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Effect of nano-$CaCO_3$-LDPE packaging on quality and browning of fresh-cut yam☆

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ABSTRACT

In order to evaluate the effects of nano-$CaCO_3$-based low density polyethylene (nano-$CaCO_3$-LDPE) packaging on the quality of fresh-cut Chinese yam, the browning index, overall visual quality (OVQ), total bacterial count (TBC), and yeast and mold count (YMC), titratable acid, ascorbic acid, total phenolic content, ethylene production, malondialdehyde content, phenylalanine ammonia-lyase (PAL), polyphenol oxidase (PPO), and peroxidase (POD) activities were determined during storage at 10 °C. TBC and YMC counts of fresh-cut Chinese yam were significantly reduced by nano-$CaCO_3$-LDPE packaging. Nano-$CaCO_3$-LDPE packaged fresh-cut Chinese yam exhibited significantly lower activities of PAL, PPO, and POD compared to the control yam samples. Meanwhile, nano-$CaCO_3$-LDPE packaging significantly inhibited the increase of browning index, total phenolic and malondialdehyde content, and maintained OVQ, titratable acid, and ascorbic acid. These results indicated that nano-$CaCO_3$-LDPE packaging and stored at 10 °C was a promising approach in inhibiting browning and maintaining quality of fresh-cut Chinese yam.

1. Introduction

Yams, the edible tubers of various species of the genus *Dioscorea*, are important items in the diets of many tropical countries because of rich carbohydrate components (Hariprakash & Nambisan, 1996; Omonigbo & Ikenebomeh, 2000). In China, the cultivation of yams has a long history for both edible and medical purposes. The most important variety is *Dioscorea opposita* Thunb. (*Huai Shan Yao*) which is not only a common food regarded as a tonic, but also has been used for more than 2000 years in traditional Chinese medicine for the treatment of diabetes, diarrhoea, asthma, and other ailments (Yang & Lin, 2008). Yam is a highly nutritional vegetable associated with functional components, such as mucin, dioscin, allantoin, choline, polyphenolases, vitamins, and essential amino acids (Bhandari, Kasai, & Kawabata, 2003; Fasidi & Bakare, 1995; Ingrid, Helen, & Ahmad, 1993; Omonigbo & Ikenebomeh, 2000).

Recently, a great increase in the consumption of fresh-cut fruits and vegetables including fresh-cut Chinese yam has been observed. Fresh-cut processing of fruits and vegetables has its own advances on convenience and nutritional value. However, fresh-cut processing such as trimming, peeling, grading, and shredding may accelerate physiological deterioration which may lead to browning, off-flavour, and further nutrition loss (Martín-Diana, Rico, & Barry-Ryan, 2008). Browning is the detrimental changes induced by these processing that make consumers unacceptable (Roura, Pereyraa, & Vallea, 2008; Saltveit, 2000). Thus, there is an urgent need to have alternative technologies to minimize the undesirable physicochemical and biological changes of fresh-cut products during storage.

Many investigations have been reported on the approaches to inhibit fresh-cut fruit browning. Chemical additive such as chlorine solutions have been used in fruit and vegetable fresh-cut industry. However, consumers are looking for fruits and vegetables free of chemical residues, since these compounds may be harmful to human health. Modified atmosphere packaging, as a physical method, is being extensively studied as alternative method for the current chemical methods in commercial applications (Rojas-Graue, Oms-Oliu, Soliva-Fortuny, & Martín-Belloso, 2009). However, properties of general polymer packaging such as thermal stability, toughness, water vapour, oxygen permeability, and antibacterial

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properties are not competent enough for food packing applications (Rhim, Hong, & Ha, 2009). Recently, the application of the nanocomposite concept has been proven to be a promising option in order to improve above mentioned properties (Azeredo, 2009; Chau, Wu, & Yen, 2007). Nanomaterials have attracted increasing interest because of their potential impact on an incredibly wide range of industries and markets (Petersen et al., 1999; Wang, Liang, Du, Zhang, & Fu, 2004). Some previous works have shown the beneficial effect of nanomaterials packing on the postharvest shelf life of fruits and vegetables, including Chinese jujube (Li et al., 2009), green asparagus (An, Zhang, Wang, & Tang, 2008) and Chinese bayberries (Wang et al., 2010). Nano-$CaCO_3$ polymer reduced oxygen permeability, and improved packaging performance (Avolio, Gentile, Avella, Carfagna, & Errico, 2013; Luo, Wang, Wang, & Feng, 2014).

The effect of nano-$CaCO_3$-based low density polyethylene (LDPE) packaging on the quality and browning of fresh-cut Chinese yam has not been studied in detail. The present study was performed to characterize the physiological and biochemical responses of fresh-cut Chinese yam to nano-packaging and to evaluate its ability for postharvest shelf life. The quality properties of fresh-cut Chinese yam, such as browning index, overall visual quality (Three bags), total bacterial count (TBC), yeast and mold count (YMC), titratable acid, ascorbic acid, total phenolic content, ethylene production, malondialdehyde content, phenylalanine ammonia-lyase (PAL), polyphenol oxidase (PPO), and peroxidase (POD) activities were examined during storage at 10 °C.

