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Antioxidative and antimicrobial activities of liquid smoke nanocapsules using chitosan and maltodextrin and its application on tuna fish preservation

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ABSTRACT

The aim of the study was to investigate the antioxidative and antimicrobial activities of liquid smoke (LS) nanocapsules from coconut shell using chitosan and maltodextrin as encapsulants and its application on tuna fish preservation. Nanocapsules were prepared by three variations of chitosan (CS)–maltodextrin (MD) i.e. CS (0.5% w/v) and MD (9.5% w/v) in acetic acid (1.0% v/v), only MD (10% w/v) in LS, and a mixture of CS (1.5% w/v) and MD (8.5% w/v) in LS. The experimental factor of varying nanocapsules concentration 0%; 2.5%; 5.0%; 7.5% and 10% w/w was used to evaluate the antioxidative and antimicrobial activities in fresh tuna fish stored at ambient temperature for 0, 12, 24, 36 and 48 h. Fresh tuna minced fish was observed for TVB-N, TPC and sensory evaluation. Results indicated that nanocapsules mixture of CS and MD in LS showed higher value in parameters evaluated i.e. total phenolic, total acid and radical scavenging activity. The addition of nanocapsules prepared of a mixture of CS (1.5% w/v) and MD (8.5% w/v) in LS higher than 5.0% could maintain the fish freshness until 48 h at room temperature and had the smallest particle size. Based on sensory evaluation, the score was neither like nor dislike for all nanocapsules concentrations. The results suggested that LS nanocapsule was an effective preservative agent for fresh tuna fish; therefore these nanocapsules are promising for food applications.

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1. Introduction

Liquid smoke (LS) is usually obtained from the condensation of wood smoke produced by smoldering wood chips or sawdust under limited oxygen. Commercial LS is commonly fractionated, purified and concentrated to yield aqueous, oil or dry powder products. Through the refining process, undesirable polycyclic aromatic hydrocarbons (PAH) are removed, and the intensity of flavor and color in the refined LS is easily adjusted (Varlet, Serot, & Prost, 2010). Refined LS generally offers more flexible applications to particular food systems when compared with LS products (Martinez, Salmerón, Guillén, & Casas, 2007).

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The main purpose of LS application in proteinaceous food products is not only to act as a coloring and flavoring agent; but also to possess antibacterial and antioxidative properties (Darmadji & Izumimoto, 1994; Varlet et al., 2010). Various phenolic compounds present in LS lead to a lower pH and destroy the bacterial cell walls (Pszczola, 1995). LS from coconut shells has been reported to contain bioactive compounds such as phenols, carbonyls and organic acids. Therefore, the coconut shell LS has the potential in increasing the shelf life of proteinaceous food products (Zuraida, Sukarno, & Budijanto, 2011).

The bioactive compounds of LS need to be protected against deterioration during the process through the nanoencapsulation technique. Nanoencapsulation of bioactive compounds represents a viable and efficient approach to increase the physical stability of active substances, protecting them from the interactions with the food ingredients, and because of the subcellular size, increasing their bioactivities (Chuah, Kuroiwa, Ichikawa, Kobayashi, & Nakajima, 2009; Quintanilla-Carvajal et al., 2010; Sekhon, 2010).

Various biocompatible and degradable natural polymers can be employed in the nanoencapsulation technique. Chitosan (CS) has been used as a wall material for encapsulation of sensitive core ingredients such as lipophilic drugs (Ribeiro et al., 1999), vitamin D_2 (Shi & Tan, 2002), astaxanthin (Higuera-Ciapara, Felix-Valenzuela, Goycoolea, & Arguelles-Monal, 2004), and ampicillin (Anal, Stevens, & Remuan-López, 2006). Another wall material is maltodextrin (MD) that most commonly uses material for encapsulation of bioactive material because of low cost and effectiveness. MD is a water-soluble material and able to protect encapsulated ingredient from oxidation. Some studies have explored the use of MD to protect sensitive compounds like vitamin C in fruit juice and to increase product stability in acerola powder (Righetto & Netto, 2005). A recent study found that MD can enhance the phenolic and anthocyanin content during processing of purple sweet potato flour compared to without using MD (Ahmed, Akter, & Eun, 2010).

