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Influence of the extrusion operating conditions on the antioxidant, hardness and color properties of extruded mango

N. Salgado [a], G.I. Giraldo [a, b], C.E. Orrego [a, b, *]

[a] Instituto de Biotecnología y Agroindustria, Departamento de Física y Química, Universidad Nacional de Colombia, Km 7 vía al Aeropuerto, Campus La Nubia, 170004, Manizales, Colombia
[b] Departamento de Física y Química, Universidad Nacional de Colombia, Km 7 vía al Aeropuerto, Campus La Nubia, 170004, Manizales, Colombia

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ABSTRACT

The effects of extrusion temperature (50–100 °C) and formulation (glycerin 0–3%, dried fruit moisture 8–14%, glucose 5–15% and xanthan gum 0–3%) on technological (hardness and color) and nutritional (antioxidant activity-AA and total polyphenol content-PC) quality parameters for extruded mango bars were analyzed using response surface methodology (RSM) and principal component analysis (PCA).

The PC increased, first, when the extrusion temperature was at lower values and the dried ingredient content was higher, and second, with higher temperatures and xanthan gum content. The AA showed similar behavior but decreased when the liquid ingredients were at their lowest values.

Extrudate hardness remained fairly constant, except for an increase at low barrel temperature and high non-fruit ingredients content. The bars measured color parameters were affected the most by fruit moisture.

Two principal components explained 73.00% of the total variability by PCA. The results for the relationships of PC and AA with barrel temperature and xanthan gum content were similar to those obtained by RSM.

Based on previous findings, some responses were set as optimization objectives that suggested two sets of conditions for optimum extrusion.

1. Introduction

Currently, one of the global trends in the food market is a strong consumer interest in food that, in addition to its nutritional value, may provide benefits to physiological functions and contribute to the maintenance of a good energy balance. Different studies have shown that inadequate nutrition is one of the causes of diseases and obesity Lock, Pomerleau, Causer, Altmann, & McKee, 2005; Potter, Stojceska, & Plunkett, 2013; Mozaffarian, 2016. Moreover, one European Union study showed that five of the six leading risk factors for ill health are linked to this factor (Troesch et al., 2015). This situation has prompted the generation of government programs to solve the problem of obesity and overweight citizens by promoting the replacement of one traditional meal or unhealthy snacks that are high in fat and in carbohydrates with the consumption of healthy foods, especially by children and the younger population (Attorp et al., 2014). Thanks to their content of minerals, vitamins, antioxidants and dietary fiber, the consumption of fruits and vegetables has been associated to lower risk of developing many chronic health conditions (Orrego, Salgado, & Botero, 2014). Different studies have indicated that a diet rich in phenolic compounds may have protective effects against various degenerative diseases and that most of the beneficial characteristics of these phenolics are attributed to their antioxidant activity (Prasad et al., 2011).

The mango is an important fruit in several parts of the world. This is likely due to its good sensorial properties (attractive color, sweet taste and luscious flavor), nutritional composition (vitamins, minerals and fiber) and antioxidant content (ascorbic acid, carotenoids and phenolic compounds) (Palafox, Yahia, & González, 2012). The fruit has a short ripening period that limits its shelf life and affects its economic value (Mahto & Das, 2013). Therefore, options to transform the mango into value-added products using extrusion processing are convenient methods to preserve the fruit.

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* Corresponding author. Instituto de Biotecnología y Agroindustria, Departamento de Física y Química, Universidad Nacional de Colombia, Km 7 vía al Aeropuerto, Campus La Nubia, 170004, Manizales, Colombia.
E-mail address: corregoa@unal.edu.co (C.E. Orrego).

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Extrusion is a technology that permits versatility of raw materials and the creation of new food products (Orrego et al., 2014). Among other goals, studies on food extrusion have focused on the improvement of sensory quality properties, an increase in dietary fiber, nutrient enrichment, maintenance of color and preservation of anthocyanins (Dehghan, Hardacre, & Brennan, 2010; Hirth, Leiter, Beck, & Schuchmann, 2014; Stojceska, Ainsworth, Plunkett, İbanoğlu, & İbanoğlu, 2008). The use of fruits in extruded snacks has also been reported for a number of fruit produce and derivatives, including blueberries (Camire, Dougherty, & Briggs, 2007), pineapple (Sharma, Ramchiary, Samyor, & Das, 2016), grapes-tomato (Altan, McCarthy, & Maskan, 2009) and passion fruit (Cortés, Guzmán, & Martínez-Bustos, 2014).

A number of extrusion process variables can influence the characteristics of the final product. These variables include mixing, conditioning and raw material characteristics, die temperature, pressure, screw speed and configuration, moisture content, flow rate, energy input and residence time. The characteristics subject to change include technological properties, palatability and the bioactive compounds of the extrudates (Brennan, Brennan, Derbyshire, & Tiwari, 2011). The influences on the latter can be either positive or negative influences.

