Journal of Cereal Science 74 (2017) 64–71

Contents lists available at ScienceDirect

Journal of Cereal Science

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

Stabilization of Tarom and Domesiah cultivars rice bran: Physicochemical, functional and nutritional properties

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ARTICLE INFO

Article history:
Received 14 June 2016
Received in revised form
18 January 2017
Accepted 30 January 2017
Available online 2 February 2017

Keywords:
Rice bran
Physicochemical
Nutritional
Stabilization
Functional

ABSTRACT

Extrusion is a multi-step thermal process which has been extensively utilized in food preparations. Effects of temperature, moisture content and speed screw on the stabilization of rice bran were optimized using response surface methodology. Furthermore, the effect of extrusion processing on the physicochemical, nutritional and functional properties of Tarom and Domesiah cultivars stabilized rice bran (SRB) were studied. The colour of rice bran was improved by extrusion processing, but the protein content was reduced, which can be related to the denaturation of protein. Extrusion had also a reduction significant effect on the phyitic acid and vitamin E in stabilized rice bran. However, the content of vitamins B_2, B_3, B_5 and folic acid were remained unchanged, but the dietary fibre was enhanced which has beneficial health effect. In comparison with raw rice bran, water holding capacity was enhanced, but the oil absorption capacity was reduced. Foaming capacity and foaming stability of SRB was more than that of untreated rice bran. Although, they were less than that of rice bran protein concentrate/isolate. As a result, extrusion process improves some functional and nutritional properties of rice bran which are valuable for industrial applications and have potential as food ingredient to improve consumer health.

1. Introduction

Rice bran is an inexpensive by-product of raw rice, which widely cultivated in many countries all over the world. The global production of paddy rice in 2014 was over 738 million metric tons (MMT), which providing approximately 70 MMT of bran (FAO, 2014). However, rice bran possesses important components such as proteins and phytochemicals that supply beneficial health effects on the human body; it is mainly used for animal feed. Being high in protein, particularly the essential amino acid lysine, soluble and insoluble dietary fibre, it exhibits high nutritional value for human consumption. Thus, these properties are considered a healthy functional food, which has hypoallergenic, hypocholesterolmic and antioxidative properties (Rafe et al., 2014). Indeed, the healthy effects of rice bran have encouraged many researchers to study its ability to use as an important source of nutrients in food ingredients (Rafe et al., 2014; Lilitchan et al., 2008).

In spite of the benefits of rice bran, due to the oxidation of edible oil, it cannot be directly utilized for human consumption and needs further processing. Since, rice bran is rich in lipids and possesses lipoxygenase which make it susceptible to hydrolytic rancidity, it needs enzymatic inactivation instantly prior to any application to avoid fatty acid liberation and to extend its shelf life and permit its commercialization for human consumption. Extrusion cooking is one of the most suitable procedures to stabilize rice bran (Ramezanzadeh et al., 1999). It is a multi-step, multi-functional thermal process which utilizes high heat, pressure and shear (Kim et al., 2006; Singh et al., 2007). The extrusion process has many advantages such as low cost, high speed, efficiency, flexibility, unique product shapes and energy savings over other common processing methods (Faraj et al., 2004). Some chemical changes including gelatinization of starch molecules, cross-linking of proteins and flavor production have occurred during extrusion. Enochian et al. (1981) have conducted the economically feasibility study for stabilization of rice bran by extrusion cooking and have shown that it would be practical in certain developing countries. Since, in a few countries such as Iran, stabilized rice bran (SRB) is not broadly available at supermarkets, its stabilization can be suitable for further applications such as food supplement.

However, many works have been accomplished on the stabilization of rice bran and the effect of extrusion on some functional properties of food have been studied (Singh et al., 2007), but they

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http://dx.doi.org/10.1016/j.jcs.2017.01.019
0733-5210/

still lack of knowledge concerning on the stabilized rice bran and surveying its functional and nutritional properties. Furthermore, there is no research work on the optimization of rice bran extrusion process by response surface methodology (RSM). Therefore, the aim of the current work is (i) to compare the functional, nutritional and biophysical characteristics of rice bran before and after stabilization and (ii) to optimize the extrusion processing variables such as temperature, feed moisture and screw speed based on the stability indices of rice bran by RSM. Certainly, these evaluations can be vital to utilize rice bran as a food ingredient for the human diet. In the view point of competitive market aspect, when more added-value was found for rice bran, and more scientific knowledge concerning with its health benefits was achieved, it is expected that more industrial interest in processing of rice bran will be more valuable for human consumption than its use as animal feed.

2. Materials and methods

2.1. Materials

The commercially dried rough rice of Tarom and Domesiah cultivars were kindly provided from Ricelands of Dargaz (Dargaz, Razavi Khorasan Province, Iran) and Kalat (Dargaz, Razavi Khorasan Province, Iran), respectively. They were packed in a hermetic plastic bag and kept in a refrigerator (3 °C) until further processing. The ingredients were all of analytical grade and purchased from Merck or Sigma-Aldrich Co. (St. Louis, MO).

