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Effects of a combination of antimicrobial silver low density polyethylene nanocomposite films and modified atmosphere packaging on the shelf life of chicken breast fillets

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ABSTRACT

Low-density polyethylene (LDPE) nanocomposite films containing different concentrations of silver (Ag) nanoparticles (NPs) (0.5 and 1% of polymer weight, w/w) were manufactured *via* extrusion and subsequently characterised. The microbiological quality of chicken breast fillets wrapped with Ag/LDPE nanocomposite films, followed by modified atmosphere packaging (using conventional laminates and employing a gas mix of 40% CO_2:60% N_2) were assessed. The tensile strength of Ag/LDPE nanocomposite films were significantly lower ($p < 0.05$) than control films (without Ag NPs), indicating that the presence of Ag NPs reduced the film strength. Independent of the concentration of Ag NPs used, Ag/LDPE nanocomposite films extended the shelf life of the chicken breast fillets and significantly ($p < 0.05$) enhanced oxidative stability compared to control films. The results indicated that LDPE nanocomposite films containing Ag NPs could potentially be used as antimicrobial packaging for food applications.

1. Introduction

Retailer and consumer demands challenge suppliers to deliver fresh products more quickly and cost-effectively. Consequently, the development of antimicrobial packaging has become a significant area of research over the past two decades, as the incorporation of antimicrobial agents into or on antimicrobial packaging materials could provide greater safety assurance, shelf life extension and quality maintenance of food products by inhibiting microbial spoilage and suppressing microbial food-borne illnesses (Appendini & Hotchkiss, 2002). Since

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microbial contamination of most food products occurs predominantly at the surface, mainly due to post-process handling, attempts have been made to improve safety and to delay spoilage through the use of antibacterial sprays or dips; however, limitations to their wider use include; neutralisation of antimicrobial compounds on contact with the food surfaces and diffusion of antimicrobial compounds into the food product (Lopez-Rubio et al., 2004).

The successful development of antimicrobial packaging is still challenging technology, and relatively few commercialised products are available on the market today. This is most likely due to the extremely strict safety and hygiene regulations adhered to by regulatory authorities, particularly within the EU. Unfortunately, these guidelines may be out of step with the pace of technological innovation and information being generated by researchers, and this will inevitably lead to consumer mistrust in such technologies, lack of technological and commercial development of antimicrobial packaging systems and perceived high costs associated with such technologies through the under development of commercial materials.

The use of silver (Ag) in antimicrobial packaging offers numerous advantages including high thermal stability, ease of incorporation into or onto numerous materials such as polyester, polyamide, and polypropylene (PP), it has been classified as GRAS (Generally Recognised as Safe) by the Food and Drug Administration (FDA) to be used as food preservative; however, the European Food Safety Authority (EFSA) classified it as one of a list of additives with general restrictions (Martínez-Abad, Lagaron, & Ocio, 2012; Zapata et al., 2011). Silver antimicrobial nanocomposite films have been used for packaging applications with horticultural produce, such as; Chinese *jujube*, lettuce, fresh fruit salad, asparagus and fresh orange juice (An, Zhang, Wang, & Tang, 2008; Costa, Conte, Buonocore, & Del Nobile, 2011; Emamifar, Kadivar, Shahedi, & Soleimanian-Zad, 2010; Li et al., 2009; Martínez-Abad, Ocio, Lagarón, & Sánchez, 2013), with the shelf life of these food products was significantly longer than those packaged with control films which did not possess Ag NPs.

Cushen, Kerry, Morris, Cruz-Romero, and Cummins (2014a), Huang et al. (2011), and Panea, Ripoll, González, Fernández-Cuello, and Albertí (2014) reported low migration of Ag from Ag/LDPE nanocomposite films into food products and food simulants. Cushen et al. (2014a) also reported that the exposure results fell well below than the exposure limits for all extreme conditions of the scenarios tested, suggesting Ag/LDPE nanocomposite films are suitable to be used as food contact material with non-acidic foods such as chicken breast fillets because they are less likely to facilitate migration.

