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# Spray-dried chitinosans
# Part I: preparation and characterization

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**Abstract**

*Purpose*: Physicochemical and micromeritic characterization of chitinosans. *Methods*: Chitinosans subjected to *N*-deacetylation and depolymerization were characterized for degree of *N*-deacetylation (DD), molecular weight (MW), p$K_a$, particle size determination and morphology, tap/bulk density measurements, surface area determinations, and determination of flow properties. *Results*: The chitinosan DDs and MWs were dependent on the processing conditions and ranged from 66 to 89% and 2–522 kDa, respectively. Chitinosan particle sizes and shapes were dependent on drying conditions (range 8–465 μm). Spray-dried chitinosans were spherical and had smaller particle sizes than the non-spray-dried materials which were irregularly shaped particles. Higher density values were obtained for processed materials than those for the raw material. Lower specific surface areas were observed for non-spray-dried chitinosans (0.28–1.59 $m^2$/g) than for spray-dried chitinosans (0.74–3.01 $m^2$/g). Weight variation of chitinosan tablets indicated that spray-dried chitinosans possessed improved flow characteristics as compared with tray-dried chitinosans. *Conclusions*: The effect of drying method employed in chitinosan manufacture, i.e. spray versus tray drying, on the physicochemical and micromeritic properties of the resultant chitinosans were evaluated. Although the drying methods did not significantly influence the physicochemical properties, they affected the micromeritic properties of the resultant chitinosans.


*Keywords:* Chitinosan; Chitosan; Chitin; Spray dried; Micromeritic

## 1. Introduction

Every year, approximately 100 billion tons of chitin is produced on the earth by crustaceans, mollusks, insects, fungi, and related organisms. This amount is comparable to that of cellulose produced by higher plants, but chitin is not widely used by the pharmaceutical industry at present. Its limited utility—principally —is the result of its poor solubility characteristics. However, its derivative, chitosan or chitinosan (Block, 1997)—prepared by *N*-deacetylation and depolymerization of native chitin—is soluble in dilute acids when the degree of *N*-deacetylation is more than 65–70% (Austin and Brine, 1981). Chitinosan is a cationic biopolymer that is bioadhesive, biocompatible, and biodegradable (Muzzarelli, 1993). These unique properties make it an attractive carrier for biomedical applications. Although the polymer was discovered in 1859, its physicochemical and micromeritic properties have not been fully elucidated to date. The incomplete characterization of chitinosans and the variability of commercial chitinosans

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has discouraged the pharmaceutical industry from adopting it as a pharmaceutical excipient or formulation component. In addition, the molecular weights (MW) of these commercial materials typically range from 50 to 2000 kDa. The heterogeneity of these chitinosans is the result of the relatively uncontrolled commercial processing of native chitin involving both *N*-deacetylation and depolymerization.

The main driving force in the development of new applications for chitinosans lies in the fact that this cationic polymer is not only readily and economically processed from naturally abundant chitin, but is also non-toxic, biodegradable, and multifunctional (Akbuga, 1995). One area of concern involves their utilization in directly compressible tablet formulations. Although chitinosans have been evaluated as directly compressible tablet excipients, virtually all formulations developed to date necessitate the addition of other ingredients to facilitate compression (Machida and Nagai, 1989; Knapczyk, 1993; Akbuga, 1995). However, more recent research from our laboratories has provided evidence to support the use of this biopolymer as a directly compressible tablet excipient (Sabnis et al., 1997; Rege et al., 1999).

In this study, we attempted to evaluate the effect of drying methods (spray drying versus tray drying) (Broadhead et al., 1992) used in chitinosan manufacture on the resultant chitinosan physicochemical and micromeritic properties. Commercially available chitinosans and their deacetylated and/or depolymerized counterparts were subjected to different drying methods to yield spray- and tray-dried batches and subsequently characterized for their degree of *N*-deacetylation, molecular weight, particle size, particle surface morphology, specific surface area, powder density, and flow properties.