The production of mango bars with a high fruit content (>80%) is an interesting option for the fulfillment of the rising market for healthy and natural snacks. To the best of our knowledge, no studies have been published on the production of such a high level of fruit extrudates. The aim of this paper is to relate processing variables (the extrusion temperature) and formulation (xanthan gum, glycerin and water content) with four product quality parameters (total polyphenol content, antioxidant activity, hardness and color) in the extrusion of high-mango-content fruit bars by using mathematical modeling generated from RSM. To further explore an understanding of the relationship between the input and output extrusion variables, PCA analysis was also performed using the experimental data. The RSM models were also used for optimizing the response for appropriate values of polyphenol content, antioxidant activity, hardness and color attributes.

2. Materials and methods

2.1. Materials and reagents

Mango fruits were obtained from local market in Manizales, Colombia, glucose and xanthan gum was purchased from Ciacomeq (Bogota, Colombia) and Folin Ciocalteu reagent and sodium carbonate (anhydrous) from Sigma-Aldrich (St. Louis, Missouri, United States). All other reagents used were of analytical grade.

2.2. Sample preparation

The mango fruits (*Mangifera indica* L.) were selected according to the skin background color (yellow-red) and with a hardness such that a slight concave deformation was produced by gently pressing the fruits with the fingertips (Villalpando-Guzman et al., 2011). After that they were washed, peeled and cut manually in slices 7 mm in thickness. The samples were dehydrated by convective drying at 60 °C in a laboratory convection oven (Thermolab TH53, Dies, Medellin) until the desired moisture content was reached (8 ± 0.2, 11 ± 0.2 and 14± 0.3%, moisture basis). These levels were chosen according to previous tests to ensure smooth operation of the extruder and to obtain proper hardness of the fruit bars. Dehydrated mango was milled in a conventional grinder and sieved. The fraction greater than 60 mesh US Standard sieve was used as the fruit ingredient for the extrusion assays.

The blends of dried mango and the other ingredients (glycerin, xanthan gum and glucose) were prepared according to the experimental design (Table 1).

Table 1
Independent variable values of the extrusion process and their coded and actual values.

Actual variables	Levels		
	−1	0	1
A: Glycerin content (%)	0	2.5	5
B: Dried Fruit moisture (%)	8	11	14
C: Die temperature (°C)	50	75	100
D: Glucose content (%)	5	10	15
E: Xanthan gum content (%)	0	1.5	3

Concentration of ingredients as g of ingredient/100 g of mango fruit solids.

2.3. Experimental design

The range of independent variables of the extrusion assays (which was based on the results of preliminary experiments) and their levels are presented in Table 1. A central composite face-centered design was used, with 21 trials and five replicates in the center. Five independent variables were considered with three levels each: glycerin (A), dried fruit moisture (B), barrel temperature (C), glucose content (D) and xanthan gum content (E). The response variables in the fruit bars were total polyphenol content, P (mg gallic acid/100 g of sample); antioxidant activity, AA (μM Trolox/g sample); hardness-H (N) and three color parameters (CieLab: L*a*b*). All of the bar analyses corresponding to the responses were performed in triplicate and their results were expressed as the average values ± standard deviation.

2.4. Extrusion

The ingredient blends for the bars (Table 1) were extruded in a single-screw extruder (Rap Ingeniería, Bogotá, Colombia) at three die temperatures (50, 75 and 100 °C) and a screw speed of 1200 rpm. Mango bar extrudates flow through a circular plate with two square holes (4 × 4 mm) placed at the output of the extruder die. Sample pieces of mango bar were cut to a length of 40 mm. The screw diameter and its length-to-diameter ratio (L/D) were 50 mm and 15:1, respectively. After extrusion, the mango samples were cooled to room temperature (22 ± 2 °C) before being packed in plastic bags.

2.5. Moisture content of mango bars

The moisture content of the extruded mango bars was tested at 80 °C by using an infrared moisture analyzer (METTLER LJ16, Greifensee, Switzerland).

2.6. Hardness measurements

The hardness (N) of the bars was measured after 1 h of storage at 20±1° C. Each mango bar (0.9 mm diameter and 25 mm length) was subjected to a compression test in a TA-XT2 texturometer (Stable Microsystems, Surrey, UK), under the following conditions: probe compression platens, 75 mm; pre-test speed, 1.0 mm/s; test speed, 1.0 mm/s; post-test speed, 10.0 mm/s; distance, 14 mm; the trigger type was set to auto and the trigger force was 5.0 g.

2.7. Color measurements

The L*a*b* color parameters of the samples were analyzed with a portable CM700d spectrophotometer (Konica Minolta, Osaka,