Food Chemistry 253 (2018) 269–276

Contents lists available at ScienceDirect

Food Chemistry

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

Stabilization of immature rice grain using infrared radiation

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ARTICLE INFO

Keywords:
Infrared
Stabilization
Immature rice
Fatty acids
Tocopherol
Gamma-oryzanol

ABSTRACT

Immature rice grain is one of the underutilized by-products of paddy milling process. Despite its high potential of use as a food ingredient, it is mainly utilized as feed due to the rancidity problem. In the present study, the composition of immature rice grain, the potential of using infrared (IR) radiation for stabilization, and the effects of IR stabilization on color, fatty acid composition, tocopherol and γ-oryzanol contents of the grain were investigated. The free fatty acid (FFA) value of the unprocessed immature rice grain was 5.49% and increased to 35.71% at the end of 3 months of storage at room temperature. However, FFA content of the grains stabilized with IR radiation at specific conditions remained unchanged throughout the storage period. Moreover, IR stabilization did not caused a negative effect on the noted components of the immature rice grain.

1. Introduction

Rice is one of the most important staple foods worldwide. According to FAOSTATS, a total of 741 million tons of paddy was produced worldwide in 2014. The Asian continent dominates in terms of global rice production by providing 90% of world's rice (FAO, 2017a). In an ideal milling process, 68–72% of milled rice or white rice was obtained depending on the variety (IRRI, 2017). The remaining co-products are rice hull, rice bran, rice germ, immature grains, and rice broken. Despite the large amount of rice produced, milled rice co-products have generally been undervalued and underutilized.

The presence of excessive amounts of immature grains in paddy lowers milling yield and increases husk production since immature grains have a husk weight ranging from 30 to 40% of the grain weight. Immature grains also reduce head rice yield because they are predominantly chalky and brittle, thus breaking easily in the process of hulling and whitening (FAO, 2017b).

Although harvest starts when the rice grains are generally mature, individual kernel moisture content vary widely and hence, some kernels are mature while others in the same field even on the same panicle may still be immature (Buggenhout, Brijs, Celus, & Delcour, 2013). Therefore, immature rice grains are always formed to some extent depending on the climatic conditions. Generally speaking, about 5% of immature rice is obtained during paddy milling process.

In rice milling technology, the primary objective is to produce a maximum number of unbroken grains that have had their bran layers uniformly removed (Satake, 2003). Immature rice grains are mainly separated from mature grains by the mechanical classification step which aims to maximize the efficiency of the husking and bran removal processes that will follow. At this stage, immature grains, which are thinner than normal grains, are removed by a thickness grader equipped with slotted cylinders. Mature grains remain inside the cylinder, while immature grains pass through the slots (Satake, 2003). Before harvest, rice grains that have a moisture content exceeding 22% are generally considered to be immature. After harvest, immaturity is defined as either thin kernels with various levels of chalkiness (10–100%) or as kernels that have green seed coat (Buggenhout et al., 2013).

The phytochemical profile of rice has been widely studied, and whole grain rice was found to contain significantly high amounts of bioactive compounds including tocopherols, tocotrienols, γ-oryzanol, phenolic acids, flavonoids, and anthocyanins. Furthermore, consumption of whole grain rice has been associated with reduced risk of some chronic diseases including type-2 diabetes, cardiovascular diseases, and cancer (Guafo and Trindade, 2017). Therefore, rather than being utilized as feed, immature rice has a significant potential for use in functional foods and nutraceuticals. However, it is susceptible to rancidity due to its fat content, which is about 4–5% and may be higher depending on the variety. Thus, in order to use immature rice grain in food based systems, there is a need for a cost effective stabilization process that does not destroy the valuable nutrients.

Infrared (IR) radiation has been used in various thermal food processes such as dehydration, baking, and pasteurization due to its advantages including versatility, fast response of heating, and low capital and operating costs (Chua and Chou, 2003; Krishnamurthy, Khurana, Jun, Irudayaraj, & Demirci, et al., 2008). Moreover, IR heating can be

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https://doi.org/10.1016/j.foodchem.2018.01.172
Received 20 September 2017; Received in revised form 23 January 2018; Accepted 28 January 2018
Available online 31 January 2018

effectively used for enzyme inactivation. Several studies have shown certain enzyme reactions involving the action of lipases, lipoxygenases, and α-amylases were affected by IR radiation (Krishnamurthy et al., 2008; Yılmaz, 2016; Yılmaz, Tuncel, & Kocabıyık, 2014a). The aims of the present study were to investigate the potential of using IR radiation for stabilization of immature rice grain, to put forward the optimum stabilization conditions, and to understand the effect of IR radiation on physical and nutritional properties of the grain.

2. Materials and methods

2.1. Material

Immature rice grains (variety of Osmancık-97) were procured from a local rice milling factory (Özer Gıda Ltd. Şti.) in Çanakkale, Turkey immediately after milling. They were separated from the mature grains by an industrial-scale thickness grader and were yellow-green in color. Impurities such as broken grains and foreign matters were separated from the immature grains using a laboratory-scale trieur (CRM-1252T, Yaşar Makina, Samsun, Turkey) and the cleaned grains were used for stabilization.