## 2. Materials and methods

Commercially available chitinosans were purchased either from Fluka Chemie AG, Buchs, Switzerland, or from Sigma Chemical Co., St. Louis, MO. These chitinosans were milled (Wiley Mill, Model # 3, A. H. Thomas, Philadelphia, PA) and passed through a 60 mesh (250 μm) sieve prior to use. Reagent grades of glacial acetic acid, hydrochloric acid, methanol, potassium chloride, sodium acetate, sodium chloride, and sodium hydroxide were used as supplied by Fisher Scientific Co., Fair Lawn, NJ. Nitrogen and helium gases (99.999% pure) were obtained from Jackson Welding Co., Pittsburgh, PA. Alumina and kaolinite reference standards (for surface area determinations) were obtained from Micromeritics Instruments Corp., Norcross, GA.

### 2.1. N-Deacetylation of chitinosans

Commercially available chitinosans (200 g each) were refluxed with 3 l of 50% w/w sodium hydroxide in a three-necked flask (capacity = 5 l) under a nitrogen blanket at 80 °C for a predetermined time period ($t = 1$ or 24 h). The reaction was stirred at 600 rpm using a Lightnin mixer (TS 2010, Mixing Equipment Corp., New York, NY) equipped with a fold-away two-blade propeller. At the end of the time period, the mixture was cooled to room temperature and its pH adjusted to neutrality with 2.5N hydrochloric acid. The precipitated polymer was then filtered and the precipitate washed several times with distilled water. Neutrality was confirmed by pH measurements of the filtrate. The resultant polymer was then used as the starting material for the depolymerization step.

### 2.2. Depolymerization of chitinosans

The deacetylated chitinosans were refluxed with 3 l of 2.5N hydrochloric acid in a three-necked flask under a nitrogen blanket at 80 °C for 1- or 4-h time period. The resultant mixture was cooled to room temperature and its pH adjusted to neutrality by the addition of 5N sodium hydroxide. The precipitated polymer was then filtered and the precipitate washed several times with distilled water. Neutrality was confirmed by pH measurements of the filtrate. The resultant polymer was then dried in a hot-air oven (tray dried) at 60 °C for 48 h or dispersed in water as a ∼1% w/v suspension and subsequently spray dried (see below). The tray-dried product was milled using a Waring blender (Model FCI 15, Waring Products Corp., NY), subsequently sieved and used.

### 2.3. Spray drying of chitinosans

Chitinosan suspensions (∼1% w/v) were spray dried using a Niro 3-ft spray dryer (Lab scale model,

Niro, Copenhagen, Denmark). The spray drying of the suspensions was conducted in a co-current manner (nozzle size = 2 mm) at inlet temperatures of 300–350 °C whereas the outlet temperature was maintained constant at 100 °C. The suspension was continuously stirred using a mixer (Model PZR 50, Caframo Ltd., Ont., Canada) equipped with a three-blade propeller. The suspension feed into the spray dryer was regulated at 55–65 g/min using a Masterflex Digital Console Drive pump (Model 7523-30, Cole Parmer Instrument Co., Niles, IL).

### 2.4. Characterization of selected chitinosans

#### 2.4.1. Degree of *N*-deacetylation determinations

The degree of *N*-deacetylation was determined by an IR spectroscopic method (Sabnis and Block, 1997) using a Perkin-Elmer FT-IR spectrometer (Model 1605, Perkin Elmer Corp., Norwalk, CT). Approximately 25 mg of dried chitinosan was triturated with 100 mg of potassium bromide (IR grade) and the mixture passed through a 100 mesh (150-μm) sieve; about 40 mg of the sieved mixture was then used to prepare a pellet.

#### 2.4.2. Degree of polymerization determinations

Chitinosan molecular weight (viscosity average) was calculated from the classical Mark–Houwink relationship:

$$[\eta] = K_m \cdot (\mathrm{MW})^a \quad (1)$$

where, $[\eta]$ is the intrinsic viscosity, $K_m = 2.14 \times 10^{-3}$, and $a = 0.657$. The values of $K_m$ and $a$ were previously determined by laser light scattering techniques (Sabnis, 1996).

