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Effect of selenium enrichment on the quality of germinated brown rice during storage

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ABSTRACT

Changes in the quality of selenized germinated brown rice (Se-GBR) and germinated brown rice (GBR) under controlled temperature storage were investigated. Samples were sealed in air-tight jars (75% RH) and stored at 15, 25, or 35 °C for 9 months. Fatty acid value (FAV), peroxide value (POV), and carbonyl value (CV) were determined every 45 d. FAV, POV, and CV gradually increased with the storage period. Samples stored under low-temperature showed lower FAVs, POVs, and CVs than samples stored at higher temperatures. Compared with GBR, Se-GBR showed lower FAVs, POVs and CVs; this indicates Se exerted a positive effect on the preservation of rice quality. Over 100 volatile compounds were identified, and 15 volatile aldehydes were further studied. To determine the distribution pattern of volatile aldehydes, principal component analysis (PCA) was employed. The first two principal components determined from the PCA of volatile aldehydes explained 50.22% of the variance observed.

1. Introduction

Rice is a staple food widely consumed by millions of people in the world, particularly in Asian, South-American and African countries. In rice-dependent economies, the proportion of rice to dietary protein is generally much higher than that of any other cereals. Rice, which is rich in proteins, sugars, vitamins, bioactive compounds, and organic acids, is considered to confer a number of health benefits. White rice is milled from brown rice and the most-often consumed type of rice. Brown rice, which consists of a bran layer (6%–7% w/w), embryo (2%–3% w/w), and endosperm (about 90% w/w) (Chen, Siebenmorgen, & Griffin, 1998), has a nutritional value higher than that of white rice on account of rice bran, a main by-product produced during rice milling. Several studies have been undertaken to obtain a general outlook of the overall effects of milling on the nutritional quality of rice crops (Lamberts et al., 2007; Liu, Cao, Bai, Wen, & Gu, 2009). Consumption of whole rice (i.e., brown rice) is highly encouraged because it is a source of high nutritional ingredients.

Rice is a seasonal product; it is harvested over a limited period of over a few weeks but is consumed throughout the year. Rice in the field is never uniform, and the characteristics of each crop harvest vary. Therefore processing and storage after harvesting exert great impacts on yield and quality of the final product (Champagne, 2008). During storage, the physicochemical properties of rice will change under the influence of internal and external factors, causing declines in quality. Rice lipids, even though they amount to only 1% of the total weight of the rice, are highly perishable because of the occurrence of a number chemical reactions, such as oxidation and hydrolysis (Jaisut, Prachayawarakorn, Varanyanond, Tungtrakul, & Soponronnarit, 2009; Wang, Wang, Jing, & Zhang, 2012), which lead to decomposed ingredients and lost properties. During decomposition, polymerization of unsaturated fatty acids changes the components of fatty acid compounds and produces volatile and nonvolatile oxidation products, including dimeric, polymeric, or cyclic substances (Asnaashari, Farhoosh, & Sharif, 2014). In fact, during lipid degradation, both undesired molecules and compounds with adverse nutritional impacts and potential dangers to humans are produced (Eshghi, Asnaashari, Haddad Khodaparast, & Hosseini, 2014).

Therefore, the waste becomes unavoidable during rice storage. To solve this problem, various methods have been proposed: for example, addition of antioxidants is commonly performed to inhibit lipid oxidation and preserve rice quality, color, flavor, and nutritive components during storage (Asnaashari et al., 2014; Hu et al., 2014). Our previous study found that brown rice can accumulate Se during germination and mainly distribute in Se-containing proteins (Liu & Gu, 2008). We also revealed that Se-containing proteins purified from selenized germinated brown rice (Se-GBR) exhibited excellent antioxidant activities and may be used as potential antioxidants. Research on many other Se-enriched foods,

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including mushroom (Maseko, Howell, Dunshea, & Ng, 2014), ovalbumin (Li et al., 2014), green tea (Molan, 2013), and *Zea mays* (Longchamp, Castrec-Rouelle, Biron, & Bariac, 2015), have confirmed that Se possesses strong functions affecting specific intracellular selenoproteins and important antioxidant activities. Therefore, we speculate that the storage quality of Se-GBR will remain relatively stable as a result of Se-containing proteins delaying lipid oxidation. Related research in this area has not yet been reported.

Given the significance of rice in the dietary requirements of many population all over the world as well as the financial requirements of its long-term storage, ascertain whether or not or to what extent the storage stability, nutritional quality, and antioxidant activity of rice grains will be affected by increasing selenium levels in brown rice is necessary. The storage time and temperature exert profound effects on the characteristics of rice and are therefore of great concern in determining the shelf-life duration of the crop. Thus, evaluating the influence of long-term storage under different temperature conditions on the quality of rice before its consumption is necessary. Rice is appreciated for its flavor, nutritional value, and other qualities. Rice volatiles, one of the main characteristics of rice, exerts a crucial impact on the quality of rice grains; during storage, however, the rice volatiles may change over time because of oxidation and quality losses. As flavor is obviously a key factor of food quality (Di Natale et al., 2006), freshness (Alimelli et al., 2007), and safety (Santonico et al., 2012), several research studies have showed its chemical constituents, considered to be responsible for its quality.

