Optimization of technological parameters to produce breakfast cereal from rice and common bean flour by extrusion

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ABSTRACT

The objective of the present work was to investigate the relevant parameters to elaborate breakfast cereal from a mix of rice and common bean flour and to evaluate the influence of formulations and processing conditions on the final product characteristics. To elaborate the breakfast cereal it was applied a complete experimental design 2^3, testing the following parameters: common bean flour percentage, moisture and processing temperature, and having the protein content, apparent density and expansion index as statistical answers. Different formulations were processed in a single-screw extrusion. Based on statistical analyses results, for the protein variable, the factors common bean flour percentage, moisture, temperature and the interaction between moisture and temperature were significant. As expected, it was observed a positive effect for common bean flour and a negative effect for moisture, that is, the increase of common bean flour percentage from 13 to 47% and of moisture from 10 to 20%, increased the protein content of the final product. The variable of temperature was significant in the quadratic model, indicating that small variations on the temperature may influence the final protein level. With bean flour contents of 30% considerable contents of protein (13%) were obtained, without prejudicing the technological parameters, once these parameters showed better answers with lower values to this variable. Besides the bean flour content, the apparent density showed as significant answers the moisture content and the interactions between bean flour *versus* moisture and bean flour *versus* temperature, since lower values of these variables reduce the apparent density value of the final product. Temperature and the interaction temperature *versus* moisture were relevant, however to obtain a cereal with lower apparent density (0.20 g/cm³) one should not increase the processing temperature to values up to 100ºC. To the expansion index, the common bean flour percentage, the moisture, the temperature and the moisture *versus* temperature interaction were significant, having been observed higher expansion indexes (approximately 9.0) when intermediate temperature and moisture were applied. Since technological characteristics are primordial to obtain a final product with quality, the better results indicated a bean flour content of 30%, moisture of 14% and temperature at the 3rd extrusion zone of 80ºC, resulting a final product with 13% crude protein, 0.20 g/cm³ apparent density and 9.5 expansion index.

Key-words: thermoplastic extrusion; experimental design; breakfast cereal; broken rice; broken common bean.

INTRODUCTION

Breakfast cereals have been defined as “processed grains for human consumption”. The industry of this kind of products arose in USA at the beginning of 20th century and has quickly grown in the last years, making the breakfast cereals economically important. Nowadays, the segment with higher participation at the market is the sugared breakfast cereals, which have a 40.7% participation in volume and 34.3% of total billing [1].

The thermoplastic extrusion is defined as the process in which diverse processes occur simultaneously, such as mixing, shear, cooking and modeling [2, 3]. The extrusion process for breakfast cereals involves ingredients, which under heat, moisture, pressure and shears influence, are transformed in a viscoelastic mass that suffers a sudden pressure drop when leaving the extruder. This fact allows the water vaporization and, consequently, the expansion of the cereal mass [4].

When developing or improving a process, or formulating a product, it is necessary to plan experimental procedures to evaluate the effects of independent variables on response (s) [5]. The experimental planning is a tool based on statistical principles where one can extract the most useful information, with a minimal number of experiments to be run [6].

The rice and common bean mixture is considered a great combination in terms of nutritional value, which is a source of energy and essential amino acids necessary for a healthy diet, besides containing reasonable amounts of vitamins, minerals and dietary fiber [7].

The objective of the present work was to investigate the relevant parameters to elaborate breakfast cereal from a mix of rice and common bean flour and to evaluate the influence of formulations and processing conditions on the final product characteristics.

MATERIALS & METHODS

To elaborate the breakfast cereal it was applied a complete experimental design 2^3, with central and axial points, testing the following parameters: common bean flour percentage (13 to 47%), moisture (10 to 20%) and processing temperature (60 to 110°C), and having the protein content, apparent density and expansion index as statistical answers. The different formulations were processed in a single-screw extrusion, with a screw speed set at 177 rpm and circular matrix of 3.85 mm. The temperature varied only at the 3rd extrusion zone, according to the experimental design, keeping constant at the 1st zone (30°C) and 2nd zone (40°C).

All responses of the experimental design were analyzed according to Neto et al. [8] with the aid of *Statistica*® software version 5.0. The protein content of the test data was determined according to the method proposed by AOAC [9], the apparent density according to Ramirez and Wanderlei [10] and the radial expansion index according to Alvarez-Martinez et al. [11].

RESULTS & DISCUSSION

Table 1 shows the results of protein, apparent density, and expansion index obtained from experiments with breakfast cereal of rice and common bean, according to the matrix of experimental design.

Table 1 Results of complete experimental design for the variables protein, apparent density and expansion index for breakfast cereal of rice and common bean.