Polymer solutions, of known concentrations, were prepared in a solvent system consisting of 0.5 M acetic acid and 0.25 M sodium chloride in deionized water. The solutions were then filtered through a 5-μm nylon filter (Magna-R, lot number 67498, Micron Separations Inc., Westboro, MA) prior to the viscosity measurements. The viscosity measurements were based on the efflux times of the filtered solutions in Ubbelohde viscometer (Model I136, Cannon Instrument Co., State College, PA) maintained in a constant-temperature bath at 25 ± 0.1 °C.

#### 2.4.3. Particle size determinations

A Nikon optical microscope (Model EL, Nikon Corporation, Tokyo, Japan) was used in the particle size analysis of the chitinosan samples. Determinations, conducted at 100× or 440× magnification, involved a total of 300 particles for every chitinosan sample (Martin et al., 1991).

#### 2.4.4. Particle surface morphology determinations

Chitinosan morphology was studied using a scanning electron microscope (Model XL 30 FEG, Phillips Corp., Holland) equipped with an EDACS-CDU LEAP detector. The chitinosan samples were coated with palladium, using a Hummer 10.2 SEM coating unit (Anatech Ltd., Alexandria, VA), dried under vacuum for 24 h, and mounted on carbon stubs, using methanol as the dispersing medium.

#### 2.4.5. Specific surfsace area determinations

Surface area determinations were conducted using a Flowsorb II apparatus (Model 2300, Micromeritics Instrument Corporation, Norcross, GA). The surface area measurements utilized nitrogen ($N_2$):helium (He) gas mixtures containing 5, 10, 20, and 30% nitrogen. The instrument was calibrated (for single-point and multi-point determinations) by injecting a precise volume of nitrogen gas (1 $cm^3$). The measurements were repeated in order to establish the accuracy and precision of the method. Reference surface area materials (i.e. alumina with surface area = 0.52 ± 0.03 $m^2/g$, and kaolinite with surface area = 15.8 ± 0.9 $m^2/g$) were used as standards to validate the instrument.

*2.4.5.1. Single-point determinations.* The instrument was calibrated and subsequently adjusted to display the surface area of a precise volume of gas. An accurately weighed sample was then transferred into the sample tube which was attached to the degas port to allow removal of residual moisture and adsorbed gases. The heating mantle was placed around the tube and the sample heated at 120 °C for 2 h while the $N_2$:He gas admixture flowed through the tube at a flow rate of 40 $cm^3$/min. Subsequent to the degassing procedure, the sample tube was attached to the test port and immersed into a Dewar filled with liquid nitrogen and adsorption was allowed to proceed. Adsorption was considered complete after the detector returned to zero. The Dewar was then lowered and the

sample allowed to equilibrate to room temperature (i.e. to desorb). Desorption was considered complete after subsequent detector stabilization and the value displayed on the Flowsorb was recorded as the sample surface area. Replicate measurements were made to validate the results and to ensure that the heating conditions used were sufficient for adsorbed gas removal.

*2.4.5.2. Multi-point determinations.* During the multi-point determination, sample preparation and experimental were identical to those described above. However, the value displayed on the Flowsorb was adjusted to display the volume of gas adsorbed at STP instead of the sample surface area (as in single-point measurements). Again, replicate measurements were made to validate the results and to ensure that the heating conditions used were sufficient for adsorbed gas removal. The gas composition was then changed and the entire procedure repeated to yield the volume of gas adsorbed (at STP) for the corresponding gas composition.

These data were then mathematically transformed and plotted in accordance with the Brunauer, Emmett, and Teller (BET) equation. The slope and intercept of the BET plot was determined and the specific surface area was calculated.

*2.4.6. Density measurements*

*2.4.6.1. Bulk density measurements.* Accurately weighed chitinosan powder was transferred into a calibrated 50-ml graduated cylinder. The volume occupied by the powder was recorded and the bulk density then calculated.

