Effect of Physical and Chemical Treatments on Chitosan Viscosity

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Abstract

Effects of physical and chemical treatments on chitosan viscosity were investigated. Chitosan viscosity was considerably affected by physical (grinding, heating, autoclaving, ultrasonication) and chemical (ozone) treatments, except for freezing, and decreased with an increase in treatment time and temperature. Freezing at -40°C for 9 days did not affect the viscosity of chitosan solution. The chitosan solution stored at 4 and 23°C for 61 days decreased in viscosity by 23 and 64%, respectively. This suggests that chitosan solution stored at 4°C is relatively stable from a viscosity point of view.

Keywords: chitosan, viscosity, physicochemical treatments, storage

INTRODUCTION

Chitosan is a modified, natural carbohydrate polymer derived by deacetylation of chitin, a major component of the shells of crustacea such as crab, shrimp and crawfish and, the second most abundant natural biopolymer after cellulose. During the past several years, chitosan has received increased attention for its commercial applications in the biomedical, food, and chemical industries (1-3).

The food processing industry extensively uses polysaccharides in food product development and processing for purposes of imparting desirable functional properties such as thickening, gelling, emulsifying, whipping, etc (1). Without exception, chitosan has been documented to possess several distinctive properties for use in water and fat uptake, emulsification, surfactant (4), thickening (5), dye binding (6), and gelation (7).

When chitosan, either in solid or solution state, is used in the food processing industry, it can be subjected to various types of processing such as grinding, heating, sterilization, sonication, freezing, or ozone treatment. During such processes, specific characteristics of chitosan, that is, viscosity and molecular weight, may be altered. Thus, changes in specific characteristics of chitosan by various processing types must be monitored since the physicochemical characteristics of chitosan influence its final functional properties (8).

The objective of the present research was to evaluate changes in viscosity of chitosan in solid or solution form by physical and chemical treatments that are commonly encountered in the food processing industry. Stability of chitosan solution under 23 and 4°C storage conditions also was investigated.

MATERIALS AND METHODS

Materials

Chitosan (a powder form and prepared from crab shell) used was a commercially available product from Kitto Life (Seoul, Korea). The chitosan was placed in an opaque plastic bottle and stored at ambient temperature during experiments. Characteristics of chitosan analyzed in our laboratory are as follows: molecular weight, $1.67 \times 10^6$; nitrogen, 7.67%; ash, 0.5%; degree of deacetylation, 98.9%.

Preparation of chitosan solution

Chitosan solution was prepared in 1% acetic acid at a 1% concentration on a dry basis. All solutions were freshly prepared before physicochemical treatments.

Physical treatment of chitosan powder

To obtain a very fine powder, chitosan [$< 0.841$ mm
(20 mesh) particle size) was ground at room temperature for 12, 24, and 36 hr using a jar mill (Young Hana Tech Co., Korea) rotating at 200 rpm speed. After determining the moisture content of the ground chitosan, chitosan solution was prepared as above in triplicate.

**Physicochemical treatments of chitosan solution**

Chitosan solutions (CS) were physically (a-d) or chemically (e) treated as follows: (a) heating 30 mL of CS in 50 mL screw-capped test tubes for 1 hr at 40, 70, and 100°C in a water bath, (b) autoclaving 30 mL of CS in 50 mL screw-capped test tubes for 5, 15, and 30 min under autoclave conditions of 121°C/15 psi, (c) ultrasonicating 50 mL of CS in 100 mL beakers in a refrigerated bath circulator (MRC-1011D, Mono-Tech Eng., Korea) at 23°C for 5, 15, and 30 min (pulse on 5 sec and pulse off 2 sec) using an ultrasonic processor (net power output, 400 W; frequency, 20 kHz; amplitude, 37%) (Model CV26, Sonics & Materials Inc., CT), (d) freezing 50 mL of CS in 100 mL plastic containers for 1, 3, and 9 days in a deep-freezer at -40°C, and (e) ozone treatment by purging ozone gas (0.5 ppm) into 50 mL of CS in 100 mL beakers at room temperature for 10, 20, and 30 min using an ozone generator (Woosung Hi-Tech Co., Korea) equipped with a monitor (Jitsugyo Co., PL-320, Japan).

Immediately following heating and autoclaving, the test tubes containing chitosan solution were rapidly cooled in running tap water. In studies of heat/pressure treatment, the autoclave was preheated to 100°C before introduction of the samples, requiring about 11 min to reach 121°C. In studies of freezing effect, the frozen samples were thawed for 10 min in a water bath at 40°C. All experiments were carried out in triplicate and means ± standard deviations reported.

**Storage of chitosan solution**

Two hundred mL of chitosan solution were placed in 250 mL screw-capped brown glass bottles and stored at 23°C in an incubator and at 4°C in a refrigerator, respectively. Samples were taken after storage of 1, 4, 7, 15, 30, 44, and 61 days and viscosity determined. Experiments were conducted in triplicate and means ± standard deviations reported.

**Determination of moisture and viscosity**

Moisture content of chitosan sample was measured using a Halogen Moisture Analyzer (HG53, Mettler Toledo, Switzerland). Viscosities of chitosan solutions were determined with a Brookfield viscometer, model LVDV-II+ (Brookfield Engineering Labs., Stoughton, MA). Measurements were made using a small sample adapter on solutions (8 mL) at 23±0.3°C and values are reported in centipoise (cP) units.

**RESULTS AND DISCUSSION**

**Effect of grinding**

A jar mill is ideal for grinding samples into a fine powder. To evaluate changes in physical property of chitosan by grinding, chitosan was ground and viscosity was determined with time.

As shown in Fig. 1, viscosity considerably decreased with increasing grinding times. The viscosity of chitosan ground for 12, 24, and 36 hr decreased by 58% (224 cP), 76% (128 cP), and 90% (51 cP), respectively, compared with that (528 cP) of the control. Grinding of chitosan with a jar mill was effective in obtaining a very fine powder, but was accompanied with a considerable decrease in viscosity due to degradation of the polymer by mechanical action of the grinding process (9).

**Effect of heating**

Chitosan solutions were heated for 1 hr at three different temperatures (40, 70, 100°C) and viscosities were compared with that of the control (23°C). Results (Fig. 2) revealed that viscosity decreased with increasing temperatures, with the most significant decrease

![Fig. 1. Effect of grinding times on viscosity of chitosan.](image-url)