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Extrusion of flavored corn grits: Structural characteristics, volatile compounds retention and sensory acceptability

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ABSTRACT

The effects of the moisture content of the raw material, extrusion temperature and screw speed on flavor retention, sensory acceptability and structure of corn grits extrudates flavored with isovaleraldehyde, ethyl butyrate and butyric acid were investigated. Higher temperature resulted in more expanded extrudates with lower density and cutting force, while higher moisture content increased ethyl butyrate retention. The most acceptable extrudates were those obtained with low moisture content, under conditions of high extrusion temperature and high screw speed, or low screw speed and low extrusion temperature, whereas the aroma intensity closest to the ideal was observed under conditions of low extrusion temperature and low moisture content of the raw material.

1. Introduction

Flavor is the sensory characteristic of food that is most affected in processes that use high temperatures, such as the thermoplastic extrusion. In the extrusion process, when the material leaves the die, expansion occurs and much of the volatiles are lost along with the steam (Reifsteck & Jeon, 2000; Yuliani, Bhandari, Rutgers, & D'Arcy, 2004).

Several factors are involved in volatile retention or loss during extrusion, including: raw material composition; extrusion conditions such as residence time, extruder temperature, moisture content of the raw material, compression and pressure; format and size of the final product; vapor loss during expansion; and diffusivity of the volatiles in the mass (Reifsteck & Jeon, 2000; Bhandari, D'Arcy, & Young, 2001; Yuliani et al., 2004).

One of the methods most commonly used for flavoring by the food industry is aromatization after extrusion, in which the flavor is sprayed onto the final product. This method, although greatly adding flavor to the extrudate, thereby increasing the pleasure sensation at the time of consumption, increases the fat content of the product and may lead to nutritional imbalance when consumed in large quantities. The lipid content in extrudates that are flavored post-extrusion ranges from 18 to 41 g/100 g, with a caloric value of 450–575 calories per 100 g of product (Heyhoe, 2000).

However, new forms of flavoring have been studied in order to reduce the fat content and the caloric value of extrudates, including pre-extrusion flavoring. In this flavoring method, flavor is added to the raw material to be extruded, thus providing uniform distribution and better oxidative stability. This flavoring method is more suitable because no lipid vehicle is needed for it to be implemented. However, considerable loss of the volatile compounds added may occur during processing, with possible changes to the texture and structure of the extrudates (Bhandari et al., 2001).

Few studies relating to this topic are found in the literature (Yuliani, Torley, D'Arcy, Nicholson, & Bhandari, 2006a; Yuliani, Torley, D'Arcy, Nicholson, & Bhandari, 2006b; Yuliani, Torley, & Bhandari, 2009; Conti-Silva, Arêas, & Bastos, 2012). Thus, further work to develop better understanding of the effect of extrusion conditions on the structure and retention of flavor in pre-flavored extrudates is required.

Therefore, the aim of this study was to investigate the effects of the moisture content of the raw material, extrusion temperature and screw speed on the structural parameters, volatile compounds retention and sensory acceptability of corn grit extrudates flavored using response surface methodology.

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2. Materials and methods

2.1. Materials

The corn grits (7.7 g/100 g protein, 1.1 g/100 g fat, 0.3 g/100 g ash and 90.0 g/100 g total carbohydrates, on a dry basis) were purchased from a local market and were not subjected to any process before extrusion. For flavoring, a mixture of three volatile liquid compounds was used: isovaleraldehyde, ethyl butyrate and butyric acid (Sigma–Aldrich, Milwaukee, USA).

2.2. Corn grits composition

The corn grits composition was determined in accordance with the AOAC (1997) for ash and proteins, and in accordance with the AOCS (2009) specifications for lipid content, and the total carbohydrates content was estimated by difference. The corn grits were ground in a knife mill (model 340, Marconi, Piracicaba, Brazil) and the analyses were performed in triplicate.