*2.4.6.2. Tap density measurements.* Accurately weighed chitinosan powder was transferred into a calibrated 50-ml graduated cylinder. The cylinder was subsequently placed in a tap density tester (Vanderkamp®, VanKel Industries, Inc., NJ), and subjected to tapping. The volume occupied by the powder after 100 "taps" was recorded and the tap density then calculated.

*2.4.7. Flow properties*

Following the procedure established by Augsburger and Shangraw (1966), chitinosan flowability was evaluated by a direct compression method. The chitinosans were compressed as is (using 5/16th-in. punches and corresponding dies) on a fixed speed rotary tablet press (No. 216, Arthur Colton Co., Detroit, MI). A total of four tablet stations were utilized; the remaining stations were fitted with blank dies. The tablets compressed during the first 10 rotations of the turret (i.e. after 40 tablets) were discarded. Subsequent to this, tablets were consecutively collected ($n = 50$) and weighed. The tablet weights were evaluated statistically and graphically to determine the pattern, if any, of weight variation.

*2.5. Statistical analysis*

*2.5.1. To determine the effect of spray drying on chitinosan properties*

A $7 \times 2$ full factorial experimental design was used to evaluate the effect of spray drying on the resultant chitinosan properties. The *independent* variables were the chitinosans used ($n = 7$) and the drying process (spray drying versus tray drying). The *dependent* variables used were the resultant chitinosan degree of *N*-deacetylation, molecular weight, particle size, surface area, and chitinosan bulk and tap densities. The experimental data were analyzed in accordance with a full factorial ANOVA using JMP (v. 3.1.5., SAS Institute, Inc., Cary, NC).

## 3. Results and discussions

Although commercial chitinosans range from ~50 to 2000 kDa, earlier research has provided evidence to the utility of the low molecular weights chitinosans in their ability to modify/control drug release (Rege et al., 1999). Hence, commercial chitinosans in the molecular weight range of 200–500 kDa were selected in this study. The chitinosans purchased from Sigma Chemical Co. (i.e. lots SP and SF) were deacetylated and depolymerized, using the procedures described above to yield lots SP12, SP21, SF11, and SF22 (with substantially lower molecular weights as compared to the commercial materials, i.e. ~2–20 kDa). The deacetylated and depolymerized chitinosans were subsequently either spray dried or tray dried. Both, lots SP and SF (labeled as chitins) were low in their degree of *N*-deacetylation, insoluble in dilute acetic acid solution, and hence could not be evaluated for their molecular weight. Furthermore, only one of the chitin

sample (lot SP) was characterized in the study. The chitinosans purchased from Fluka Chemie (i.e. lots FLMW and FHMW) were not chemically treated (i.e. deacetylated or depolymerized) but were suspended in water and subsequently tray dried or spray dried. Tray drying invariably resulted in hard tenacious masses, which had to be ground in a Waring blender in order to obtain free-flowing powders, whereas spray drying produced particulate chitinosans, which did not require additional milling.

### 3.1. Effect of the drying method on the degree of N-deacetylation of the resultant chitinosans

The degrees of *N*-deacetylation of the chitinosans used in this study as determined by FT-IR spectroscopy are shown in Table 1. A full factorial ANOVA indicated that the degrees of *N*-deacetylation of the spray- or tray-dried chitinosans were not significantly different ($P > 0.05$).

### 3.2. Effect of the drying method on the molecular weights of the resultant chitinosan

The viscosity average molecular weights of the chitinosans used in this study are shown in Table 1. A full factorial ANOVA indicated that the molecular weights of the spray- or tray-dried chitinosans were not significantly different ($P > 0.05$). Thus, the drying process used in chitinosan manufacture did not significantly affect the degree of *N*-deacetylation or the molecular weight of the resultant chitinosans.