2.2. Infrared stabilization

Before stabilization, cleaned immature grains (500 g) were soaked in water for 10 min and were allowed to drain for 5 min. Then, the grains were placed on a laboratory-type IR stabilization system as a single layer and stabilized at the noted conditions described below. The design of the laboratory-type IR stabilization system was clearly explained in our previous studies (Yılmaz et al., 2014a; Yılmaz, Tuncel, & Kocabıyık, 2014b). It is a semi-closed chromium chamber consisting of IR emitters mounted above and a conveyor system with a Teflon belt (20 cm width and 110 cm length). In this study, both medium wave (Item no: 09755054) and short wave (Item No: 09751741) IR emitters (Heraeus Noblelight, Hanau, Germany) were used. Distance between the emitters and the sample (belt) was maintained constant at 15 cm throughout the experiments. During preliminary analysis, IR emitters were used at the range of 800–2200 W for varying process times. Process time was kept as long as possible for stabilization purposes and the process conditions that did not resulted in wet or burnt samples were selected. Stabilization was carried out at the selected conditions and the samples were allowed to cool at room temperature, ground in a micronizer mill (Yuhong, IC-02A, China) and sieved through a 100-mesh sieve. Either control (unprocessed) or stabilized samples were stored in ground form in aluminum zip-lock bags for 3 months at room temperature and the free fatty acid (FFA) contents were monitored at 15 days of intervals. At the end of the storage period, 10 stabilization conditions, which resulted in the lowest FFA content, were selected. As a second part of the study, another immature rice sample set (same variety) was procured from the same factory immediately after milling. These samples were also cleaned and stabilized at the selected 10 IR stabilization conditions using exactly the same procedure as noted above. After stabilization, they were ground, sieved through a 100-mesh sieve and stored in refrigerator until analysis. In order to understand the effects of the selected IR conditions on immature rice grains; color, fatty acid composition, tocopherol and gamma-oryzanol contents of these samples were analyzed.

2.3. Determination of proximate and mineral composition of the immature rice grain

Proximate analyses were carried out according to standard methods (AACC, 2000). Moisture content of the ground samples was measured gravimetrically at 130 °C. Crude fat content was determined with Soxhlet extraction using hexane. Crude protein content was determined using macro Kjeldahl method (N conversion factor: 5.7). Crude ash amount was measured gravimetrically using a muffle furnace. Soluble, insoluble and total dietary fiber contents were measured according to the enzymatic-gravimetric method (Method No: 32-07) using a commercial enzyme kit (Megazyme, Wicklow, Ireland) (AACC. 2000). Briefly, 1 g of sample was homogenized with MES-TRIS buffer and incubated with α-amylase, protease, and amyloglucosidase enzymes, respectively. Insoluble dietary fiber was filtered and the remained filtrate and water washings were precipitated with 95% of hot (60 °C) ethanol for soluble fiber determination. Total dietary fiber was calculated as the sum of soluble and insoluble fiber. Phytic acid content of the grains was determined spectrophotometrically using the anion-exchange method (Method No: 986.11) (AOAC. 2000). For the mineral analysis, 0.5 g of ground sample was digested with 10 mL of nitric acid in a microwave digestion system (Berghof SW-4, Eningen, Germany) at 200 °C for 20 min and analyzed with ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry) (Perkin Elmer, Optima 8000, MA, USA). The instrument conditions were as follows: Pump speed: 30 rpm, plasma gas flow: 12 L/min, cooling gas (argon) flow: 1 L/min, and power: 1400 W. Results were expressed as mg/kg.

2.4. Determination of free fatty acids content

FFA contents of the unprocessed (control) and IR stabilized immature rice grains were determined using AOCS method (No. Ca 5a-40) (AOCS, 1997). Results were expressed as oleic acid equivalents.

2.5. Color

L^* (lightness/brightness), a^* (greenness-redness) and b^* (blueness-yellowness) values of unprocessed and IR stabilized immature rice grain flours were measured using a CR-400 model colorimeter (Konica Minolta, Osaka, Japan) immediately after the stabilization procedure. Other color characteristics such as chroma, Hue angle, redness, and total color change (ΔE) were calculated by using the formulas shown below.

$$\text{Chroma} = (a^{*2} + b^{*2})^{1/2}$$

$$\text{Hue angle} = \tan^{-1}(b^*/a^*)$$

$$\text{Redness} = a^*/b^*$$

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

2.6. Determination of fatty acid composition

Fatty acid composition of the samples was determined according to the modified procedure outlined by Yılmaz et al. (2014a). Fatty acid methyl esters (FAME) were prepared using methanolic KOH according to AOCS procedure (Method No: Ce 2-66) (AOCS, 1997). Analyses were carried out using a gas chromatograph (Agilent 1100, Waldbronn, Germany) equipped with a flame ionization detector (FID) and a DB-23 column [(%50-cyanopropyl)-methylpolysiloxane] (60 m × 0.25 mm i.d. × 0.25 μm film thickness). The carrier gas was helium at a flow rate of 1.7 mL/min and the split ratio was 1: 10. The injection volume was 0.2 μL and FAME mix standards (C4-C24, Supelco, Darmstadt, Germany) were used for determination. Results were expressed as relative area percentage of total FAME.

2.7. Determination of tocopherols

Tocopherol analysis was carried out according to Panfili, Fratianni, and Irano (2003) with slight modifications. Immature grain flour (100 g) was extracted with 300 mL of hexane: petroleum ether (50:50, v/v) at 25 °C in a shaking incubator (Jeio Tech, IS-971-R, Seoul, Korea) for 2 h. This procedure was repeated twice; the supernatants were pooled and evaporated to dryness at 40 °C under vacuum. The extracted