LWT - Food Science and Technology 78 (2017) 281–288

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Simultaneous rough rice drying and rice bran stabilization using infrared radiation heating

Tianxin Wang [a, b], Ragab Khir [a, c], Zhongli Pan [a, d, *], Qipeng Yuan [b]

[a] Department of Biological and Agricultural Engineering, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA
[b] College of Life Science and Technology, Beijing University of Chemical Technology, Beijing, 100029, China
[c] Department of Agricultural Engineering, Faculty of Agriculture, Suez Canal University, Ismailia, 41522, Egypt
[d] Healthy Processed Foods Research Unit, USDA-ARS-WRRC, 800 Buchanan St., Albany, CA 94710, USA

ARTICLE INFO

Article history:
Received 19 September 2016
Received in revised form
19 December 2016
Accepted 21 December 2016
Available online 24 December 2016

Keywords:
Rough rice
Rice bran
Drying
Infrared
Stabilization
Tempering
Milling quality

ABSTRACT

The objective of this study was to develop a new rice drying method using IR heating followed by tempering. Freshly harvested medium grain rice (M206) samples with different initial moisture contents (IMCs) were used in this study. The samples were dried for one- and two-passes using a catalytic IR emitter to reach rice surface temperature of 60 °C. After IR heating, the samples were tempered in an incubator at 60 °C for different durations ranging from 1 to 5 h. The effects of new drying method on moisture removal, milling quality, and shelf life of rice bran were evaluated. High heating and drying rates and good milling quality of rough rice were achieved. It took only 55 s to heat the rice samples to 60 °C. For one-pass drying and 4 h tempering treatment, the total moisture removals were 3.33, 3.78 and 5.89 g moisture/100 g dry solid for samples with initial moisture contents of 20.06, 25.53 and 32.50 g moisture/100 g dry solid, respectively. IR heating did not generate adverse effects on milling quality of rough rice. Importantly, the storage stability of rice bran from the new drying method was extended to 38 days compared 7 days from current drying practice.

1. Introduction

Rice bran, an important by-product of rice milling, constitutes 8–10% of the weight of brown rice. It contains valuable components such as proteins, vitamins and essential minerals and has 15–22% of edible oil with high nutritional and functional characteristics (Luh, 1980). The antioxidants in the rice bran also showed effect in lowering cholesterol in humans (Carvalho, 2006). Despite of its high nutrition value rice bran is underutilized and frequently wasted, except it is used for producing oil. In general, utilization of rice bran is severely restricted by the activity of endogenous enzymes, such as lipase, which can hydrolyze the triglyceride into glycerol and free fatty acids (FFAs). When rice is milled, bran is scoured and lipase is exposed to the oxygen in air, then the oxidation starts, resulting in the deterioration of the oil quality and forming off flavor (Luh, 1980). It takes only less than one week to make the FFAs in the oil exceed 10%, and then the rice bran oil is no longer suitable for human consumption (Desikachar, 1977; Qian, Gu, Jiang, & Chen, 2014). In order to better utilize the rice bran from rice milling process, the oil must be extracted quickly after milling process to control FFAs at a low level. However, this practice may not be feasible due to restriction of facility and production schedule (Randall et al., 1985). Therefore, it is a normal practice that the bran undergoes a stabilization process to inactivate the potent lipase enzyme immediately after milling to extend storage time at ambient conditions for controlling the FFAs concentration at a low level (less than 10%) before oil extraction.

Many approaches on the stabilization of rice bran have been investigated and reported, such as chemical methods (Prabhakar & Venkatesh, 1986), heat methods (Rao Lakkakula, Lima, & Walker, 2004), extrusion (Sayre, Nayyar, & Saunders, 1985) and microwave treatment (Tao, Rao, & Liuzzo, 1993). The most common method used in rice industry is extrusion even though it is an energy intensive process. The rice bran stabilization depends on temperature, duration of heat treatment, moisture content, PH, and other parameters (Luh, 1980; Tao et al., 1993). Hot air heating could be used, but it may not be able to heat the bran quickly to the needed temperature with desired uniformity (Kim, Byun, Cheigh, & Kwon, 1987; Pacheco de Delahaye, Jimenez, & Perez, 2005). The

* Corresponding author. Department of Biological and Agricultural Engineering, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA.
E-mail addresses: zlpan@ucdavis.edu, zhongli.pan@ars.usda.gov (Z. Pan).

http://dx.doi.org/10.1016/j.lwt.2016.12.041
0023-6438/Published by Elsevier Ltd.

severe and non-uniform heating could damage valuable components and also result in high energy consumption. Moreover, these stabilization processes are typically operated right after rice milling, which may not be feasible for certain rice mills.

Freshly harvested rough rice is subjected to drying to reduce the MC to the safe storage level (14.9 g moisture/100 g dry solid). At present, the hot air drying at a low air temperature (about 43 °C or ambient air) is typically used in the rice industry to minimize the fissure of rice caused by high heat. The low drying temperature extends the required drying time and cannot inactivate the enzymes in the rice bran. Therefore, it is ideal to develop alternative techniques that can simultaneously achieve drying of rough rice and stabilization of rice bran.