Table 1
Degrees of *N*-deacetylation and molecular weights of chitinosans used in this study

| Chitinosan | Degree of *N*-deacetylation (%)[a] | Molecular weight (kDa)[a] |
|---|---|---|
| FLMW spray dried | 88.9 ± 0.2 | 280.3 ± 10.2 |
| FLMW tray dried | 86.0 ± 0.5 | 287.3 ± 10.1 |
| FHMW spray dried | 85.3 ± 0.2 | 522.1 ± 12.6 |
| FHMW tray dried | 87.3 ± 0.5 | 519.6 ± 10.5 |
| SP spray dried[b] | 66.7 ± 0.9 | – |
| SP tray dried[b] | 65.9 ± 0.3 | – |
| SP12 spray dried | 82.2 ± 0.7 | 2.0 ± 0.9 |
| SP12 tray dried | 81.4 ± 0.5 | 1.8 ± 0.1 |
| SP21 spray dried | 86.3 ± 0.1 | 15.8 ± 0.4 |
| SP21 tray dried | 86.6 ± 0.2 | 16.6 ± 0.5 |
| SF11 spray dried | 82.5 ± 0.5 | 6.5 ± 0.3 |
| SF11 tray dried | 81.7 ± 0.4 | 6.7 ± 0.1 |
| SF22 spray dried | 85.7 ± 0.6 | 5.0 ± 0.1 |
| SF22 tray dried | 85.8 ± 0.5 | 4.9 ± 0.2 |

[a] Mean ± S.D.; $n = 3$.
[b] Insoluble material and hence molecular weight could not be determined using the methods used herein.

Table 2
Size distribution parameters and specific surface areas of chitinosans

| Chitinosan | Size distribution parameters[a] | | Specific surface area ($m^2/g$)[b] |
|---|---|---|---|
| | Geometric mean diameter ($d_g$) (μm) | Geometric standard deviation ($\sigma_g$) (μm) | |
| FLMW spray dried | 255 | 0.010 | 0.994–0.997 |
| FLMW tray dried | 465 | 0.009 | 0.884–1.007 |
| FHMW spray dried | 235 | 0.015 | 0.973–0.975 |
| FHMW tray dried | 420 | 0.009 | 0.830–0.882 |
| SP spray dried | 320 | 0.011 | 1.981–2.053 |
| SP tray dried | 450 | 0.008 | 1.591–1.637 |
| SP12 spray dried | 24 | 0.108 | 2.320–2.410 |
| SP12 tray dried | 116 | 0.026 | 0.769–0.785 |
| SP21 spray dried | 8 | 0.321 | 3.038–3.039 |
| SP21 tray dried | 86 | 0.034 | 0.477–0.547 |
| SF11 spray dried | 12 | 0.168 | 1.758–1.759 |
| SF11 tray dried | 72 | 0.042 | 0.322–0.328 |
| SF22 spray dried | 24 | 0.117 | 0.747–0784 |
| SF22 tray dried | 82 | 0.035 | 0.278–0.313 |

[a] $n = 300$.
[b] Range, $n = 2$.

### 3.3. Effect of drying method on the particle size and particle shape of the resultant chitinosans

The geometric mean diameters ($d_g$) and the geometric standard deviations ($\sigma_g$) for each chitinosan evaluated are listed in Table 2. The drying method had a significant impact on the particle size of the chitinosans ($P < 0.002$). In general, even after milling, the tray-dried chitinosans exhibited larger particle sizes than the corresponding spray-dried materials. The particle shape was also dependent on the drying method used. Spray-dried powders were generally more spherical in shape in contrast to the tray-dried powders which were composed of irregularly shaped particles. Specifically, the commercially available untreated chitinosans (i.e. FLMW, FHMW, and SP) did not show any appreciable changes in particle shape after spray drying of their dispersions. However, the chitinosans which were synthesized "in-house" (i.e. SP12, SP21, SF11, and SF22) *were* markedly affected by spray drying: their particles were spherical, for the most part, whereas those obtained by tray drying comprised a mixture of spherical and irregularly shaped particles. These visual observations were confirmed by scanning electron microscopy (SEM). The SEMs were obtained at both lower and higher magnifications in order to obtain information about the powder characteristics (i.e. particle size and shape) and the particle surface (i.e. texture). Representative SEMs are shown in Fig. 1.

