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Decoloration of chitosan by UV irradiation

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Abstract

Decoloration of chitosan by UV irradiation, which was used to replace a bleaching step during chitosan preparation, was evaluated under four separate treatments (effect of irradiation time, chitosan/water ratio, stirring speed, and UV light source). The optimal decoloration condition was defined as that producing white chitosan with higher viscosity. Decoloration of chitosan could be achieved effectively using a UV-C light by stirring unbleached chitosan in water (1:8, w/v) for 5 min at 120 rpm. UV irradiation applied under the optimal conditions could be used to produce chitosan with desirable white color ($L^* = 76.95$, $a^* = -0.37$, and $b^* = 14.04$) and high viscosity (1301.7 mPa s at 0.5% w/v in 1.0% v/v acetic acid).

Keywords: Chitosan; Color; Decoloration; UV irradiation; Viscosity

1. Introduction

Chitosan is a natural biopolymer derived by deacetylation of chitin, a major component of the shells of crustacean such as crab, shrimp, and crawfish. The typical production of chitosan from crustacean shell generally consists of three basic steps: demineralization (DM), deproteinization (DP), and deacetylation (DA) (No & Meyers, 1995); In chitin production, the DM and DP steps produce a colored chitin product. When a bleached chitinous product is desired, pigments can be removed with organic solvents or bleaching agents (No & Meyers, 1995). In general, the organic solvents are not as effective as the bleaching agents such as sodium hypochlorite, hydrogen peroxide or ozone in removing pigments from crab or crawfish shell (Brine & Austin, 1981; Moorjani, Achutha, & Khasim, 1975; No & Lee, 1995; No, Meyers, & Lee, 1989; Seo, King, & Prinyawiwatkul, 2007). As bleaching agents considerably reduce the viscosity of the chitosan product (Moorjani et al., 1975; Seo et al., 2007), an alternative, yet effective and economical decoloration method that will yield decolorized chitosan with high viscosity should be developed.

Earlier investigations have revealed that higher molecular-weight (or viscosity) chitosans were more effective as food preservatives than lower molecular-weight chitosans in extending the shelf life of foods such as bread (Lee et al., 2002), pork (Lee, Park, & Ahn, 2003), sausage (Youn, Park, & Ahn, 2000), and fish (Jeon, Kamil, & Shahidi, 2002). Furthermore, some studies reported that chitosan was more effective in inhibiting growth of bacteria than were chitosan oligomers (No, Park, Lee, & Meyers, 2002; Uchida, Izume, & Ohtakara, 1989). Therefore, production of chitosan with high viscosity is a primary concern. Once high-viscosity chitosan is prepared, low-viscosity chitosan, if necessary, can be subsequently obtained by chemical or enzymatic hydrolysis (No, Nah, & Meyers, 2003).

Investigations from our laboratory (Youn, No, & Prinyawiwatkul, 2007) demonstrated that decolorized chitosan

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with high viscosity could be simply prepared by sun drying after the DA step without using a bleaching agent. Removal of pigments of chitosan with the aid of sun drying is mainly attributed to the UV radiation in the sun light (Sionkowska, 2006). However, applicability of sun drying for decoloration of chitosan is entirely dependent on the weather condition. It is realized that UV light irradiation may serve as an alternative and effective decoloration method that will yield decolorized chitosan without having to depend on weather conditions.

The objective of the present research was to prepare decolorized chitosan with high viscosity by UV irradiation without using a bleaching agent.

2. Materials and methods

2.1. Materials

Dried crab (*Chionoecetes opilio*) leg shell was obtained from Keumho Chemical (Seoul, Korea). The shell was ground through a Wiley mill (model 4, Thomas Scientific, Swedesboro, NJ, USA) with a 2-mm mesh screen and subsequently sifted with 20 (0.841 mm) and 40 mesh (0.425 mm) sieves using a portable sieve shaker (JISICO, Seoul, Korea). The ground shell with 0.841–0.425 mm particle size was used throughout this research to obtain reproducible and consistent results.

