LWT - Food Science and Technology 64 (2015) 490–496

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Antioxidant activity, free gamma-aminobutyric acid content, selected physical properties and consumer acceptance of germinated brown rice extrudates as affected by extrusion process

Parisut Chalermchaiwat [a, b], Kamolwan Jangchud [a, *], Anuvat Jangchud [a], Chulaluck Charunuch [c], Witoon Prinyawiwatkul [d]

[a] Department of Product Development, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand
[b] Department of Home Economics, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand
[c] Institute of Food Research and Product Development, Kasetsart University, Bangkok 10900, Thailand
[d] School of Nutrition and Food Sciences, Louisiana State University, Agricultural Center, Baton Rouge, LA 70803, USA

ARTICLE INFO

Article history:
Received 22 October 2014
Received in revised form
26 April 2015
Accepted 28 April 2015
Available online 9 May 2015

Keywords:
Antioxidant activity
Extrusion
Gamma-aminobutyric acid (GABA)
Germinated brown rice flour
Phenolic content

Chemical compounds studied in this article:
Gallic acid (PubChem CID: 370)
2,2-Diphenyl-1-picrylhydrazyl (PubChem CID: 2735032)
Sodium acetate (PubChem CID: 517045)
Sodium carbonate (PubChem CID: 10340)
2,4,6-tri-(pyridin-2-yl)-1,3,5-triazine (TPTZ) (PubChem CID: 77258)
Dabsyl Chloride (PubChem CID: 91660)
Methanol (PubChem CID: 887)

ABSTRACT

Effects of feed moisture (14, 18, and 22 g/100 g) and screw speed (300, 350 and 400 rpm) on selected physical properties, gamma-aminobutyric-acid (GABA) content, antioxidant activity and consumer acceptance of extruded snacks from germinated brown rice flour (GBRF) were investigated. Changes in feed moisture significantly affected physical properties of extrudates whereas screw speed showed less effects. Decreasing feed moisture caused a decrease in bulk density and hardness, but an increase in expansion ratio. Decreasing feed moisture increased destruction of free GABA in extrudates. DPPH radical-scavenging activities, ferric reducing antioxidant power and total phenolic content of extrudates were significantly lower than those of the non-extruded GBRF. The predicted optimum extrusion condition (16–19 g/100 g feed moisture; 300–320 rpm screw speed) would yield extrudates with 25–30 mg/100 g extrudate (dry-basis) free GABA content and an overall liking score of 6.0 (on a 9-points hedonic scale).

1. Introduction

Extrusion has become a very important process in the manufacture of snack foods due to its ease of operation and ability to produce a variety of desirable sizes, shapes and textures (Brennan, Derbyshire, Tiwari, & Brennan, 2013). Many studies (Brennan, Brennan, Derbyshire, & Tiwari, 2011; Singh, Gamlath, & Wakeling, 2007) have reported positive and negative effects of the extrusion process on nutritional quality of food and feed mixtures produced under raw material characteristics (composition and particle size) and various extrusion conditions (temperature, feed moisture, and screw speed). Feed moisture is a critical factor affecting the extrusion temperature and pressure, product texture and nutrients. Screw speed affects the degree of mixing of ingredients, and product quality and uniformity.

Extrusion cooking inactivated some antinutritional factors, especially trypsin inhibitors, haemagglutinins, tannins and phytates, all of which inhibit protein digestibility (Singh et al., 2007). In addition, it was effective in improving protein and starch digestibility, and increasing fibre solubility (Repo-Carrasco-Valencia,

* Corresponding author. Tel.: +66 2 562 5007; fax: +66 2 562 5005.
E-mail address: fagikwj@ku.ac.th (K. Jangchud).

http://dx.doi.org/10.1016/j.lwt.2015.04.066

Pena, Kallio, & Salminen, 2009). However, an extrusion process reduced antioxidant activities in the extruded products of grain, cereal and beans (Anton, Fulcher, & Arntfield., 2009). Extrusion resulted in loss of phenolic compound in red bean-corn starch mixed extruded product (Anton, Fulcher, & Arntfield., 2009) and sorghum grain (Dlamini, Taylor, & Rooney, 2007), and tocopherols and tocotrienols content in extruded cereal (Zielinski, Kozlowska, & Lewczuk, 2001). In contrast, some studies showed good retention of some antioxidant compounds during extrusion for rice (Ohtsubo, Suzuki, Yasui, & Kasumi, 2005), wheat, barley, and rye (Zielinski et al., 2001). Greater consumer demand for nutritious extruded snacks with enhanced bioactive compounds has shifted research focus towards incorporation of bioactive compound-rich ingredients in extruded starch materials (Brennan et al., 2011).

Germinated brown rice flour (GBRF) has become an attractive healthy ingredient due to its high gamma-aminobutyric acid, GABA (Charoenthaikij et al., 2009), phenolic compound (Tian, Nakamura, & Kayahara, 2004) and fibre content. Kayahara and Tsukahara (2000) found that continuous intake of germinated brown rice would prevent colon cancer, regulate a blood sugar level and prevent heart disease. Some researchers investigated the extruded products from GBRF. For example, Chanlat, Songsermpong, Charunuch, and Naivikul (2011) reported that feed moisture content and screw speed had insignificant effect on the GABA content of extruded snacks made from pre-germinated brown rice. However, physicochemical properties, GABA and antioxidant activity of extruded snacks from GBRF prepared from Khao Dawk Mali 105 (*Oryza sativa* L. cv. KDML-105) have not been fully studied. Khao Dawk Mali 105 is the most famous Thai rice variety for its overall quality, particularly taste, soft texture and unique aroma. It is widely accepted for consumption worldwide.