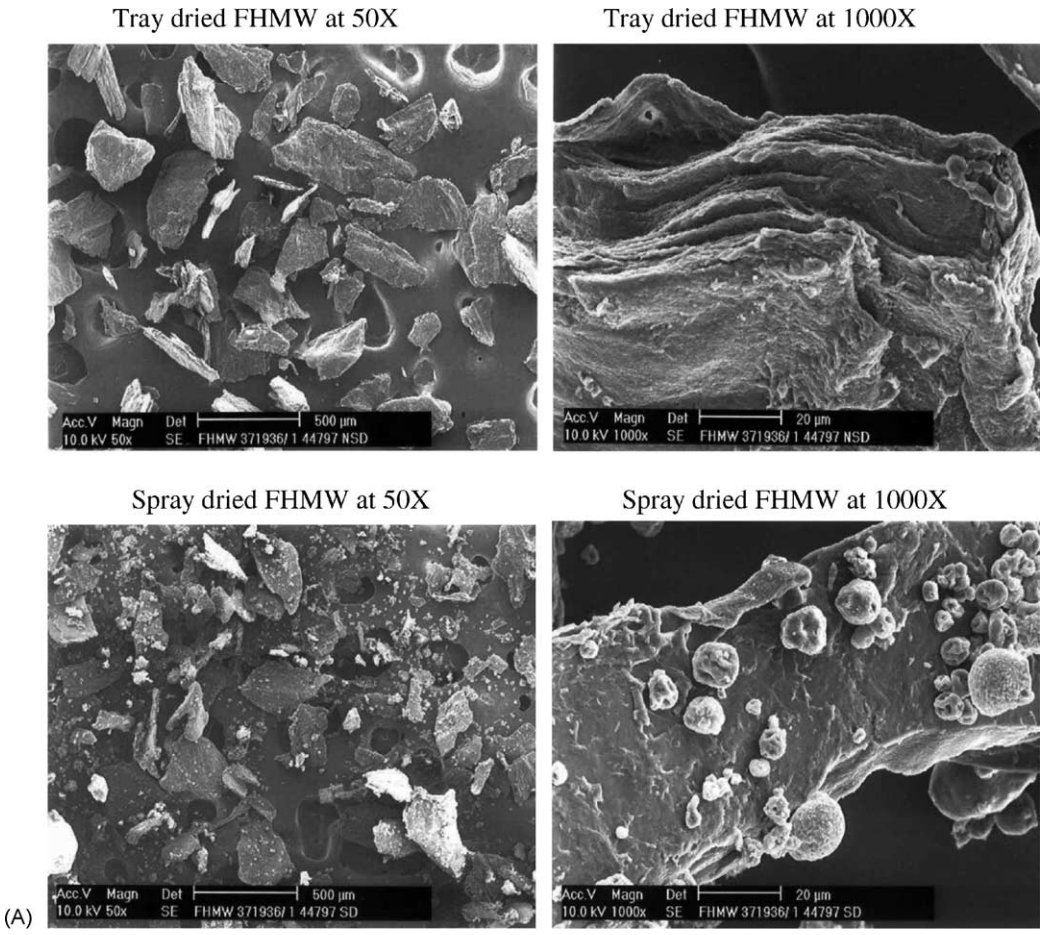


Fig. 1. Representative SEMs of chitinosans after tray and spray drying.

