Food Chemistry 239 (2018) 23–31

Contents lists available at ScienceDirect

Food Chemistry

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

Effect of nano packaging on preservation quality of Nanjing 9108 rice variety at high temperature and humidity

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ARTICLE INFO

Article history:
Received 15 February 2017
Received in revised form 12 June 2017
Accepted 13 June 2017
Available online 15 June 2017

Keywords:
Rice
Nano packaging
High temperature and humidity
Electronic nose
Protein oxidation

ABSTRACT

A nano packaging material containing nano Ag, nano TiO_2, nano attapulgite and SiO_2 was prepared, and its impact on quality of Nanjing 9108 rice at 37 °C and 85% relative humidity was studied. Effects of the packaging on ambient gases and chromatic aberration of rice were determined. Moreover, oxidation level, molds growth and flavor of rice were also analyzed. Results showed that nano packaging material had antimicrobial effects and maintained low O_2 and high CO_2 content in the packages. The packages thereby inhibited the growth of molds and the production of fatty acids, restrained the increase of lipase activity, and reduced the oxidation of fats and proteins. As a result, the production of yellow and white-belly rice were inhibited. Furthermore, the color and flavor of rice were maintained. Therefore, the nano-packing material could be applied for preservation of rice to improve preservation quality.

1. Introduction

Rice is the staple food for more than half the world's population, primarily for Asian populace. China is the largest rice producer and consumer in the world with yields of approximately 2.08×10^{11} kg, accounting for 40% of the world's production in 2015. Rice production in south of China accounted for less than 50% of the country's production. Nevertheless, temperatures of up to 38–41 °C and a relative humidity of up to 85–98% in summer in the southeast and southern of China accelerate the deterioration of rice and increase the post-harvest losses. Aging, yellowing and molds growth are the typical deteriorations of rice on exposure to this environment (Smanalieva, Salieva, Borkoev, Windhab, & Fischer, 2015; Zhou, Yang, Su, & Bu, 2016), which affect the edible quality and safety of rice to consumers. Post-harvest losses accounted for 8% on storage in current state. As a result, the edible quality and safety of rice grains were affected, thereby having an impact on consumers. Therefore, it is imperative to develop new storage techniques so as to retard quality deterioration during storage, transportation and sale.

Currently, woven polypropylene and composite plastic bags are commonly used for rice storage. However, these techniques perform poorly because of some disadvantages, such as poor moisture and gas barrier properties and antimicrobial activity (Gross & Kalra, 2002). At present, polymer nanocomposites have a unique large application in food storage due to good barrier performance against O_2 and CO_2 (Duncan, 2011). Nanocomposites have been proved to enhance the moisture and gas barrier properties, tensile strengths, and heat resistance of packaging material (Silvestre, Duraccio, & Cimmino, 2011). Recent studies have shown that the addition of nanocomposites, such as nano Ag, nano TiO_2, nano attapulgite and SiO_2, confers higher mechanical strength to the packaging material and lower O_2 and water permeability properties compared to the normal packaging materials (Chaudhry et al., 2008; Jordan, Jacob, Tannenbaum, Sharaf, & Jasiuk, 2005). In addition, the antimicrobial property is introduced (de Azeredo, 2013). Different nano packaging materials have been developed for various foods such as dairy products, fruits and vegetables with impressive preservation effects (Arora & Padua, 2010; Sozer & Kokini, 2009). For example, a novel nano packaging material could extend the Chinese jujube's shelf life and improve its preservation quality (Li et al., 2009). Zhou, Lv, He, He, and Shi (2011) used the nano structured LDPE/Ag_2O film bags to decrease microbial spoilage in apple slices. However, little information is available on the application of nano packaging materials for rice storage. Therefore, the development of a simple, economical, practical and novel fresh-keeping material is of great importance to prevent mildew and delay the deterioration phenomenon of rice during storage.

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http://dx.doi.org/10.1016/j.foodchem.2017.06.082
0308-8146/

Nanjing 9108 rice grows most in the southern areas of China, and due to its good taste, aroma and high nutrition, it is considered as a high quality rice. According to our study, the Nanjing 9108 rice consists of 72.23% starch, 7.23% protein and 0.37% fat. However, some quality deterioration of this rice occurs easily when subjected to high temperature and humidity. Moreover, the temperature of 37 °C and relative humidity of 85% were predominant climate conditions in summer. Therefore, it is necessary to research the effect of nano packaging on preservation quality of Nanjing 9108 rice variety at high temperature and humidity.

The main objective of this study was to evaluate the effects of nano-composites filled nano packaging on quality preservation of Nanjing 9108 rice at 37 °C and relative humidity 85%. Rice indexes such as chromatic aberration, O_2 and CO_2 percentages in three treatment groups, fatty acid, lipase activity, carbonyl groups content, sulfhydryl groups and disulfide bonds were examined during storage. Additionally, molds growth and flavor of rice were also analyzed.

2. Materials and methods

2.1. Preparation of nanocomposite-based packaging materials

Nanocomposite-based packaging materials were prepared according our previous study (Fang et al., 2016) with 0.30% nano Ag, 0.35% nano TiO_2, 0.25% nano attapulgite and 0.10% nano SiO_2. The permeability of O_2, CO_2 and relative humidity of the nano packaging material were also determined according to Chinese Standard GB/T 1038-1970 and GB/T 16928-1997, and the results were 1204.92 $cm^3/(m^2 \cdot 24\ h \cdot 0.1\ MPa)$, 4962.43 $cm^3/(m^2 \cdot 24\ h \cdot 0.1\ MPa)$ and 2.86 $g/(m^2 \cdot 24\ h)$, respectively. Transverse and longitudinal tensile strengths were also determined by Chinese Standard GB/T 1040.3-2006, and the results were 23.53 Mpa and 20.73 Mpa, respectively.

