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Processing parameter optimization for obtaining dry beans with reduced cooking time

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ABSTRACT

The objectives of this study were to investigate the effects of processing beans by soaking and blanching in salt solutions on the quality parameters of the common bean and, in order to obtain a dry product with a reduced cooking time using experimental design techniques. A Plackett and Burman design was used to evaluate the effects of nine factors, soaking, blanching and drying under different conditions, in bean processing. A central composite rotational 2^3 design was used with the factors of soaking time, concentration of $NaHCO_3$ and drying temperature. An increase in the concentration of $NaHCO_3$ from 0 to 4 g.100^{-1} mL reduced the cooking time by 10 min. However, increasing the $NaHCO_3$ concentration increased the level of damage to the product and darkened the bean seed coat, producing greater color differences in the processed bean. The selected conditions for the production of dry quick cooking beans was a time of 13.1 h, a concentration of $NaHCO_3$ in the soaking solution of 2.3 g.100 mL^{-1} and a drying temperature of 50 °C. Under the select conditions, it was possible to reduce the cooking time by 53%, with of 5.36 g.100 g^{-1} of damaged grains and color difference of 8.39.

1. Introduction

The common bean (*Phaseolus vulgaris* L.) is an important staple in the diets of many populations because it is a nutritionally rich food that provides protein, carbohydrates, fiber, vitamins and minerals (Vargas-Torres, Osorio-Diaz, & Agama-Acevedo, 2006). In addition to its nutritional value, the common bean has health-promoting properties that contribute to reducing the rates of cardiovascular diseases, degenerative diseases, and obesity (Pan, Atungulu, Wei, & Haff, 2010).

Beans have to be processed by cooking before consumption. However, if the product is of low quality, then the required preparation and cooking time are longer, thus limiting bean consumption. Many factors affect the quality of the beans, such as the morphological and physiological characteristics of the species. The need to prepare high-quality food quickly and conveniently is a current reality, and the processing industry works to meet the aspirations of the modern consumer. Time-consuming food preparation is cited as a main factor that must be eliminated to reduce time of household work and contributes to a higher number of people eating their meals outside of the home. Currently, because of time-related factors, there has been a decrease in the consumption of beans, and beans have been replaced with less nutritious foods, foods with faster cooking times and precooked foods (Siqueira, Vianello, Fernandes, & Bassinello, 2013).

Research has contributed to advances in the implementation of the technological processing of beans. These advances have added value to the product, brought benefits to the consumers, indirectly impacted the profitability of producers and the processing industry, and increased consumption. Several studies have proposed methods to reduce the cooking time of beans and other legumes, thus increasing the inclusion of these foods in the diet (Bertoldo, Rocha, Barili, Vale & Coimbra, 2010; Iyer, Salunkhe, Sathe, & Rockland, 1980; Pan et al., 2010; Paredes-López, Cárabez-Trejo, Palma-Tirado, & Reyes-Moreno, 1991; Rehman, Salarya, & Safar, 2001; Urga, Fufa, Biratu, & Gebretsadik, 2006; Uzogara, Morton, & Daniel, 1990).

Processing by soaking is a process in which the product soaks prior to cooking. Soaking is a stage that allows the absorption of water, which is essential to assure softness and reduce the cooking time, and is a process that is usually carried out by the consumer (Rehman et al., 2001). Another process for treating the beans is blanching, a method used to inactivate enzymes and remove gases from the surface and intercellular spaces of the beans. These two

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processes, soaking and blanching, followed by drying, can be performed in salt solutions to reduce the cooking time of the beans. Legumes are processed to obtain a dehydrated, quick cooking product. The development objective of dried beans is to reduce the preparation time for consumers (Cai & Chang, 1997a). Legume processing is still not used industrially, but it has the potential to be a part bean-based food preparation in the future market. One of the problems associated with this type of processing is that it leads to the rejection of the product due to structural defects, such as the division of the beans or the rupture of the tegument. Research on pre-cooked dried beans is mainly focused on the following two areas: reducing the time of preparation and reducing structural defects (Pan et al.., 2010).

The objective of this study was to investigate the effects of processing beans by soaking and blanching in salt solutions to obtain dry beans with a reduced cooking time using experimental design techniques.

