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Optimization of the extrusion process for development of high fibre soybean-rice ready-to-eat snacks using carrot pomace and cauliflower trimmings

Mohammed Shafiq Alam*, Shivani Pathania, Anjali Sharma

Department of Processing and Food Engineering, College of Agricultural Engineering, Punjab Agricultural University, Ludhiana, Punjab, 141004, India

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ABSTRACT

Ready-to-eat low-cost and nutritious extruded snack was developed from composite flour comprising rice, defatted soybean flour, carrot pomace powder and cauliflower trimmings powder. Experimental design was carried out using Box Behnken design of response surface methodology. Experimental variables included die temperature (125–175 °C), screw speed (300–500 rpm) and cauliflower trimmings and carrot pomace powder (7.5–17.5 g/100 g), pulse powder (7.5–17.5 g/100 g) in rice flour (65–85 g/100 g). Extrudate properties were assessed by analyzing bulk density, expansion ratio, water absorption index, water solubility index, hardness, color change, overall acceptability, protein content and fibre content. Analysis of variance revealed that die temperature had the most significant impact among all variables followed by rice flour. The optimum extrusion conditions were 164 °C die temperature, 313 rpm screw speed and 85 g/100 g rice flour with a desirability value of 76.0%. Results showed that optimum composite flour blends 15 percent of defatted soybean flour, carrot pomace powder and cauliflower trimmings powder in rice flour. The blend proportions under optimum extrusion conditions had improved nutritional quality with 10.25 g/100 g protein and 0.84 g/100 g of fibre content.

1. Introduction

The consumption pattern for ready-to-eat, convenient and inexpensive snacks is increasing at a dramatic pace especially in developing countries (Oluwamukomi, Oluwalana, & Akinbowale, 2011; Omoba, Awolu, Olagunju, & Akomolafe, 2013). Different protein sources viz. kresting groundnut, chickpea, mungbean have been added to improve the nutritional quality of rice based snacks (Alam, Khaira, Pathania, Kumar, & Singh, 2015; Awolu, Oluwaferanmi, Fafowora, & Oseyemi, 2015; Pathania, Singh, & Sharma, 2013). Soybean, (*Glycine max*) a grain legume, is one of the richest and cheapest sources of plant protein that can be used to improve the diet of millions of people. The defatted soybean flour, a by-product of oil processing industry, has been used to augment the protein content of the extruded snacks. The plant-derived waste co-products contain significant amount of valuable components, which remain unexploited in the current processes (Stojceska, Ainsworth, Plunkett, & Ibanoglu, 2008; Stojceska, Ainsworth, Plunkett, Ibanoglu, & Ibanoglu, 2008).

The production of high value waste products from food processing industries is a concern. Large amounts of byproducts consisting mainly of peel and pomace and representing 25–35% of the fruit weight are generated. Most of these byproducts are inappropriately disposed causing environmental issues. It is vital to reuse industrial byproducts in order to improve the process economics and sustainability.

Pomace, obtained during carrot juice processing, is a valuable byproduct. It has been reported to be a good source of crude protein, crude fibre, iron, calcium, β-carotene and dietary fibre (Gull, Prasad, & Kumar, 2015; Singh & Kulshrestha, 2008). Dried pomace has β carotene in the range of 9.87–11.57 mg and ascorbic acid in the range of 13.53–22.95 mg per 100 g (Upadhyay, Sharma, & Sarkar, 2008). Another important crop with a high wastage index is cauliflower (*Brassica oleracea* var. Botrytis). The edible leaves and stems are often trimmed after utilizing the 'curd' of this vegetable. They have been widely described as sources of fibre and antioxidants. These bioactive properties make them healthy and nutritious alternatives to be utilized in current food chain (SanzPuig, Pina-

* Corresponding author.
E-mail addresses: ms_alam@rediffmail.com (M.S. Alam), shivani.phd.ft@gmail.com (S. Pathania), anjali.pfe@gmail.com (A. Sharma).

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Perez, Rodrigo, & Lopez, 2015; Stojceska, Ainsworth, Plunkett, & Ibanoglu, 2008; Stojceska, Ainsworth, Plunkett, Ibanoglu, & Ibanoglu, 2008). Recommended dietary fibre intake is being met through innovative ways of introducing dietary fibre into new and appealing products (National Academy of Science, 2002).

Extrusion is a unique food processing operation which utilizes high temperature, short time (HTST) and high shear force to produce a product with distinct physical and chemical characteristics. Extruded products have great potential for growth among the snack foods since they can be made into varieties that capture the imagination of the consumers. Hence, carrot pomace and cauliflower trimmings could profitably be utilized to develop value added products using this technology (Goyal, 2004; Sharma, Karki, Thakur, & Attri, 2012).

The aim of this study was to optimize the extrusion process for development of high fibre, ready-to-eat extruded snacks from composite flour comprising rice, defatted soybean, carrot pomace powder and cauliflower trimmings powder. The effect of novel ingredients on the nutritional properties of ready-to-eat snack was also studied.

