20 s^{-1} (a) and 50 s^{-1} (b).

The effect of processing temperature on the rheological properties at shear rates of 20 and 50 s^{-1} of the pastes in displayed in Figure 3. The addition of BSG increased the paste viscosity for both processing temperature conditions, however it was greater at low temperature (100 °C). By increasing the process temperature, a decrease of viscosity value was clearly observed. This decrease of viscosity might be a result of starch breakdown, because higher temperature leads to an increase of starch breakdown. The paste integrity was more pronounced when temperature was kept low, indicating an interesting condition for preparing porridge. It would be preferred to process rice and BSG at low processing temperature, which in this case was at 100 °C.



(a) (b)

Figure 3. Means plot of steady-shear viscosity at shear rates of 20 s^{-1} (a) and 50 s^{-1} (b).

5 Conclusion

All samples showed a pseudoplastic behavior, following an Ostwald-de Waele model.

The flow behavior characteristic was influenced by the BSG concentration and processing temperature at certain shear rates. At shear rates higher than 50 s^{-1}, viscosity was independent of these two variables, at least for the range chosen herein.

It was possible, by analyzing the rheological results, to infer that, processing rice and brewery spent grain at lower temperature (100 °C) would produce a paste suitable for porridge making.

6 Acknowledgements

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