LWT - Food Science and Technology 50 (2013) 279–289

Contents lists available at SciVerse ScienceDirect

LWT - Food Science and Technology

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

Protein rich extruded products prepared from soy protein isolate-corn flour blends

Liang Yu [a], Hosahalli S. Ramaswamy [a,*], Joyce Boye [a,b]

[a] Department of Food Science and Agricultural Chemistry, McGill University, Macdonald Campus, 21111 Lakeshore, Ste Anne-de-Bellevue, PQ, H9X 3V9, Canada
[b] Agriculuture and Agri-Food Canada, St Hyaninthe, PQ, Canada

ARTICLE INFO

Article history:
Received 7 September 2011
Received in revised form
7 May 2012
Accepted 20 May 2012

Keywords:
Twin screw extrusion impacts
Physical properties
Soy protein isolate-corn starch blend
Optimum processing conditions

ABSTRACT

Protein rich extruded products were prepared from soy protein isolate and corn flour blends using a twin screw extruder and the physical properties of the extruded product were evaluated and related to process variables: soy protein isolate (SPI) (32.2–66.6 g protein/100 dry matter), feed moisture (31.6–48.4 g/100 g) and process temperature (126.4–193.6 °C). A central composite rotate design (CCRD) and response surface methodology was used to evaluate the significance of independent and interaction effects of extrusion process variables on the product's various physical properties (breaking stress, bulk density, expansion ratio, water solubility index, rehydration rate and color). Second order polynomial regression equations were developed to relate the product responses to process variables as well as to obtain the response surfaces plots. The independent variables had significant ($p \le 0.05$) effects on physical properties of extrudates: (i) higher SPI and feed moisture contents increased the breaking stress and bulk density, but decreased the expansion ratio, water solubility index, and rehydration rate, (ii) higher SPI content decreased the color *L* value, whereas higher feed moisture content increased it, (iii) higher temperatures increased breaking stress, expansion ratio, rehydration rate and *L* value, but decreased the bulk density and water solubility index.

1. Introduction

Since the consumer always demands healthy and nutritious foods, finding nutritional products is a food producer's unchangeable target. Degradation in the nutritional quality of finished food products arising from thermal processing of foods is a challenging matter under most traditional cooking methods. Extrusion cooking is a high temperature short time (HTST) cooking technique which provides thermal and shear energy to a food material to induce desirable physical and chemical changes. HTST extrusion process can minimize heat degradation of food nutrients, while improving digestibility by gelatinizing starch and denaturing protein (Harper, 1981) as compared to traditionally thermal processed foods. The extrusion cooking technique is preferable to others in terms of process continuity with high productivity and significant nutrient retention (Guy, 2001; Singh, Gamlath, & Wakeling, 2007). The functional properties of the food ingredients are modified during the extrusion processing process (Asp & Bjorck, 1989); extrusion also destroys or inactivates the anti-nutritional or toxic compounds (i.e. trypsin inhibitors, hemagglutinins, and gossypol etc.), undesirable enzymes such as lipoxigenases, peroxidases, lipoxidases and lipases, microorganisms and other food-borne pests (Harper, 1981).

Extrusion of corn flour products has been extensively studied (Chinnaswamy & Hanna, 1988; Gomez & Aguilera, 1984); however, when such products are made exclusively from corn ingredient, they often lack in macro-nutrients like proteins. There has been a general interest in enriching the nutrient content of extruded foods by adding other nutritional ingredients to the feed mix used in the extrusion process (Guy, 2001; Konstance et al., 1998). Incorporating soy protein isolates (SPI) into corn flour can significantly increase its protein content and quality characteristics of the extruded product (Harper, Mercier, & Linko, 1989). With the development of the soybean processing industry, the soy crop has proven to be a low cost, and widely available source of superior quality protein. The use of SPI in extrusion products provides a high quality protein source, rich in lysine and bland in flavor, while reducing the flatulence factors and reducing sugars associated with whole soy flour. Thus SPI, widely used as a functional ingredient in the food industry, is believed to contribute to the overall improvement in extrusion product quality (Konstance et al., 1998).

* Corresponding author. Tel.: +1 514 398 7919; fax: +1 514 398 7977.
E-mail address: hosahalli.ramaswamy@mcgill.ca (H.S. Ramaswamy).

0023-6438/$ – see front matter
http://dx.doi.org/10.1016/j.lwt.2012.05.012

Showing a high potential to improve the nutritional profile of starch-based extruded food products (Sun & Muthukumarappan, 2002), SPI also has been credited with several potential health benefits. People with high (*vs.* low) soybean intakes have lower rates of coronary heart disease, breast cancer and osteoporosis (Liu, 2004; Sun & Muthukumarappan, 2002). Indeed, a statement that "including 25 g of soy protein per day in a diet low in saturated fat and cholesterol may reduce the risk of heart disease by lowering blood cholesterol levels" was approved by the US Food and Drug Administration (FDA, 1999). To uphold this soy protein health claim a single serving of the food must contain a minimum of 6.25 g of soy protein (FDA, 1999). Meeting the FDA soy protein threshold necessary to make such health claims can be achieved by producing SPI-enriched food products (i.e. extruded soy-corn blend food products) for all three meals and for snacks.