A polyethylene packaging bag was used as the normal packaging, which was prepared according to the method of nano packaging materials but without nanocomposites. The O_2, CO_2 and relative humidity permeability of the normal packaging material were 1392.66 $cm^3/(m^2 \cdot 24\ h \cdot 0.1\ MPa)$, 5298.01 $cm^3/(m^2 \cdot 24\ h \cdot 0.1\ MPa)$ and 3.46 $g/(m^2 \cdot 24\ h)$, respectively. The transverse and longitudinal tensile strengths were 20.57 Mpa and 19.64 Mpa, respectively.

2.2. Preparation of rice sample

Polished rice grain (Nanjing 9108) was purchased from Jiangsu Nongken Rice Industry Co., Ltd. Three groups, namely nano packaging group, normal packaging group and no packaging group were used. Two portions of 500 g of rice were randomly packed in nano packaging (15 cm × 20 cm, 50 bags) and normal packaging (15 cm × 20 cm, 50 bags), which were then sealed. Another portion of 500 g of rice was placed in 15 cm × 20 cm tray as the no packaging group (50 replicates). All the samples were stored at 37 °C ± 0.5 and 85% relative humidity for 10 weeks in an artificial climate tank. Related indices of samples were analyzed every 2 weeks during storage.

2.3. Determination of O_2 and CO_2 percentages in packages

The O_2 and CO_2 percentages in packages were determined using the method described by Turan and Kocatepe (2013) on a portable gas analyzer (OXYBABY M + O_2/CO_2). A septum was put on the packages and the gas was collected by a sample needle, and the O_2 and CO_2 percentages automatically read by the portable gas analyzer.

2.4. Sensory evaluation and determination of flavor substances in rice during storage

The rice samples were used to evaluate sensory profiles. Ten sensory panelists were selected to detect differences in rice flavors. Sensory quality was evaluated using a nine-point hedonic scale (1 = extremely weak; 9 = extremely strong) for pleasant aroma, rancid odor and musty odor intensity.

The electronic nose analysis of odors was performed according to Reinhard, Sager, and Zoller (2008). An electronic nose (FOX 3000, Alpha MOS, Toulouse, France) equipped with 12 metal-oxide semiconducting sensors (LY2/LG, LY2/G, LY2/AA, LY2/GH, LY2/g CTL, LY2/g CT, T30/1, P10/1, P10/2, P40/1, T70/2, PA2) was used in this study. As the carrier gas, dry clean air at 150 mL/min was used. Approximately 6 g samples from different groups at various storage times were prepared in 20 mL sealed sample vials and incubated for 120 s at 40 °C under agitation (500 rpm). From the headspace, volumes of 1 mL were withdrawn by a syringe and kept at 50 °C.

2.5. Determination of chromatic aberration of rice

The chromatic aberration of rice sample was determined using a Minolta Chroma Meter (CM-5, Minolta, Tokyo, Japan). Before the start of the study, a blank calibration film was used for calibrating instrument under the transmission measurement model. Afterwards, the objective external color of 15 g rice samples stored for 0 weeks was measured as target. The color difference ΔE was recorded after determination under the target mode.

2.6. Determination of fat acidity and lipase activities

Lipid oxidation of rice was determined using the method described by Sung, Kim, Kim, and Kim (2014) with slight modifications. About 10 g of rice powder (80 mesh) was sealed in an Erlenmeyer flask with 50 mL of pure alcohol, shaken for 30 min and centrifuged for 5 min at 3000 rpm to obtain a supernatant. Three aliquots of 10 mL of the supernatant were then added into 150 mL Erlenmeyer flasks, mixed with 50 mL of distilled water and 3–5 drops phenolphthalein-ethanol solution, which was used as the color indicator. Subsequently, the cocktail was titrated with 0.0075 M KOH-C_2H_5OH, and a final titration volume (V_1) was obtained. A reagent blank containing 10 mL pure alcohol was used as a control (V_0). The fatty acid value was calculated in milligrams (mg) of potassium hydroxide per 100 gram (g) using the Eq. (1):

$$\text{Fat acid value (KOH mg/100 g)} = (V_1 - V_0) \times 56.1 \times \frac{50}{10} \times \frac{100}{m(100-\omega)\%} \times c \times 100 \quad (1)$$

where 50 is the volume of pure alcohol that was used to extract sample, 10 is the volume of supernatant used to titrate, m is the sample weight and ω is the moisture content in each 100 g sample.

Lipase activities of the samples were determined using a lipase assay kit, which was based on chromatometry (Nanjing Jiancheng Bioengineering Institute). Triglyceride was mixed with water to form micelles, which can be hydrolyzed by lipase. The decrease of micelles turbidity was determined as the lipase activity. The lipase activity was expressed as U/g protein.

2.7. Determination of carbonyl group, sulfhydryl group and disulfide bond content

Rice proteins were extracted from rice flour based on their solubility in specific solutions, using the method described by