Therefore, the objectives of this research were to study the effect of extrusion conditions (feed moisture and screw speed) on selected physicochemical properties, free GABA content and antioxidant activity of extruded snacks made from GBRF, and to preliminarily identify an optimal extrusion condition to produce an acceptable GABA-enriched snack.

2. Materials and methods

2.1. Preparation of paddy rice and germinated brown rice flour (GBRF)

Khao Dawk Mali 105 (*Oryza sativa* L. cv. KDML-105) paddy rice was provided by the Department of Agriculture, Sakhonnakorn province, Thailand. It was packed in plastic bags made of linear low-density polyethylene (LLDPE), placed in cardboard containers and stored at 8 °C prior to the experiment. Brown rice was produced by mechanically removing the husk of paddy rice. GBRF (≥60 mesh) was prepared according to the method of Songtip, Jangchud, Jangchud, and Tungtrakul (2012).

2.2. Extrusion process

GBRF was thoroughly mixed with soy protein isolate (9 g/100 g flour) and calcium carbonate [0.45 g/100 g flour; to increase crispness, smooth texture, and non-gritty mouthfeel (Frame, 1994)] by a mixer for 10 min, packed in LLDPE bags and stored at 25 °C before extrusion. A co-rotating twin-screw extruder (Hermann Berstorff Laboratory, ZE 25 x 33D, Hannover, Germany), equipped with a barrel with 7 sections, ending with a 24.5-mm thick die plate and one circular die hole (2.5 mm diameter), was used. The barrel length-to-diameter ratio (L/D) of the extruder was 870:25. The mixed flour was fed into the extruder with a volumetric feeder (K-Tron soder AG 5702, type 20, Switzerland). Tap water was pumped into the first barrel section to maintain the required moisture content. The barrel temperature profile was 35 °C (section 1), 45 °C (section 2), 55 °C (section 3), 95 °C (section 4), 125 °C (section 5), 140 °C (section 6), 130 °C (section 7) and 120 °C (at the die plate). The feed rate was controlled at 3.6 kg/h. After extrusion, the extrudates were collected, dried in a forced-air oven at 80 °C for 10 min, vacuum packaged in LLDPE plastic bags, and stored at 25 °C until further analysis. Two separate batches of extrudates were prepared.

2.3. Experimental design

A 3 × 3 factorial arrangement in a completely randomised design (CRD) with three levels of feed moisture (14, 18 and 22 g/100 g) and screw speed (300, 350 and 400 rpm) was used. The non-extruded GBRF served as a control. Two separate batches of extrudates were measured for physicochemical properties, free GABA content, antioxidant activities, and sensory acceptability.

2.4. Physical properties of extrudates

2.4.1. Bulk density (BD) and expansion ratio (ER)

BD was measured using a seed displacement method (Bhatnagar & Hanna, 1995). BD (g/cm^3) on a dry basis was calculated as [Weight of the extrudates/volume displaced]; each value was an average of ten independent measurements. A Vernier caliper (Mitutoyo Co., Ltd., Japan) was used to measure a diameter of extrudate (ten randomly chosen pieces), and the sectional ER of the extrudate was reported as a ratio of the averaged diameter of the extrudate to the die hole (Alvarez-Martinez, Kondury, & Harper, 1988).

2.4.2. Texture hardness

Hardness of the extrudates was measured with a TA-XT plus Texture Analyzer (Stable Micro System, Texture Technologies Crop. NY, USA) using the following conditions: a 36 mm cylinder probe, at 5 mm/s pre-test speed, 5 mm/s test speed, and 10 mm/s post-test speed. The moisture content of the extrudates was 2.5 ± 0.5 g/100 g (wet-basis) for texture analysis. Each piece of sample was compressed into half of its height until broken (Ding, Ainsworth, Tucker, & Marson, 2005). Hardness was expressed as an average of maximum peak force from ten independent measures.

2.5. Determination of free GABA content, total phenolic content (TPC) and antioxidant activity

Free GABA content was determined in triplicate according to the method of Cohen and Michaud (1993), using HPLC (Agilent 1100 Series, Agilent Technologies, Calif., USA) equipped with a column (Supelcosil™ LC-DABS, 4.6 mm I.D.×150 mm, Sigma–Aldrich Co. LLC, St. Luis, Mo., USA). Acetonitrile-acetate buffer pH 6.8 (20:80, v/v) was used as the mobile phase with a flow rate of 1.0 mL min^{-1} and an injection volume of 10.0 μL. The column temperature was 40 °C and the UV detector was set at 315 nm. For a model validation, triplicate measurements were performed for the extrudates prepared under selected conditions.

Ground extrudate (2.0 g) was mixed with methanol, agitated using a magnetic stirrer for 30 min at room temperature, and then centrifuged at 2500 *g* for 10 min. The supernatant was collected. The residue was re-extracted twice under the same conditions, resulting finally in 50 mL extract in methanol. All extracts were used for total phenolic content and antioxidant activity. TPC (mg gallic equivalent [GAE] per 100 g extrudate, db) was determined using the Folin-Ciocalteau assay (1927). The antioxidant activity was evaluated in triplicate in the methanol resuspended extracts by