Among the analytical techniques currently available for extracting and quantifying volatile compounds in samples, headspace solid-phase micro-extraction (HS-MPSE), has been widely used to analyze volatile compounds in foods and beverages because its simplicity, versatility, flexibility, efficient sample preparation, and sensitive detection (Belliardo et al., 2006). HS-SPME with Divinyl benzene/Carboxen/Polydimethylsiloxane (DVB/CAR/PCMS) fibers has been used to monitor the evolution of volatiles directly during storage (Bryant & McClung, 2011; Laguerre, Mestres, Davrieux, Ringuet, & Boulanger, 2007; Zeng, Zhang, Chen, Zhang, & Matsunaga, 2008). The widespread use of the combination of gas chromatography and mass spectrometry (GC–MS), a technique that can shorten quantitative and qualitative analysis times, has also been reported (Griglione et al., 2015). However, few systematic studies have yet indicated the changes in quality or profiled the degree of lipid peroxidation and flavor characteristics of Se-GBR during storage.

The objectives of this study are to (1) investigate changes of lipid oxidation index and volatile components in Se-GBR and germinated brown rice (GBR) during storage, (2) monitor the composition of Se-GBR and GBR volatile compounds at different temperatures of storage, in order to establish the differences of key volatile compounds between Se-GBR and GBR, and (3) explore the impact of selenium on maintaining the quality of rice. Three indices, namely, fatty acid value (FAV), peroxide value (POV), and carbonyl value (CV), were adopted and the results were compared. HS–SPME coupled with gas chromatography–mass spectrometry (GC–MS) was performed to characterize the aroma of Se-GBR and GBR completely.

2. Materials and methods

2.1. Materials and chemicals reagents

Rough rice of lianjing 7 was purchased from the Jiangsu Academy of Agricultural Science (JAAS). The brown rice was gained directly from rough rice hulled with the hulling machine (JGMJ8098, Shanghai Jiading Grain and Oil Instrument Co. Ltd., China).

Benzene and ethyl alcohol used to determine CV were of GC grande. Potassium hydroxide, hydrochloric acid, trichloromethane, hydrogen peroxide, methyl alcohol, trichloroacetic acid (TDA), potassium thiocyanate, potassium thiocyanate petroleum ether were of analytical grade. Distilled water was used in all testes.

2.2. Preparation of samples

Se-GBR was prepared as described previously (Liu, Chen, Zhao, Gu, & Yang, 2011). Brown rice was germinated in the dark with 60 μmol/L sodium selenite at 25 °C for 60 h. After germination, samples were washed with ultrapure water, and dried at 40 °C for further use. GBR was prepared with the distilled water with the same process.

2.3. Storage and sampling

Se-GBR and GBR were monitored under 75% relative humidity over 9 months. Temperatures were controlled at different levels (15 °C, 25 °C and 35 °C) using biochemical incubator. At each of the specified sampling day (every 45 d), triplicate rice samples were randomly selected from each treatment and control groups. Then mixed each samples well and stored in refrigerator at −60 °C for subsequent analysis. All analyses were measured in triplicate.

2.4. Preparation of rice oil

Rice samples were ground into powder after storage for a given period of time and extracted for oil using a Soxhlet extraction apparatus for 8 h. Ether was used as the extractant. After evaporating in a rotary evaporator for 30 min and drying at 40 °C in a drying cabinet for 10 min, the residue was weighted and kept for further examination.

2.5. Determination of oxidative stability

2.5.1. Fatty acid value (FAV)

The FAV of stored samples was determined following the titrimetric procedure described in AACC method 02-01A AACC, 2000. FAV was quantified in terms of milligrams of NaOH required to neutralize the acid in 100 g of dried sample. Phenolphthalein solution was used as an indicator.

2.5.2. Peroxide value (POV)

The POV of stored samples was determined following the method proposed by Shantha and Decker (1994). Rice oil samples were measured at 500 nm with an ultraviolet spectrophotometer. The oil samples (0.010–0.100 g) were dissolved in 5 mL of a mixed solution of chloroform and methanol (7:3, v/v). This solution was transformed into a 10 mL volumetric flask and diluted with chloroform–methanol (7:3, v/v) to the mark. Ferrous chloride solution (3.5 g/L) and potassium thiocyanate solution (300 g/L) were then added. After 5 min of standing at room temperature, the sample was shaken well and placed into a cuvette. Thereafter, the absorbance of the mixture was read. Results are presented in terms of milliequivalents per kilogram of rice.

2.5.3. Carbonyl value (CV)

For CV determination, the method described in AOAC (1995) was followed. Ethanol and benzene were refluxed for 1 h to dislodge carbonyl elements in the solvent. Then, a 0.025–0.500 g of oil sample was made by adding the solvent including benzene to reach 25 mL. Three milliliter of trichloroacetic acid solution and