Journal of Food Measurement and Characterization (2021) 15:2430–2439
https://doi.org/10.1007/s11694-021-00836-7

ORIGINAL PAPER

# Fabrication and characterization of LDPE/silver-copper/titanium dioxide nanocomposite films for application in Nile Tilapia (*Oreochromis niloticus*) packaging

**Helen Efatian[1] · Hamed Ahari[1] · Delavar Shahbazzadeh[2] · Bahareh Nowruzi[3] · Shima Yousefi[1]**

Received: 16 November 2020 / Accepted: 20 January 2021 / Published online: 5 February 2021


## Abstract

Proper packaging is an essential issue in seafood safety leads to the preservation of food quality and extending the shelf life. In this study, fabrication and characterization of LDPE/Ag/$TiO_2$ and LDPE/Ag + Cu/$TiO_2$ nanocomposite films for application in Nile Tilapia packaging were evaluated. After investigation of scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), disk diffusion test, minimum inhibitory concentration, and minimum bactericidal concentration, the antimicrobial effect of produced nanocomposite films was evaluated on the Tilapia fish samples stored at 4 °C and − 20 °C for 5 and 10 days. Chemical features (pH, protein and fat concentrations, and free fatty acid profile) of the Tilapia fish covered with the produced nanocomposites and nanoparticle migration were also assessed. EDS and SEM techniques confirmed the presence of nanoparticles on the polymer surface and their relative homogeneity. The antibacterial tests of LDPE/Ag + Cu/$TiO_2$ nanocomposite film exhibited strong antibacterial activities against *Escherichia coli* and *Listeria monocytogenes* bacteria (P = 0.000). The microbiological tests revealed that Ag + Cu-contained film had significantly higher antimicrobial efficacy on the Nile Tilapia samples (P < 0.05). The overall result of the series of chemical experiments showed that Tilapia samples packed in Ag + Cu film had the least changes in chemical properties compared to fresh samples (P < 0.05 for pH, fat concentration, and free fatty acid profile). Besides, the migration of Ag and Cu nanoparticles from the film to Tilapia samples was slightly (the amount of Ag and Cu release was < 2.0 µg/Kg and < 10 µg/Kg, respectively). From the obtained results, it could be concluded that a film containing 2.5 % silver, 2.5 % copper, and 5 % titanium dioxide nanoparticles had the most significant antimicrobial effect on the Nile Tilapia fish. Therefore, using LDPE/Ag + Cu/$TiO_2$ nanocomposite film can be a promising approach to create active packaging in the seafood industry.

**Keywords** Nanocomposite · Shelf life · Antimicrobial activity · Fish · Packaging

## Introduction

Proper packaging is an increasingly important issue in food safety levels, leading to food quality preservation and extending the shelf life [1]. In this regard, nanotechnology, which uses particles with nanometre dimensions, provides innovations in the packaging industry by applying nanoparticles (NPs) that are capable of reducing permeability to oxygen or moisture. Moreover, the existence of nanoparticles in food packages enhance the biocidal properties of them since it is one of the most significant concerns in the prevention of foodborne infections [2]. A broad range of approaches has been performed for the synthesis of nanoparticles, such as evaporation-condensation and laser ablation (physical methods), chemical reduction by organic and inorganic reducing agents, microemulsion techniques, UV-initiated photoreduction, photoinduced reduction, electrochemical synthetic method, irradiation methods, and microwave-assisted synthesis [3, 4].

Among various nanoparticles used for food nano-packaging, nanotitanium dioxide ($TiO_2$), nanosilver (Ag), and nanocopper (Cu) are especially valuable. $TiO_2$ is often used

✉ Hamed Ahari
dr.h.ahari@gmail.com

[1] Department of Food Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran

[2] Biotechnology Research Center, Pasteur Institute of Iran, Tehran, Iran

[3] Department of Biology, Science and Research Branch, Islamic Azad University, Tehran, Iran