2. Material and methods

2.1. Raw material

Beans (*P. vulgaris* L., carioca group) from the first crop (summer 2010/2011) of the cultivar IAPAR 81 were used, obtained by a conventional producer from the municipality of Catanduvas, PR, Brazil. After the harvest, the beans were dried and cleaned, and the water content was determined to be 12.0 g.100 g^{-1} (Brazil, 2009). Beans were stored at room temperature (25 °C ± 1 °C) for 45 days before processing.

2.2. Screening design for processing

The Plackett & Burman (PB) factorial design was used to study the influence of the processing treatments on the quality of the beans (Plackett & Burman, 1946). Table 1 shows the factors evaluated during bean processing with their respective levels coded as −1 and +1, which were defined by preliminary tests and results of other studies (Abu-ghannam & Mckenna, 1997; Gowen, Abu-ghannam, Frias, & Oliveira, 2007; Iyer et al., 1980; Zimmermann, Coelho, Christ, & Nóbrega, 2009). The proposed plan was type PB 16, which featured four central points, totaling 20 randomly conducted tests.

A sample of 100 g of beans was used for each test; the beans were subjected to various conditions of soaking, blanching and drying (Table 1). Soaking was performed in a 400 mL solution with concentrations of sodium chloride (NaCl) and sodium bicarbonate ($NaHCO_3$) ranging from 0 to 4 g.100 mL^{-1}, in accordance with the factor conditions X_2 and X_3, for a period of time (X_1) and at a certain temperature (X_4) defined by the PB planning. Blanching was held at a specific temperature (X_5) for a period of time (X_6) determined by the planning in a water bath apparatus containing 400 mL at a concentration of NaCl (X_7) and $NaHCO_3$ (X_8), as defined by the PB 16 experimental matrix. After these steps, the beans were dried in an air circulation and renewal oven at a determined temperature for each test (40–60 °C), and then they were subjected to a technological quality analysis, which is described below.

Table 1
Levels of the Plackett & Burman design factors and their respective real values.

Factor	Code	−1	0	+1
Soaking time (h)	X_1	4	10	16
NaCl concentration in soaking (g.100 mL^{-1})	X_2	0	2.25	4.5
$NaHCO_3$ concentration in soaking (g.100 mL^{-1})	X_3	0	2.25	4.5
Soaking solution temperature (°C)	X_4	25	35	45
Blanching temperature (°C)	X_5	70	80	90
Blanching time (s)	X_6	30	105	180
NaCl concentration in blanching (g.100 mL^{-1})	X_7	0	2.25	4.5
$NaHCO_3$ concentration in blanching (g.100 mL^{-1})	X_8	0	2.25	4.5
Drying temperature (°C)	X_9	40	50	60

2.3. Cooking time

For the processed beans, the cooking time (minutes) was determined using a modified Mattson cooker at atmospheric pressure, following an adapted method proposed by Proctor and Watts (1987). The cooking time was considered to be the time it takes for 52% of the beans have been drilled through the cooker metal rods. The cooking time was also determined for the control beans (which had not been processed). Using the cooking time values of the processed bean samples and the control, the change in cooking time (CCT) of the beans was calculated using the following expression:

$$CCT = \left(\frac{CT_{control} - CT_{sample}}{CT_{control}}\right) \times 100 \quad (1)$$

where:

CCT = Change in cooking time of the sample relative to the control (%);
$CT_{Control}$ = time required for cooking the control beans (unprocessed), in minutes;
CT_{Sample} = time required for cooking the processed beans, in minutes.

2.4. Percentage of damaged grains (DG)

After processing, the percentage of damaged grains was evaluated using the methodology of Pan et al. (2010). The total bean mass was manually sorted into two portions, damaged and undamaged. For the classification of damaged beans, the following were considered: presence of cracks in the seed coat, coat shedding and presence of broken beans. The damaged grains were weighed and expressed as the mass of damaged beans per 100 g of sample.

2.5. Grain color

The color of the product was determined using a colorimeter (Konica Minolta, CR410, Osaka, Japan) with a 50 mm aperture. The color parameters L^*, a^* and b^*, which measure lightness, redness and yellowness, respectively, were determined using the CIE color space. The colorimeter was previously calibrated using a ceramic plate according to standards pre-established by the manufacturer ($Y = 85.8$; $x = 0.3195$; $y = 0.3369$) using the D65 illuminant, which represents average daylight. The product was placed on the accommodation accessory for granular-type samples (model CR-A50), and readings were performed in triplicate. First, a grain color control was determined, and then the processed samples were measured to obtain mean values for the color difference in processed grain compared to the control (ΔE) using the expression (Minolta, 1993):

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (2)$$