2.3. Experimental design

The response surface methodology was applied using a rotational central composite design for three independent variables (Barros-Neto, Scarminio, & Bruns, 2010), namely: the moisture content of the raw material (dry basis), the extrusion temperature (temperature in third barrel zone) and the screw speed. The dependent variables used were the expansion ratio, density, cutting force and volatile retention for each compound individually and in total for all the compounds. Seventeen tests were performed: eight tests of factorial points (2^3) (three levels for each factor), six axial points (two for each variable) and three repetitions of the central point (Table 1).

The results from the dependent variables were subjected to multiple regression analysis using the Statistica 7.0 software (StatSoft Inc., Oklahoma, EUA) and coefficients with p values below 0.05 were considered significant. The regression was evaluated by means of analysis of variance: the regression was considered to be significant when $p \leq 0.05$, but no lack of fit at $p > 0.05$. Linear and quadratic models were tested to explain the influence of independent variables on the response variables, because in Response Surface Methodology, the relationship between these variables is unknown and, therefore, it is necessary to find an adequate approximation to the true relationship between the response and the independent variables (Montgomery & Runger, 2006).

2.4. Adjustment of the moisture content of the corn grits

Samples of 400 g of grits were prepared to achieve moisture contents of 10, 12, 15, 18 and 20 g/100 g on a dry basis. The amount of water required to raise the moisture content of the corn grits to 15, 18 and 20 g/100 g (db) was added to the sample under constant stirring with the aid of a planetary mixer at low speed. After addition of water, the samples were packed in polyethylene bags and refrigerated for 24 h for homogenization. To adjust the moisture content of the samples to 10 and 12 g/100 g on a dry basis, drying was performed at 70 °C for approximately 60 and 30 min, respectively. The moisture content of the corn grits after adjustment to the desired values was then determined by drying at 105 °C (AOAC, 1997).

2.5. Flavoring of the corn grits

Each volatile compound was added at proportion of 1.5 g/100 g to the corn grits, as described by Conti-Silva et al. (2012). The volatiles were added by volume, based on the density of the compounds. Therefore, 7.53, 6.83 and 6.26 mL of isovaleraldehyde, ethyl butyrate and butyric acid, respectively, were added to 400 g of corn grits to each extrusion conditions. Sample homogenization was performed manually in the packaging and then the packages were sealed and kept at room temperature for 2 h before extrusion.

2.6. Extrusion process

The flavored corn grits were extruded in a single screw extruder (LAB 20, AX Plásticos, Diadema, Brazil) with four independent heating zones. The first and second zones were maintained at 50 and 90 °C, respectively; the third zone was adjusted according to the experimental design (Table 1); and the fourth zone was adjusted to 10 °C below the temperature of zone 3. The length/diameter ratio of the barrel was 26:1, and the screw used had a compression ratio of 4.6:1. The die diameter was 3.3 mm and feed rate was kept constant at 46 g min^{-1}.

Table 1
Experimental design with encoded and real values of the independent variables used under each extrusion condition.

Extrusion conditions	Encoded variables			Real variables		
	X_1	X_2	X_3	Moisture content (g/100 g)	Extrusion temperature (°C)	Screw speed (rpm)
1	−1	−1	−1	12	157	165
2	+1	−1	−1	18	157	165
3	−1	+1	−1	12	177	165
4	+1	+1	−1	18	177	165
5	−1	−1	+1	12	157	175
6	+1	−1	+1	18	157	175
7	−1	+1	+1	12	177	175
8	+1	+1	+1	18	177	175
9	−1.682	0	0	10	167	170
10	+1.682	0	0	20	167	170
11	0	−1.682	0	15	150	170
12	0	+1.682	0	15	184	170
13	0	0	−1.682	15	167	162
14	0	0	+1.682	15	167	178
15	0	0	0	15	167	170
16	0	0	0	15	167	170
17	0	0	0	15	167	170