Innovative Food Science and Emerging Technologies 11 (2010) 742–748

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Evaluation of nanocomposite packaging containing Ag and ZnO on shelf life of fresh orange juice

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A R T I C L E I N F O

Article history:
Received 9 November 2009
Accepted 14 June 2010

Editor Proof Receive Date 12 July 2010

Keywords:
Orange juice
Nanocomposite
Nano-ZnO
Nanosilver

A B S T R A C T

Nanocomposite LDPE films containing Ag and ZnO nanoparticles were prepared by melt mixing in a twin-screw extruder. Packages prepared from the films were then filled with fresh orange juice and stored at 4 °C. Microbial stability, ascorbic acid (AA) content, browning index, color value, and sensory attributes of them were evaluated after 7, 28, and 56 days of storage. Packages containing the nanomaterials, expect 1% nano-ZnO, kept the microbial load of fresh juice below the limit of microbial shelf life (6 log cfu/ml) up to 28 days The least degradation of AA (80.50 mg/100 g), development of brown pigments ($OD=0.23$) and losing of color ($\Delta E=6.0$) were observed in pouches containing 0.25% nano-ZnO, after the same time. Sensory attributes were also ranked highest for the juice thus packed in the recent packages after 28 days ($p<0.05$). Packages containing nanosilver increased shelf life of fresh juice although part of its sensory attributes were lost.

Industrial relevance: Compared with pure packaging materials, antimicrobial nanocomposite packages containing Ag and ZnO as an alternative non-thermal technology can extend the shelf life of fresh orange juice up to 28 days. However, a certain concentration of nano-ZnO in the packages showed less adverse effects on sensory characteristics.

1. Introduction

Orange juice is one of the most globally accepted fruit products (Meléndez-Martínez, Vicario, & Heredia, 2007). Demand for natural orange juice with high quality in terms of nutritional value, physico-chemical properties and sensory characteristics with minimal or no heat treatment has increased considerably (Bull et al., 2004; Souza, Benassi, Meneghel, & Silva, 2004). Natural orange juice, even kept under refrigeration, has a short shelf life due to increasing microbial spoilage (Souza et al., 2004). Recently, extensive studies have been conducted to develop non-thermal processing techniques (PEF, HHP, IR, UV, and US) as replacements for thermal processing in order to keep the freshness of the juice along with extending its shelf life (Baxter, Easton, Schneebeli, & Whitfield, 2005; Elez-Martínez, Soliva-Fortuny, & Martín-Belloso, 2006; Foley et al., 2002; Tran & Farid, 2004; Valero et al., 2007). Although some of these technologies are capable of decontaminating orange juice, they are energy-intensive and require costly equipment; hence, their yet relatively limited commercial applications (Han, 2007). Nanotechnology recently introduced in the food packaging industry can potentially provide solutions to food packaging challenges such as short shelf life (Chaudhry et al., 2008; Joseph & Morrison, 2006). Antimicrobially active packaging is a new generation of nano food packaging based on metal nanocomposites which are made by incorporating metal nanoparticles into polymer films (Chaudhry et al., 2008). The high performance of nanoparticles is due to their high surface area/volume ratio, which is the main reason for increasing antimicrobial activity of metal nanoparticles (Damm, Neumann, & Münstedt, 2006).

Nanoparticels (NP) of Ag and ZnO are being used industrially for several purposes (Gajjar et al., 2009). ZnO has found many applications in daily life such as in drug delivery, cosmetics, and medical devices (Yan et al., 2009) due to its strong antimicrobial effect on a board spectrum of microorganisms (Jones, Ray, Ranjit, & Manna, 2008). Moreover, it is currently listed by FDA as a generally recognized as safe (GRAS) material (Jin, Sun, Su, Zhang, & Sue, 2009). Silver has also been long known to have microbial inhibition (Lok et al., 2006). The antimicrobial activity of these nanoparticles may be related to several mechanisms including, induction of oxidative stress due to generation of reactive oxygen species (ROS) which may cause the degradation of the membrane structure of the cell (Sawai, 2003; Sawai & Yoshikawa, 2004; Sawai et al., 1998), release of ions from the surface of nanoparticles that has been reported to cause bacterial death due to binding to cell membrane (Feng et al., 2000; Sondi & Salopek-Sondi, 2004). However, the mechanism of toxicity is still only partially understood (Li et al., 2008).

Several methods are generally used to produce antimicrobial polymer nanocomposites. Because of the thermal stability of metal nanoparticles and the thermal processing method used for producing the LDPE film as a contacting juice layer in the package, melt mixing is

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1466-8564/$ – see front matter © 2010 Published by Elsevier Ltd.
doi:10.1016/j.ifset.2010.06.003