2.2. Production of chitosan

The production of chitosan involved the demineralization (DM), deproteinization (DP), deacetylation (DA), and decoloration (DC) steps (No, Lee, Park, & Meyers, 2003). The ground crab leg shell was demineralized with 1 N HCl for 30 min at ambient temperature with a solid/solvent ratio of 1:15 (w/v). Following the DM step, the demineralized shell was collected on a 100-mesh sieve, washed to neutrality in running tap water, rinsed with deionized water, and filtered to remove excess moisture. The DP step was accomplished by treating the demineralized shell with 3% NaOH for 15 min at 15 psi/121 °C and a solid/solvent ratio of 1:10 (w/v). The unbleached chitin was collected, washed as mentioned above, and dried at 60 °C for 4 h in a forced-air oven.

The DA step was achieved by treating chitin under conditions of 15 psi/121 °C with 45% NaOH for 30 min and a solid/solvent ratio of 1:10 (w/v). The resulting chitosan residue was washed and filtered as mentioned above, and subjected to decoloration (DC) by UV irradiation.

2.3. Decoloration of chitosan by UV irradiation

Four separate treatments were sequentially conducted at different time intervals at room temperature. In Treatment 1 (selection of the optimum reaction time), 5 g wet chitosan and 40 mL water were placed in an open-glass petri dish [9 cm inside diameter (ID) × 1.8 cm height (H)], stirred at about 120 rpm using a vortex mixer, and irradiated by 20 W UV-C light (lamp length, 41 cm; wavelength, 254 nm; Germical GL-15, Philips, Holland) for 5, 10, 15, 30, and 60 min.

In Treatment 2 (selection of the optimum water volume), 5 g wet chitosan and 0, 5, 10, 20, 40, 80, or 140 mL water (a chitosan:water ratio of 1:0, 1:1, 1:2, 1:4, 1:8, 1:16 or 1:28) were placed in a petri dish (14 cm ID × 2.3 cm H), stirred at 120 rpm, and irradiated by 20 W UV-C light for 5 min (based on the optimum reaction time from Treatment 1).

In Treatment 3 (selection of the optimum stirring speed), 5 g wet chitosan and 40 mL water (a 1:8 ratio) were placed in a petri dish (9 cm ID × 1.8 cm H), stirred at different speeds (120, 180, 300, and 420 rpm), and irradiated by 20 W UV-C light for 5 min. The chitosan:water ratio and irradiation time were selected based on results of Treatments 1 and 2.

In Treatment 4 (selection of the optimum light source), 5 g wet chitosan and 40 mL water were placed in a petri dish (9 cm ID × 1.8 cm H), stirred at 120 rpm, and irradiated by three different UV lights (A, B, C) for 5 min. The chitosan:water ratio, stirring speed, and irradiation time were selected based on results of Treatments 1–3. The wavelength of UV-A lamp (Philips actinic BL 15 W, Holland) and UV-B lamp (Philips TL-D 15 W, Holland) was 365 and 312 nm, respectively. Immediately following UV irradiation, all chitosans were filtered and dried at 60 °C for 4 h in a forced-air oven for determination of moisture, viscosity and color. From the four separate treatments, the optimal decoloration condition was selected and defined as that producing white chitosan with higher viscosity.

A schematic diagram of a UV-treatment system for chitosan decoloration is shown in Fig. 1. In Treatments

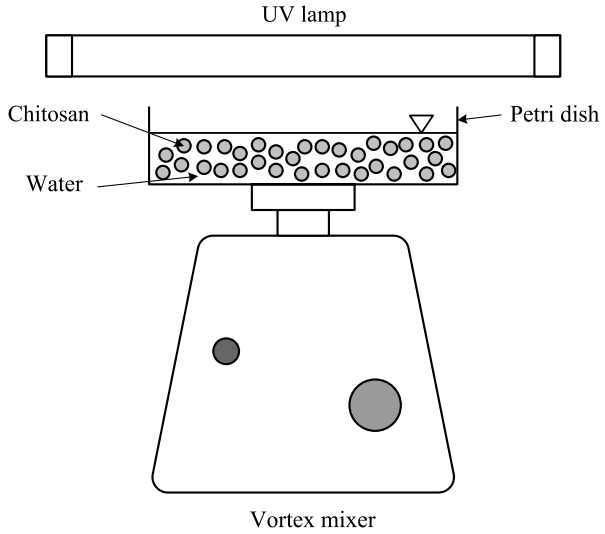

Fig. 1. A schematic diagram of a UV-treatment system for chitosan decoloration.