A number of studies have attempted to meet these goals. Konstance et al. (1998) produced extrudates combining corn meal with soy flakes, soy protein concentrate and soy oil. Faller, Klein, and Faller (1999) developed acceptable extruded snack products containing soy protein, and evaluated the influence of soy protein type, soy content, and moisture content. Muhungu et al. (1999) extruded corn flour and soy protein to investigate the influence of barrel temperature, moisture content, and relative residence time on extruder response and isoflavone profile. Sun and Muthukumarappan (2002) examined the effects of defatted soy flour content, feed moisture, screw speed and temperature on the functionality of soy-based extrudates. Seker (2005) evaluated the expansion ratio, bulk density and water solubility index of extrudates of SPI-modified corn starch mixtures. The effects of moisture content, screw speed and soybean content on the textural qualities of soybean-corn starch extrudates were studied by Li, Zhang, Jin, and Hsieh (2005).

In our previous study (Yu, Ramaswamy, & Boye, 2009), the effects of feed moisture, screw speed and barrel temperature on physical properties of extruded corn flour-SPI (20 g protein/100, dry matter basis) blends were studied to understand the influence of extrusion process on the product and to identify working range of parameters. Within the framework of this study, processing conditions (*e.g.*, extrusion temperature, feed moisture and screw speed) were analyzed for constraint based optimization to provide end-products with a wide range of physical quality parameters (e.g., expansion ratio, bulk density, breaking stress, water solubility index, rehydration ratio and color). While the study showed very promising results producing high value products, the protein content was limited to a maximum of about 25 g/100 g (dry matter basis). This was because of the experimental design and somewhat broader objectives.

The previous experimental design was refined to include much higher levels of protein content (32.2–66.6 g/100 g dry matter basis) so that the product could be used as a protein supplement. In order to limit the experimental variables to 3, only two of the three factors from the previous study (moisture content and temperature) were employed in this study so that the same 20 run CCRD design could be employed. While the study may look similar, the influencing parameters and their ranges selected were quite different (temperature in the range of 126.4–193.6 °C and feed moisture content in the range of 31.6–48.4 g/100 g (wet basis) as compared with the earlier 140–180 °C, and 18–38 g/100 g, respectively) making the study and the product significantly different. The overall objectives were to evaluate the effects of processing parameters (protein content, feed moisture content, and extrusion processing temperature) on the quality of extruded protein rich products and assess their optimization scenarios.

2. Materials and methods

2.1. Materials

Corn flour from Brar Natural Flour Mills (Winnipeg, MB) was purchased from a local market. The composition of the flour was: fat, 1.7 g/100 g (wet basis); carbohydrate, 76.7 g/100 g (wet basis); protein, 10 g/100 g (wet basis) and moisture, 12 g/100 g (wet basis). Soy protein isolate containing protein, 90 g/100 g (wet basis); carbohydrates, 5 g/100 g (wet basis) and moisture 5 g/100 g (wet basis) was obtained from American Health & Nutrition (Ann Arbor, MI), while soy flour containing protein 40 g/100 g (wet basis); fat, 22 g/100 g (wet basis); carbohydrates 33.5 g/100 g (wet basis) and moisture, 4.5 g/100 g (wet basis) was obtained from Soyador (Quebec, Canada). The purpose of adding soy flour to the mixture was to provide some natural fat for lubrication of the extruder during the process. To a small extent some fat also came through corn flour. The moisture contents of all the flours were measured before mixing. The soy flour used was full fat regular ground flour. The amount of soy flour added was relatively small to give a calculated 2 g/100 g (dry basis) of fat in the product. It was found necessary in our laboratory system to have this fat in the feed mix so that the extrudates emerge out easily. We assumed it was due to the lubrication and resulting in less stickiness problem during clean-up.

2.2. Extrusion process

A co-rotating twin screw extruder (DS32-II, Jinan Saixin Food Machinery, Shandong, P. R. China) was used in all extrusion processes. The barrel was equipped with four independent temperature controlled zones. The first zone (after the feeding section) temperature was controlled at 110 °C, second and third zones (mixing part) were controlled at 135 °C and 150 °C, the temperature of the fourth barrel zone (metering section) was adjusted to the required levels as one of the variables. The diameter of the screw was 30 mm. The length to diameter ratio of the extruder barrel was 20:1. The diameter of the hole in the die was 5 mm with a die length of 27 mm. A constant screw speed of 100 revolutions per minute (rpm) was selected based on previous experimental results, and to limit the number of process variables to three. The extruder was fed automatically through a conical hopper, keeping the flights of the screw fully filled and avoiding accumulation of the material in the hopper.

After stable conditions were established, extrudates were collected and cut into 35 mm long cylindrical specimens and air dried at 55 °C for 120 min by a convection oven with an air velocity of 0.1 m/s as measured by an anemometer to a moisture content of 9–10 g/100 g wet basis. Dried samples were stored in air-tight plastic containers at room temperature until analysis.

2.3. Experimental design of soy protein isolate and corn starch blend extrusion

In a previous experiment (Yu et al., 2009), different variables including screw speed, moisture content and barrel temperature were tested, in order to get a protein enriched product by maintaining a 20 g/100 g SPI level in the feed mixture. In this study, protein content was used as one of the prime variable and two other independent variables (barrel temperature and moisture content) were selected and investigated using a central composite rotatable design (CCRD) (Draper, 1982). Protein content was varied from 32.2 to 66.6 g/100 g (dry basis); feed moisture content from 31.6 to 48.4 g/100 g (wet basis); and extrusion barrel temperature (metering section) from 126.4 to 193.6 °C. Overall, 20 experimental runs were made, each with 8 (2^3) factorial points (three level for