LWT - Food Science and Technology 44 (2011) 933–939

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Extruded puffed functional ingredient with oat bran and soy flour

L.P. Lobato, D. Anibal, M.M. Lazaretti, M.V.E. Grossmann*

Departamento de Ciência e Tecnologia dos Alimentos, Universidade Estadual de Londrina, CP 6001, 86051-970 Londrina, PR, Brazil

ARTICLE INFO

Article history:
Received 30 April 2010
Received in revised form
4 November 2010
Accepted 9 November 2010

Keywords:
Vegetable protein
Dietary fiber
Extrusion cooking
Mixture design
Corn starch

ABSTRACT

Extrusion cooking is a food processing technique that is used worldwide to transform various ingredients. The aim of this work was to apply extrusion to develop a functional puffed ingredient with defatted soy flour and oat bran and the minimum amount of corn starch required to attain good textural properties. The proportions of the feed ingredients and the processing conditions (extruder temperature, moisture, and inulin percentage as a technological coadjutant) were optimized. Applying mixture experimental design to study the effect of feed ingredients on expansion and textural properties of extruded product, the formula containing 250 g/kg corn starch, 375 g/kg soy flour, and 375 g/kg oat bran was selected as the best between tested. Using this blend and applying incomplete factorial design, the best process conditions (250 g/kg moisture; 45 g/kg inulin and 130 °C) were chosen. Based on the results of the process, optimization step temperatures higher than 130 °C were tested and showed that 160 °C increased the radial expansion ratio and decreased hardness the most. The obtained puffed product had 212.6 g/kg fiber, 281.0 g/kg protein, and a caloric value of 319.1 kcal/100 g. It was well accepted by the panelists in the sensory evaluation, mainly in terms of texture.

1. Introduction

Extrusion, classified as a high temperature/short time process, is an important food processing technique used worldwide for the production and modification or improvement of quality of various products. In the extruder, the food mix is thermomechanically cooked at high temperature under pressure and shear stress generated in the screw barrel assembly. The cooked melt is then texturized and shaped in the die. The thermomechanical action during extrusion brings about starch gelatinization, protein denaturation, and inactivation of enzymes, microbes and many antinutritional factors. All this occurs in a shear environment, resulting in a plasticized continuous mass (Battacharya & Prakash, 1994).

The product properties are influenced by extruder operating parameters, such as barrel and die temperature, screw speed, screw configuration, and die shape, as well as raw material formulation, namely the moisture, protein, starch, and lipid contents (Moraru & Kokini, 2003). Furthermore, ingredients such as sugar, salt, protein, and fiber can affect extrusion system variables, as well as product characteristics, such as texture, structure, expansion, and sensory attributes (Jin, Hsieh, & Huff, 1994). There is abundant literature describing the effects of ingredient incorporation on extruded product microstructure and physicochemical properties (Jin, Hsieh, & Huff, 1995; Kokini, Ho, & Karwe, 1992; Mendonça, Grossmann, & Verhé, 2000; Moraru & Kokini, 2003).

Dietary fibers have a number of health benefits. However, their incorporation into extruded puffed snack foods and breakfast cereals limits puffing and reduces crispness, therefore decreasing bowl life. Almost invariably, it has been found that increasing fiber concentration in the extrudate formulations reduces the expansion volume of extruded foods. Mendonça et al. (2000) reported that co-extrusion of corn bran and corn meal with increased bran content resulted in less radial expansion and undesirable product textural characteristics. In general, it has been observed that reduction in expansion during extrusion results in products that are dense, tough, and non-crispy (Lue, Hsieh, & Huff, 1991).

Adding cereal fibers to extruded products has been limited to a maximum of 100–300 g/kg fiber substitution for flour due to increase in product hardness and decrease in consumer acceptance (Hsieh, Mulvaney, Huff, Lue, & Brent 1989; Jin et al., 1995; Lue, Hsieh, Peng, & Huff, 1990). Liu, Hsieh, Heymann, & Huff (2000) have studied the addition of up to 200 g/kg fibers to extruded products because of the numerous health benefits of high food fiber content.

Several researchers have reported about the addition of soy protein to extruded starch products with conflicting results. Faubion and Hoseney (1982) reported that wheat starch with 10–80 g/kg soy protein isolate expanded more than pure starch. However at 100 g/kg soy protein isolate, expansion decreased. Zasypkin and Lee (1998) showed that increasing the proportion of

* Corresponding author. Tel.: +55 043 33714565; fax: +55 043 33714080.
E-mail address: victoria@uel.br (M.V.E. Grossmann).

0023-6438/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.lwt.2010.11.013

soybean flour to 100 g/kg in a wheat flour–soybean flour blend resulted in a decrease in expansion ratio at 160 g/kg barrel moisture content, and an increase at 170–180 g/kg moisture content. Further addition of soy flour up to 400 g/kg led to continuous decrease in expansion ratio. Beyond 400 g/kg, the trends for expansion depended again on moisture content and also on a possible phase inversion occurring beyond that level of soy flour. Li, Zhang, Jin, and Hsieh (2005) reported that the addition of soybean flour to corn meal in the range from 0 to 400 g/kg increased expansion ratio. The different results could be explained by the differences in blends, proportion of the ingredients, and process conditions.

Mixing different ingredients to make a puffed ready-to-eat product using the extrusion process is difficult. Oat bran, for example, has a high level of fat and soluble gum. However, the negative effects of fibers or proteins in the extruded dough or the products can be minimized if some additives are used, such as monoglycerides, modified starches, modified gelatin, oligofructose, or inulin.