Infrared (IR) radiation heating offers many advantages compared to conventional drying methods (Das, Das, & Bal, 2004; Sharma, Verma, & Pathare, 2005). It may offer a promising potential in achieving efficient drying and simultaneously inactivating the lipase in rice bran without affecting the rice quality. When IR is used to heat or dry moist materials, the radiation impinges on the exposed material and penetrates it, and then the radiation energy is converted into heat (Ginzburg, 1969). The penetration could provide more uniform heating in the rice kernel and may reduce the moisture gradient during heating and drying. Also, the rice can be quickly heated to high temperatures in a short time. Our previously consecutive studies have confirmed that high moisture diffusivity corresponding to high drying rate for rough rice can be achieved by using infrared (IR) heating to 60 °C followed by tempering treatment for 4 h and natural cooling. Simultaneously, effective disinfestation and disinfection have also been achieved without compromising milling quality. Extended shelf life of both rough and brown were also achieved (Ding et al., 2015, 2016; Khir, Pan, Salim, Hartsough, & Mohamed, 2011; Khir et al., 2014; Pan et al., 2008, 2011; Wang et al., 2014). Accordingly, drying using IR heating followed by tempering treatment may be an effective approach to achieve stabilized rice bran and extent its shelf life after milling without additional stabilization process. However, there is no literature published about the effects of IR heating and tempering treatment under one- and two-pass drying processes on drying characteristics, milling quality and shelf life of rice bran. Therefore, the objectives of this research were to (1) investigate the effects of IR heating and tempering treatment on the drying characteristics and milling quality of rough rice under one- and two-pass drying; (2) determine the effect of new drying method on the FFA concentration of rice bran oil over different storage periods; and (3) investigate the kinetics of lipase enzyme inactivation under IR heating and tempering treatments.

2. Materials and methods

2.1. Samples

Freshly harvested medium grain rice, variety M206, obtained from the Farmers' Rice Cooperative (West Sacramento, CA), was used for conducting this research. The initial moisture content (IMC) of rough rice at harvest was 32.51 ± 0.09 g moisture/100 g dry solid. In order to obtain rice samples with different (IMCs), the rice sample with the high MC was equally divided into three portions. Two portions were spread evenly on the floor in the thickness of 5 cm and slowly dried to MC of 25.54 ± 0.11 and 20.07 ± 0.04 g moisture/100 g dry solid under ambient conditions of temperature of 21±1 °C and relative humidity (RH) of 42 ± 3%. During drying, the rice was mixed frequently to ensure to be uniformly dried. Finally, the rice samples with different IMCs of 20.07 ± 0.04, 25.54 ± 0.11 and 32.51 ± 0.09 g moisture/100 g dry solid were kept in polyethylene bags and sealed till they were used for IR drying and stabilization tests. All reported MCs are determined by the air oven method (130 °C, 24 h) and reported on dry basis (d.b) (ASAE Standards, 1995).

2.2. IR heating

The rough rice samples with different IMCs were heated using IR device developed in the Food Processing Laboratory in the Department of Biological and Agricultural Engineering, University of California, Davis, California, USA. The detailed descriptions for IR unit were mentioned in our previous publications (Khir et al., 2011, 2014; Pan et al., 2008, 2011). The samples of a single layer with loading rate of 2 kg/m^2 were heated for one and two drying passes under radiation intensity of 5000 W/m^2. They were heated for 55s to reach surface temperature of 60 °C during each drying pass. The temperature of 60 °C was determined based on previous findings (Khir et al., 2011, 2014; Pan et al., 2008, 2011) that indicted that the high drying rate corresponding to good milling quality could be achieved by heating rough rice to aforementioned temperature level using IR. The temperature was measured by a Type T thermocouple (Omega Engineering Inc. Stamford, CT) immediately after samples were heated. The thermocouple was kept at the center of rough rice in a container until the temperature reading was stabilized, which took from 10 to 30s. The rice sample masses were measured by a balance with two-decimal accuracy before and after IR heating. The mass loss during heating and IMC were used to calculate the moisture removal during the IR heating durations. The moisture loss was calculated as the difference between the IMC and the MC after IR heating and is reported as g moisture/100 g dry solid.

2.3. Tempering and cooling treatments

After IR heating, the tempering and cooling treatments were conducted. The tempering treatment was conducted by keeping the samples in closed container placed in an incubator set at 60 °C for various durations (1, 2, 3, 4 and 5 h). After tempering treatment, the samples were cooled under ambient conditions at temperature of 21±1 °C and RH of 42 ± 3%. They reached to the ambient temperature after 1 h. Then after tempering and cooling treatments the samples were further dried to MC of 14.94 g moisture/100 g dry solid using the ambient air.

For the two-pass drying, after infrared heating followed by tempering and cooling treatment as the first pass, the rough rice with initial high MC was left in the room temperature overnight. The samples were heated using IR to the surface temperature to 60 °C again, and then followed by tempering for different durations ranging from 0 to 5 h. The mass changes caused by tempering and cooling treatment were recorded at the end of cooling and used to calculate the moisture loss based on the MCs after the corresponding IR treatment.

2.4. Evaluation of milling quality

The indicators of rice milling quality including, total rice yield (TRY), head rice yield (HRY) and whiteness index (WI) were evaluated. The treated and untreated rice samples were dehulled and milled using a Yamamoto Husker (FC-2K) and Yamamto Rice Mill (VP-222N, Yamamoto Co. Ltd., Japan). The samples were milled three times to achieve well-milled rice as defined by the Federal Grain Inspection Service (USDA, 1994). The setting of throughput and whitening were 1 and 4, respectively, during the first two milling passes and 1 and 5 during the third milling pass.

TRY, HRY and WI were used to evaluate the effects of IR heating and tempering treatments on milling quality. The HRY was