2. Materials and methods

2.1. Preparation of nano-$CaCO_3$-LDPE bags

The food grade LDPE (density 0.92 kg/m^3, softening point 95 °C; Jiangsu Linhai Resin Technology Co. Ltd, Linhai, China) was used as matrix material. The nano-$CaCO_3$ in the range of 60–100 nm was obtained from a commercial company (Zhejiang Xuefeng Calcium Carbonate Co. Ltd, Changshan China). Firstly a nano-$CaCO_3$-LDPE masterbatch containing 30 g/100 g of the commercial nano-$CaCO_3$, 56 g/100 g of LDPE granule and 14 g/100 g of cross-link reagent γ-methacryloxypropyltrimethoxysilane were immingled in uniformity through a high-speed mixer (WK-06, Zhangjiagang Wankai Machinery Co. Ltd, Zhangjiagang, China) for 1 h. After air cooling at room temperature, they were extruded to nano-$CaCO_3$-LDPE pellets using a twin-screw extruder (SHJ-20, Nanjing Guangda Chemical Equipment Co., Ltd, Nanjing, China) heated at 180 °C with a screw diameter of 22 mm, a screw length/diameter ratio of 42 and a screw speed of 600 rpm. In the second extrusion step, 1.5 kg of pellets and 38.5 kg of LDPE granule were immingled for 30 min. Subsequently the compounds were blown into a film of 50 μm thickness via a plastic extruder (SJ50 × 30/FM1300, Dalian Plastic Machine Factory, Dalian, China) heated at 200 °C. After cooling, films of 50 μm thickness were used to make bags of 10 × 15 cm^2 using a heat sealer (FBD-300W, JiaQi Packaging Machiner Co. Ltd, Zhejiang, China). LDPE bags of the same thickness and size without nano-$CaCO_3$ served as controls.

2.2. The transmission rate evaluation

The permeability of O_2 and CO_2 was determined by a Gas Permeability Tester (Labthink Instruments Co., Ltd., Jinan, China) followed the instrument introductions and converted into SI units.

2.3. Plant materials and minimal processing

Chinese yam (*Dioscorea* spp.) was purchased from a local wholesale market (Hangzhou, China) and then transported to the laboratory. Chinese yam was washed with tap water, peeled, and cut into 50 × 20 × 3 (mm) slices using a stainless steel knife. About 3600 g of selected slices were randomly packed into nano-$CaCO_3$-LDPE (18 bags) and normal LDPE (18 bags) with a size of 10 × 15 cm^2 respectively, then sealed and stored at 10 °C with 90% relative humidity for 5 days. Browning index, acceptability, microbiological stability, ethylene production, and malondialdehyde content were determined every day. Chinese yam slices (about 30 g each) were frozen in liquid nitrogen and stored at −70 °C until used for the measurement of titratable acid, ascorbic acid and total phenolic content, PAL, PPO and PPO activity.

2.4. In-package atmosphere determination

Samples of 2 mL of headspace gas were withdrawn from the packages with disposable syringes. Concentrations of CO_2 and O_2 were measured with a gas chromatograph equipped with a thermal conductivity detector (Shimadzu Instruments (Suzhou) Co., Ltd, Suzhou, China). The carrier gas was helium. CO_2 concentration was determined with Porapak Q column. The injector, oven and detector were kept at 80, 120 and 180 °C, respectively. O_2 concentration was measured by using Molecular Sieve 5A column (Shanghai Zeolite Molecular Sieve Co., Ltd, Shanghai, China). The injector, oven and detector were kept at 60, 40 and 180 °C, respectively. Three independent replicates were conducted in each treatment.

2.5. Evaluation of browning index and OVQ

Three bags of Chinese yam slices were taken every day from each storage treatment for evaluation of browning disorder. Browning index was determined by measuring the extent of the total brown area on each fresh-cut yam surface using the following scale: 1 = no browning, 2 = <20% of the surface, 3 = 20–40% of the surface, 4 = 40–60% of the surface and, 5 = >60% of the surface. The flesh browning index was calculated as Σ (browning level × number of pieces with that browning level)/(total number of pieces).

Samples were transferred to closed plastic boxes coded with random numbers for OVQ evaluation. Fresh appearance, browning, and general acceptability of samples were scored ranging from 1 to 9 based on the following scale: 9 = excellent, just sliced; 7 = very good; 5 = good, limit of marketability; 3 = fair, limit of usability; and 1 = poor, inedible.

2.6. Microbiological analysis

The microbiological methods were followed as detailed in ICMSF (International Commission for the Microbiological Specifications of Foods, 2002). Total microbial load was determined using the standard pour plate method. Each 10 g sample of Chinese yam slices was mixed with 90 mL aseptic physiological saline (0.85 g/100 g NaCl–water) and the mixture was shaken with appropriate sterile glass rods for 3 min. Serial dilutions were prepared and appropriate dilutions were pour plated on different plates to determine the microbial load. TBC was determined using plate count agar plates and the colony forming units (CFU) were counted after incubating at 30 °C for 36 h. YMC was determined using potato dextrose agar (PDA) plates which were incubated at 28 °C for 36 h. Three replicates were analysed in duplicate and microbiological counts were expressed as log CFU g^{-1} of fresh yam.

2.7. Measurement of titratable acid and ascorbic acid

Frozen flesh (5 g) from six yam slices was homogenized and then centrifuged at 10,000 *g* for 20 min. Titratable acidity was