Inulin has already been used as an additive in extrusion (Ascheri, Couri, & Madeira, 2006). It was selected from among other additives to be used as an extrusion coadjutant in this investigation based on preliminary experiments to determine optimum extruder operating conditions. Inulin can provide a number of functional properties to extruded cereal, including greater expansion (Niness, 1999).

Consumption of either soluble fiber or vegetable protein decreases serum cholesterol (Anderson et al., 1992; Anderson, Johnstone, & Cook-Newel, 1995; Jenkins et al., 1993). Jenkins et al. (1999) investigated the combined effect of protein (soy) and soluble fiber added to a standard cholesterol-lowering diet. They concluded that this combination reduced both LDL cholesterol and the LDL: HDL cholesterol ratio in diets with low saturated fat and cholesterol ingestion in the diet. Therefore, extrusion cooking of soy flour in combination with nutritionally complementary cereal grains, such as oat, is of even greater interest, because it can be used to produce nutritionally balanced ingredients in the well-accepted form of an extrudate.

The objective of this study was to develop a potential functional extruded ingredient combining defatted soy flour and oat bran by selection of the best proportions among ingredients and optimization of process parameters. Preliminary studies showed that it is impossible to obtain a product with good sensory characteristics extruding only defatted soy flour and oat bran with the lowest amount possible of corn starch in the formulation. Furthermore, the process was possible only with the addition of inulin, because of its contribution to better mass flow during the process.

2. Material and methods

2.1. Ingredients

Oat bran (225 g/kg dietary fiber [95 g/kg soluble and 130 g/kg insoluble], 267 g/kg protein and 75 g/kg lipids, db) was provided by SL Alimentos (Mauá da Serra, Brazil). Defatted soy flour (160 g/kg dietary fiber [10 g/kg soluble and 150 g/kg insoluble], 555 g/kg protein and 10 g/kg lipids, db) was purchased from Vitao Alimentos (Curitiba, Brazil), Inulin Beneo ST® (920 g/kg purity, DP $\geq$ 10) and corn starch were obtained from Clariant (São Paulo, Brazil) and Unilever (Mogi das Cruzes, Brazil), respectively.

2.2. Sample preparation

Corn starch, oat bran, and defatted soy flour constituted a ternary mixture and were blended in predetermined ratios, as stated by the experimental design in the first step. To each blend, 50 g/kg inulin (calculated on total formulation) was added to promote better extrusion flow. The blended samples were conditioned to 250 g/kg moisture by spraying a calculated amount of water and mixing continuously in a mixer. The samples were sealed in plastic bag and stored at 4 °C overnight. The feed material was then allowed 1 h to equilibrate at room temperature prior to extrusion. This preconditioning procedure was employed to ensure uniform mixing and hydration and to minimize variability. In other steps of the study, the ingredient proportion in the ternary mixture was fixed at corn starch (250 g/kg), oat bran (375 g/kg), defatted soy flour (375 g/kg), and the moisture and inulin percentage was varied according to the experimental design.

2.3. Extrusion

A single screw laboratory extruder (BGM, EL-25 model, Brazil) was used. The barrel diameter (D) and the length-to-diameter ratio (L/D) were 25 mm and 26:1. The extruder had four zones with electrical resistance band heaters and thermocouple sensors to monitor the temperature, a 3:1 compression ratio screw, and a die with six 2-mm diameter holes. In the first step (formula optimization), the processing temperatures were 80, 100, 120, and 120 °C at zones 1, 2, 3, and die, respectively. In the second and third steps (process optimization), the temperatures of zone 3 and of the die were varied according to experimental design. The screw speed was fixed at 70 rpm and the extruder was operated at a steady state for each set of conditions. Attainment of these conditions was judged by constant amperage. Samples (approximately 1000 g) were collected and dried overnight at 80 °C in a forced-air convection oven to moisture values of around 30 g/kg. Part of the extrudates was coarsely or finely ground for further physical and chemical determinations. The other part, used in texture tests, was hand cut, placed in polyethylene bags, sealed, and stored until testing.

2.4. Product characteristics

2.4.1. Radial expansion ratio (RER)

RER was calculated by dividing the average cross-section area of extrudate (mm) (obtained with calipers) by the extruder die cross-section area (mm). Each treatment was measured 15 times.

2.4.2. Specific length (SL)

Specific Length was calculated by dividing the average length (mm) of extrudate by its weight (g) (Alvarez-Martinez, Kondury, & Harper, 1988). The extrudates were cut by hand in pieces of about 5 cm in length. Each treatment was measured 15 times.

2.4.3. Specific volume

The specific volume of each extrudate, the ratio between its volume and weight, was expressed as cm^3/g. The volume was obtained using the rapeseed displacement method (method 10–05) (AACC, 2000).

2.4.4. Textural properties

The hardness (peak force during first compression) and fracturability (force at yield break) of extrudates (Bourne, 1978) were determined using a TA.XT2 Texture Analyzer (Stable Micro System, U.K.) with a 5-blade Kramer shear cell probe and the software XTRAD. The samples were cut by hand in pieces with the size of the cell (about 7.5 cm). Approximately 80 pieces of each sample were put horizontally and downright with the knives in multiple layers in the cell to fill up to a standard height of 2 cm. The knives had a crosshead speed of 1 mm/s, were 10 mm apart and had a 0.05-N force threshold.

2.4.5. Proximate composition

Moisture (method 44–15), crude fat (method 30–25), ash (method 08–01), and crude protein (method 46–10) contents in g/