2.2. Stabilization of rice bran

Rice bran was stabilized by a twin-screw co-rotating, self-cleaning extruder (DS56-X, Jianan Saixin Machinery Co., Jinan, China), with length/diameter ratio of 25, screw speed up to 600 rpm. A computerized control and data acquisition system were used to control temperatures and rotor speed. The barrel zone temperatures were set constant at 30, 60 and 100 °C. The die temperature was changed according to the experimental design. Based on our preliminary experiments; temperatures varied from 100 to 130 °C, moisture changed from 10 to 13% by adding appropriate amount of water at the first zone of extruder and screw speed was selected from 300 to 450 rpm. The bran was kept for 3–5 min in the extruder to ensure lipase inactivation. Then, it was cooled to ambient temperature, milled and sieved by mesh of 500 μm. Ultimately, the bran samples were immediately packed in polyethylene bags and stored at 4 °C until analyses were completed.

2.3. Experimental design and analysis

A three-level, three-variable, central composite design was used. The independent variables were die temperature (X_1), screw speed (X_2) and moisture content (X_3). These variables were coded at levels of −1.68, −1, 0, 1 and + 1.68. The range of variables was established based on literature and preliminary tests. Dependent variables were specific as FFA content and residual peroxidase activity as product responses in percent. The results were analyzed by quadratic model to describe the effects of variables and experimental data were fitted to the selected models. Statistical significance of the terms was examined by analysis of variance (ANOVA) for each response.

Desirability functions as one of the useful approaches to optimization of multiple responses was applied as follows: (i) perform experiments and fit response models (y_i) for all m responses, (ii) describe individual desirability functions for each response (d_i) and (iii) maximize the overall desirability with respect to the controllable factors. The general approach is first to convert each response y_i into an individual desirability function d_i that varies from 0 to 1 value in which $d_i = 1$ at the target value and $d_i = 0$ outside an acceptable region. The design variables were selected to maximize the overall desirability as $D_o=(d_1 d_2,\ldots\ d_m)^{1/m}$, where m is the number of responses and D_o is the overall desirability. Since, the individual desirability functions are not differentiable, overall desirability is computed by Design-Expert for evaluation of optimal processing conditions (Myers and Montgomery, 2002).

2.4. Quality characteristics of stabilized rice bran

The peroxidase activity was evaluated based on the colorimetric method and maximum absorbance was measured at 430 nm. Lipase activity was assayed by a calorimetric method described by Kim et al. (2006) where the free fatty acids (FFA) released from a triolein emulsion with an extract of defatted bran per unit time at defined conditions was determined as the colour developed from a complex between the FFA and cupric ion. Residual lipase activity in the stabilized bran was calculated as a percentage of the activity in raw bran.

2.5. Physicochemical characteristics

The protein, fat, moisture and ash of unstabilized rice bran (USRB) were measured by the methods of Association of Official Analytical Chemists Society (AOAC, 2000). Soluble dietary fibre was also determined with some modifications by the procedure of Zhang et al. (2011). The carbohydrate content was calculated by subtracting the amount of other ingredients from 100.

The physical properties of samples were determined by bulk density and solubility index. Bulk densities of rice bran before and after 100-tapping were determined based on our previous work (Esmaeili et al., 2016). An aliquot of 50 g of rice bran powder was poured into a 100-ml graduated measuring cylinder. The cylinder was tapped several times (100) on a lab bench to approach a constant volume. Then, the bulk density (ρ_b) values were calculated prior to and after tapping and were given as g/ml. The solubility of bran was also determined by preparing 10% solution of rice bran in distilled water. The solutions were centrifuged at 5000 g for 5 min and the supernatant was removed. The insolubility index was determined in percent.

2.6. Appearance characteristics (image processing)

Image acquisition and processing of processed and untreated of rice bran was performed based on the published literature (Abdollahi Moghaddam et al., 2015). Briefly, the images were captured by a colour digital camera (Canon EOS 1000D, Taiwan) with resolution (2272 × 1704 pixels) in a wooden black box, and they were saved on a computer with software (Canon Utilities Zoom Browser EX version 6.1.1) in JPEG format. The image processing was accomplished by the Image J software (National Institutes Health, Bethesda, Md, USA) after improving the image quality. Then, RGB images were converted into L*a*b* units in which L* is lightness (0 (black) to 100 (white)), a* is varied from red (+60) to green (−60) index and b* is ranging from yellow (+60) to blue (−60). The total colour change (ΔE) was also determined by the following equation:

$$\Delta E = \sqrt{\left(L_2^* - L_1^*\right)^2 + \left(a_2^* - a_1^*\right)^2 + \left(b_2^* - b_1^*\right)^2} \quad (1)$$

where, subscribes 1 and 2 are before and after processing with extrusion cooking, respectively.