Chicken meat is a popular source of protein worldwide, high in nutritional value and relatively cheap (van Horne & Bondt, 2013). However, it is very perishable and contains more pathogenic bacteria than other types of meat (Mantilla et al., 2012; Rodríguez-Calleja, Cruz-Romero, O'Sullivan, García-López, & Kerry 2012). Under aerobic chilled conditions the shelf life of chicken breast fillets was determined to be not more than 4 days (Balamatsia, Patsias, Kontominas, & Savvaidis, 2007; Patsias, Badeka, Savvaidis, & Kontominas, 2008); however, under chilled and modified atmosphere packaging (MAP) conditions the shelf life was extended up to 7 days (Chouliara, Badeka, Savvaidis, & Kontominas, 2008; Patsias et al., 2008). Any packaging systems that would provide for longer product shelf life would be of significant interest to poultry processors, retailers and consumers alike.

From an extensive review of the scientific literature, little is known about the effects of LDPE nanocomposites containing Ag NPs on protein-rich food products, such as fresh chicken breast fillets. Therefore, the objectives of this study were to manufacture LDPE nanocomposite films containing different concentrations (0.5 or 1%) of Ag NPs (Ag/LDPE nanocomposites) *via* extrusion and subsequently characterise the manufactured materials, and investigate the effects of wrapping chicken breast fillets with Ag/LDPE nanocomposite films followed by MAP (using conventional laminates and employing a gas mix of 40% CO_2:60% N_2), on the physicochemical and microbiological quality of chicken breast fillets during chilled storage at 4 °C.

2. Materials and methods

2.1. *Reagent and supply*

Silver nitrate ($AgNO_3$), poly(N-vinylpyrrolidone) (PVP, $M_W = 40{,}000$), ethanol ≥99.5% and acetone were purchased from Sigma–Aldrich. All chemicals were used without further purification. Low-density polyethylene pellets were supplied by Boxmore plastics (Ireland), and skinless breasts of chicken fillets of similar sizes were purchased from a local supplier (Shannon Vale, Ireland). Stomacher bags were obtained from Seward (UK) and Plate Count Agar (PCA) was purchased from Merck (UK). Pseudomonas Agar Base with selective supplement CFC (cetrimide, fucidin, cephaloridine) (SR0103E); Streptomycin Thallous Acetate Actidione (STAA) supplemented with Streptomycin Sulphate and Thallous Acetate (SR0151E); de Man, Rogosa and Sharpe (MRS) agar, Maximum Recovery Diluent (MRD) and Oxidase Touch Sticks were purchased from Oxoid (Basingstoke, UK). Compact Dry-EC chromogenic plates were obtained from Nissui Pharmaceutical (Co. Ltd. Japan).

2.2. *Synthesis and characterisation of Ag nanoparticles*

Silver NPs of 10 nm particle size was synthesised as outlined in Cushen et al. (2014a). Images of Ag NPs were taken by scanning electron microscopy (SEM, FEI Company, FEG Quanta 6700) at 5.0 kV. The stability, surface properties, and average size of Ag NPs (0.1%, w/v) dissolved in absolute ethanol and ultrasonicated (Cole-Palmer 8891) for 30 min was measured using the Zetasizer (Zetasizer Nano ZS, Malvern, US). In order to confirm the presence of the Ag NPs in the ethanolic solution, spectrophotometric scanning at a wavelength range of 300–800 nm was carried out in a UV–visible spectrophotometer (Varian Cary 300 Bio, USA) using ethanol as blank.

2.3. *Manufacture of LDPE films*

The Ag/LDPE nanocomposite used in this study was prepared on a micro 27 labscale twin screw extruder (Leistritz, Nuernberg, Germany) with a 27 mm screw diameter and a 38/1 length to diameter ratio, using the screw geometry as previously outlined by Cushen et al. (2014a). In the compounding process, the