2. Materials and methods

2.1. Materials

Broken rice (*Oryza sativa*), defatted soybean flour (*Glycine max*) and salt were purchased from local market in Ludhiana, Punjab. Carrot pomace and cauliflower trimmings were collected from juice vendors and local vegetable market in Ludhiana, Punjab, A laboratory scale co-rotating twin-screw extruder with intermeshing (Model BC2; Clextral, Firminy Cedex, France) available in the Department of Food Science and Technology, Punjab Agricultural University, Ludhiana was used for the extrusion study. All reagents used were of analytical grade.

2.2. Methods

2.2.1. Experimental design for the preparation of composite flour

The experimental design for optimization of rice flour, defatted soybean flour, carrot pomace powder and cauliflower trimmings powder based snacks were carried out using the Box Behnken model of response surface methodology (Design-Expert software version 8.0.3.1, Stat-Ease Inc., Minneapolis, U.S.A) which gave 17 experimental runs (Giles, Wagner, & Eldridge, 2004). The variables were die temperature (DT), screw speed (SS) and rice flour (RF) while the responses were bulk density (BD), expansion ratio (ER), water absorption index (WAI), water solubility index (WSI), Hardness (H), Color change (CC), overall acceptability (OA), Protein content (PC) and Fibre content (FC).

2.2.2. Ingredient preparation

The broken rice were ground with electronic grinder (Make: Sujata 750 W, Mittal Electronics, New Delhi, India) to make flour (RF). Carrot pomace and cauliflower trimmings were pretreated with 1% w/v citric acid separately. The pretreated pomace and trimmings were uniformly placed on a tray dryer at 65 °C till 6.0% (d.b) moisture content was achieved. Dried product was ground in Sujata 750 W grinder (Mittal Electronics, New Delhi, India) to obtain carrot pomace powder (CPP) and cauliflower trimmings powder (CTP) which was stored in sealed laminated aluminum pouches till further use.

2.2.3. Ingredient formulations for preparation of ready to eat extruded snack

The ingredients used for extruded snack preparation were: rice flour, defatted soybean flour, carrot pomace powder, cauliflower trimmings powder and salt (Table 1). CPP and CTP were mixed in equal proportion in a food processor with mixture attachment (Kenstar Karishma Royal 600-Watt Multi Processor, Maharashtra, India). The rice flour (65–85 g/100 g), defatted soy flour (7.5–17.5 g/100 g) and CPP and CTP powder (7.5–17.5 g/100 g) were mixed in given proportions in a food processor with mixer attachment. After mixing, samples were packed and stored in polyethylene bags at refrigerated temperature for 24 h (Stojceska, Ainsworth, Plunkett, & Ibanoglu, 2008; Stojceska, Ainsworth, Plunkett, Ibanoglu, & Ibanoglu, 2008).

2.2.4. Protein and fibre analysis

Protein and fibre content of the extrudates was determined by standard procedures outlined by Association of Official Analytical Chemists (AOAC, 2005).

2.2.5. Determination of functional properties of the composite flour

2.2.5.1. Bulk density (BD). The volume of expanded sample was measured by rapeseed displacement method using 100 ml graduated cylinder. The volume of 20 g randomized samples was measured for each test. The ratio of ample weight to the replaced volume in the cylinder was calculated as BD (w/v) (Patil, Berrios, Tang, & Swanson, 2007).

$$Bulk\ Density = \frac{4m}{\pi d^2 L}$$

where m is mass, g of a length L, cm of extrudates with diameter d, cm.

2.2.5.2. Expansion ratio (ER). The diameter of extrudate was determined as the mean of 10 random measurements made with a vernier caliper (Fan, Mitchell, & Blanshard, 1996). The ER was calculated as

$$\text{Expansion ratio} = \frac{\text{Extrudate Diameter}}{\text{Die Diameter}}$$

2.2.5.3. Water absorption index (WAI) and water solubility index (WSI) of extrudates. A 2.0 g ± 0.005 g sample was placed in a tarred centrifuge tube and 20 ml distilled water was added. After keeping for 15 min (with intermittent shaking every 5 min), the sample was centrifuged at 4000 rpm for 15 min. The supernatant was decanted into a tarred aluminum pan and weight gain in the gel was noted (Kaur & Singh, 2006). WAI was calculated as the increase in weight of sediment obtained after decanting the supernatant as:

$$\text{WAI} = \frac{\text{Weight of wet sediment(g)}}{\text{Weight of dried sediment(g)}}$$

The supernatant was evaporated at 105 °C to dryness until constant weight. WSI was determined as (Nyombaire, Siddiq, & Dolan, 2011):

$$\text{WSI}(\%) = \frac{\text{Weight of dried supernatant(g)}}{\text{Weight of dried sample(g)}} \times 100$$

2.2.5.4. Hardness (H). Hardness of extrudates was determined by crushing method using a TA-XT2i (Stable Micro-Systems, Surrey, England). The tests were conducted at pre–test speed of 1.0 mm/s, test speed of 5 mm/s, post test speed of 5 mm/s, strain-50%, trigger force of 0.4903 N and load cell of 50 kg.