Experiment	Levels of variables in real units					
	Common bean flour (%)	**Temperature (°C)**	**Moisture (%)**	**Protein (%)**	**Apparent density**	**Expansion Index**
1	20	70	12	11,18	0,17	10,68
2	40	70	12	13,83	0,20	9,15
3	20	100	12	10,76	0,17	7,32
4	40	100	12	13,29	0,20	6,06
5	20	70	18	10,43	0,38	6,43
6	40	70	18	13,15	0,40	5,21
7	20	100	18	10,79	0,22	6,61
8	40	100	18	13,19	0,38	4,68
9	13	85	15	9,44	0,17	12,35
10	47	85	15	14,74	0,20	7,73
11	30	60	15	12,83	0,17	8,83
12	30	110	15	12,68	0,17	7,31
13	30	85	10	12,71	0,17	7,41
14	30	85	20	12,02	0,51	5,21
15	30	85	15	13,52	0,20	9,54
16	30	85	15	13,26	0,20	9,64
17	30	85	15	13,15	0,20	9,13
18	30	85	15	13,57	0,21	9,92
19	30	85	15	13,63	0,20	9,68
20	30	85	15	13,46	0,20	8,94

* Average of 3 replicates.

Based on statistical analyses results, for the protein variable, was observed that the factors common bean flour percentage, moisture, temperature and the interaction between moisture and temperature were significant. As expected, it was observed a positive effect for common bean flour and a negative effect for

moisture, that is, the increase of common bean flour percentage from 13 to 47% and of moisture from 10 to 20%, increased the protein content of the final product. The variable of temperature was significant in the quadratic model, indicating that small variations on the temperature may influence the final protein level. The contorn surface for the variable protein is presented in Figure 1.

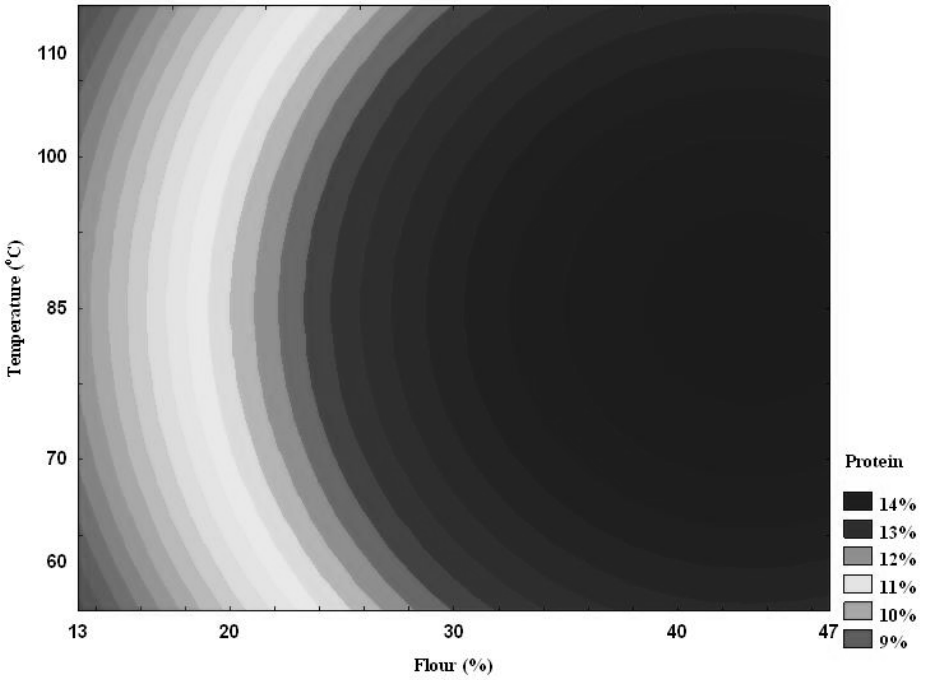

Figure 1. Graphic contour surface for the variable protein (*Flour versus Temperature*).

Besides the bean flour content, the apparent density showed as significant answers the moisture content and the interactions between bean flour x moisture and bean flour x temperature, since lower values of these variables reduce the apparent density value of the final product. The temperature and the interaction temperature x moisture were relevant, however to obtain a cereal with lower apparent density (0.20 g/cm^3) one should not increase the processing temperature to values up to 100ºC. The contorn surface for the variable apparent density is presented in Figure 2.