A previous study demonstrated the ability of CS assembled into nanoparticles of 400–600 nm (Grenha et al., 2010). Preparing nanoparticles in this size range is facilitated by the use of adequate cross-linking agents. TPP is a non-toxic polyanion known for its capacity to cross-link CS, a reaction mediated by electrostatic forces, resulting in the formation of ionic cross-linked networks (Rodrigues, Rosa da Costa, & Grenha, 2012).

In the present study, CS and MD have been chosen as the polycationic and anionic matrices. However, there is no study reporting the nanoencapsulation of LS components and a little is known on CS–MD as encapsulant at different concentrations into LS for antioxidative and antimicrobial activities. The aims of this study were to investigate antioxidative and antimicrobial activities of LS nanocapsules from coconut shell using CS and MD as encapsulant and its application on tuna fish preservation.

2. Materials and methods

2.1. Materials

Raw coconut shell liquid smoke used was obtained from Tropica Nucifera Industry, Yogyakarta, Indonesia. Liquid smoke was purified using the redistilation method in the laboratory. Chitosan (CS) was purchased from Biotech Surindo, Indonesia (deacetylation degree 91.5%, moisture 10.43%, ash content 0.71%). Maltodextrin (MD) with dextrose equivalent (DE) 10.8% was from the Grain Processing Corp. (Iowa, USA), Sodium tripolyphosphate (TPP) and glacial acetic acid (HOAc) were supplied by Sigma Chemicals Ltd. (Munich, Germany). The other chemicals used for analysis were of analytical grade. *Bacillus subtilis* FNCC 0059, *Escherichia coli* FNCC 0091, *Pseudomonas fluoroscens* FNCC 0070 and *Staphylococcus aureus* FNCC 0047 were obtained from the Food and Nutrition Culture Collection (FNCC), Center for Food and Nutrition Study, Gadjah Mada University, Yogyakarta, Indonesia. Tuna fish (*Euthynnus affinis*) was obtained from a commercial fish processing plant in Sadeng, Gunung Kidul Regency Yogyakarta, Indonesia.

2.2. Preparation of nanocapsules

CS–MD mixed nanoparticles were prepared with a slight modification of previously described method of Grenha et al. (2010), based on the polyelectrolyte complexation of CS with MD and additional ionic gelation of chitosan with sodium tripolyphosphate (TPP) anions. CS (0.5% w/v) and MD (9.5% w/v) dispersed in an aqueous solution of glacial acetic acid (1.0% v/v) were prepared and referred to as F1 sample code. In addition, CS and MD dissolved in coconut shell liquid smoke were also prepared at a ratio of CS: MD (0%: 10%) and referred to as F2 sample code, and (1.5%: 8.5%) referred to as F3 sample code.TPP (1.0 mg/mL) was added in these mixtures and agitated using a magnetic stirrer at 200 rpm for 30 min at room temperature. Nanoparticles were isolated by centrifugation (Centrifuge Damon/IEC Division, Connecticut, USA) at 3000 rpm in a 50 mL conical tube for 30 min at room temperature. Supernatant was discarded and nanoparticles were vacuum filtered (Gast, USA) using Whatman #2. The dispersed nanoparticles were heated at 50 °C in a waterbath for 15 min and were homogenized using homogenizer (Ultraturrax T50 Basic IKA Werke, Germany) at 4000 rpm for 2.5 min. Subsequently, the dispersed sample was fed into a Büchi B-290 mini spray dryer (Flawil, Switzerland) for drying. The operating conditions were aspirator rate 50%, drying inlet air temperature a 150 °C (±2 °C), while the outlet air temperature varied between 70 and 82 °C, feed flow rate was set at 5.1 mL/min. Then, the spray-dried powders were collected, kept in amber bottles and stored under desiccated conditions at room temperature prior to application.

2.3. Chemical analyses of nanocapsules

Phenol content of nanocapsules was determined following the procedure established by Senter, Robertson, and Meredith (1989) and carbonyl was quantified according to Lappin and Clark (1951). Total acidity was determined by using titration, by weighing 1 mg of sample in a 250 ml beaker diluted with 100 ml of distilled water. Then, it was titrated with 0.1 N sodium hydroxide solution to an equivalence point of pH 8.15, as determined by using a pH meter. Acidity was calculated as percent by weight of acetic acid using the factor: 1 ml of 0.1 N sodium hydroxide is equivalent to 60.05 mg acetic acid. A pH-meter (Schott, Deutschland,

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