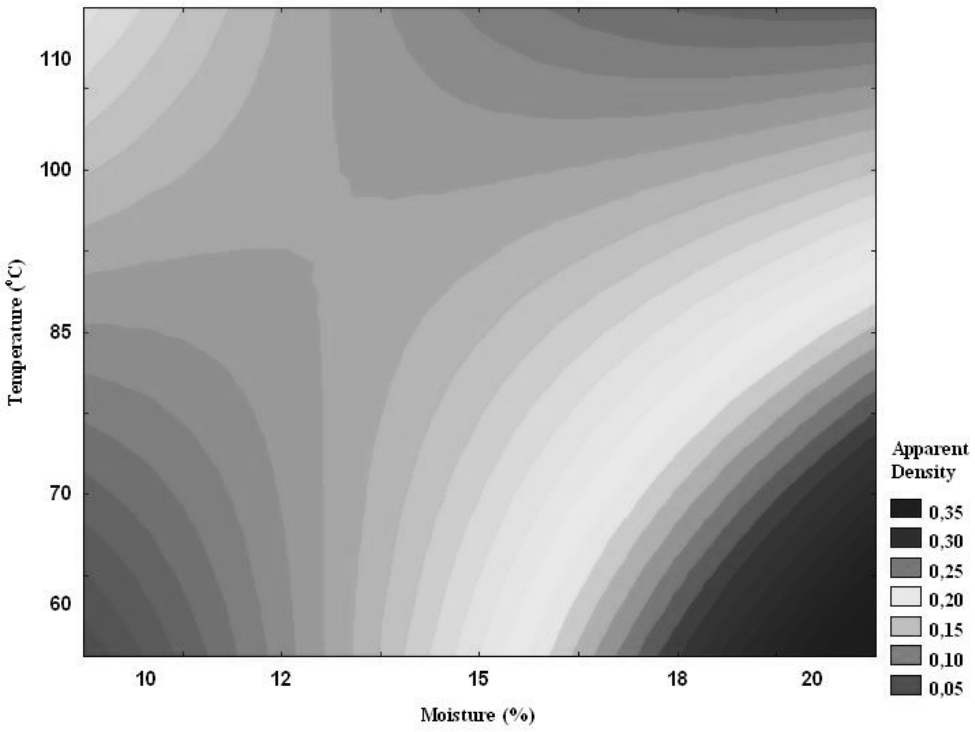

Figure 2. Graphic contour surface for the variable Apparent Density (*Temperature versus Moisture*).

To the expansion index answer, the common bean flour percentage, the moisture, the temperature and the moisture x temperature interaction were significant, having been observed higher expansion indexes (approximately 9.0) when intermediate temperature and moisture were applied. The contorn surface for the variable apparent density is presented in Figure 3.

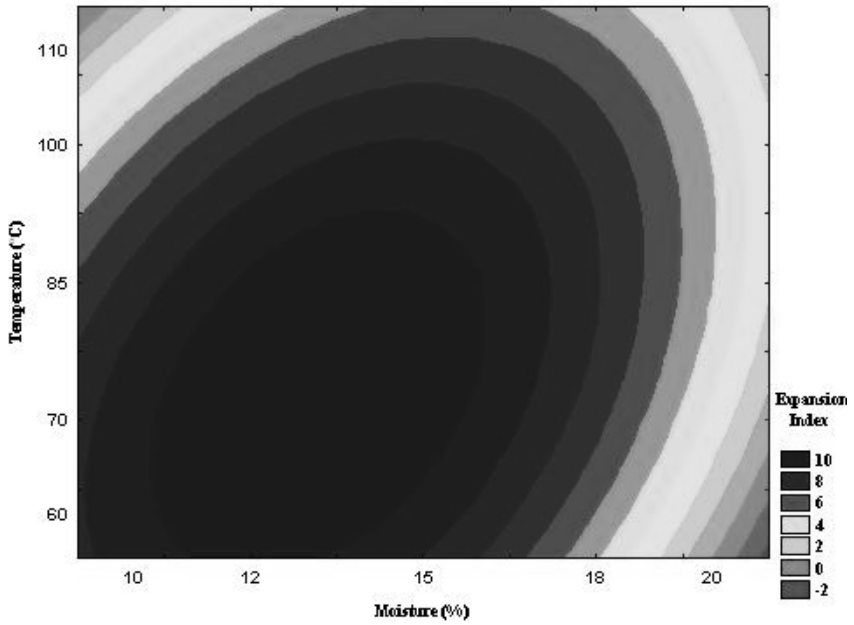

Figure 3. Graphic contour surface for the variable Expansion Index (*Temperature versus Moisture*).

CONCLUSION

Since technological characteristics are primordial to obtain a final product with quality, the better results indicated a bean flour content of 30%, moisture of 14% and temperature at the 3rd extrusion zone of 80°C, resulting a final product with 13% crude protein, 0.20 g/cm³ apparent density and 9.5 expansion index.

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