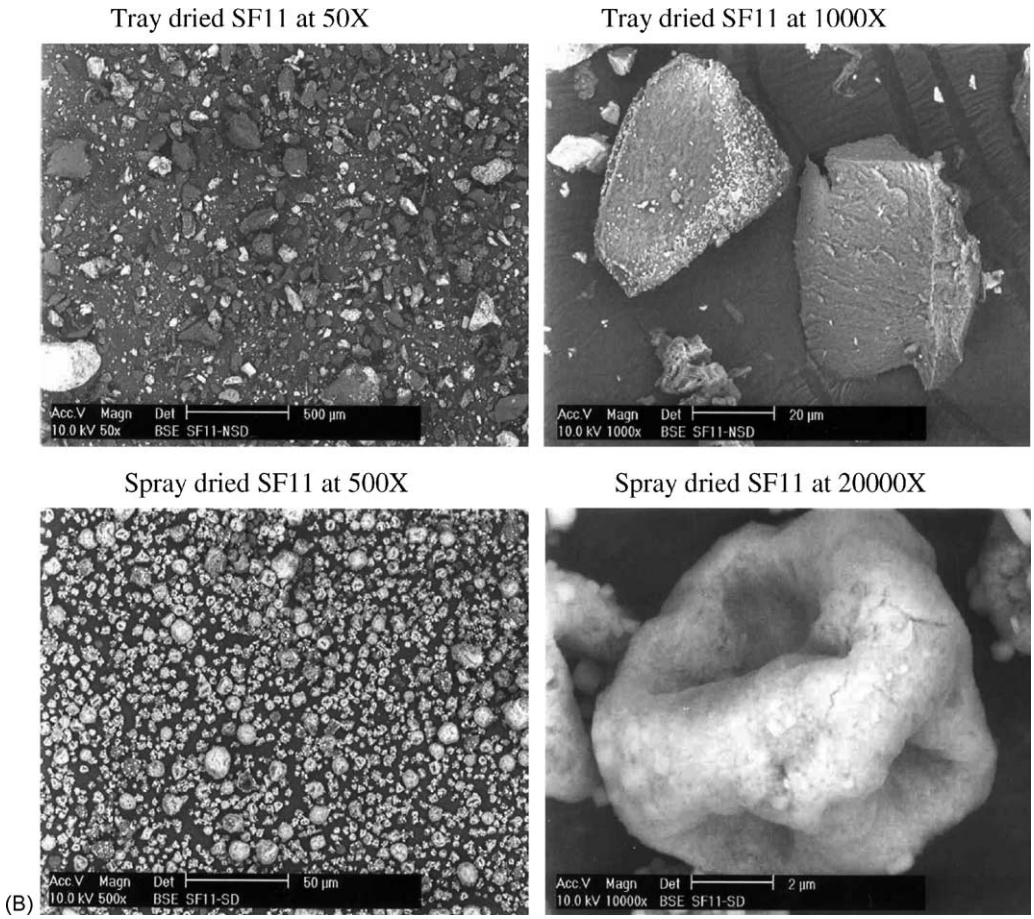


Fig. 1. (*Continued*)

### *3.4. Effect of drying method on the particle specific surface area of the resultant chitinosans*

The volumes of nitrogen gas adsorbed by the various chitinosans at STP were determined using different nitrogen–helium gas compositions (i.e. 5, 10, 20, and 30% nitrogen) as described earlier. The BET adsorption isotherms were subsequently generated for each of the chitinosans used in this study. A representative BET adsorption isotherm is shown in Fig. 2. The specific surface areas of the chitinosans as determined by the BET method are reported in Table 2. The drying process significantly affected the chitinosan specific surface areas. Since the drying techniques were shown to have affected the particle size (Table 2), it is not surprising that the spray-dried chitinosans, with smaller particle sizes, exhibited larger specific surface areas than the corresponding tray-dried chitinosans. The statistical analysis of the data identified the drying method as a critical variable ($P < 0.04$) in the processing of chitinosan.

### *3.5. Effect of drying method on the bulk and tap densities of the resultant chitinosans*

The bulk and tap densities of the chitinosans are reported in Table 3. The spray-dried particles, in general, were hollow spheres (visually confirmed by SEM analyses), presumably with lower particle density than the relatively solid tray-dried particles. However, with respect to powder packing characteristics, the small, spherical spray-dried particles would be expected to

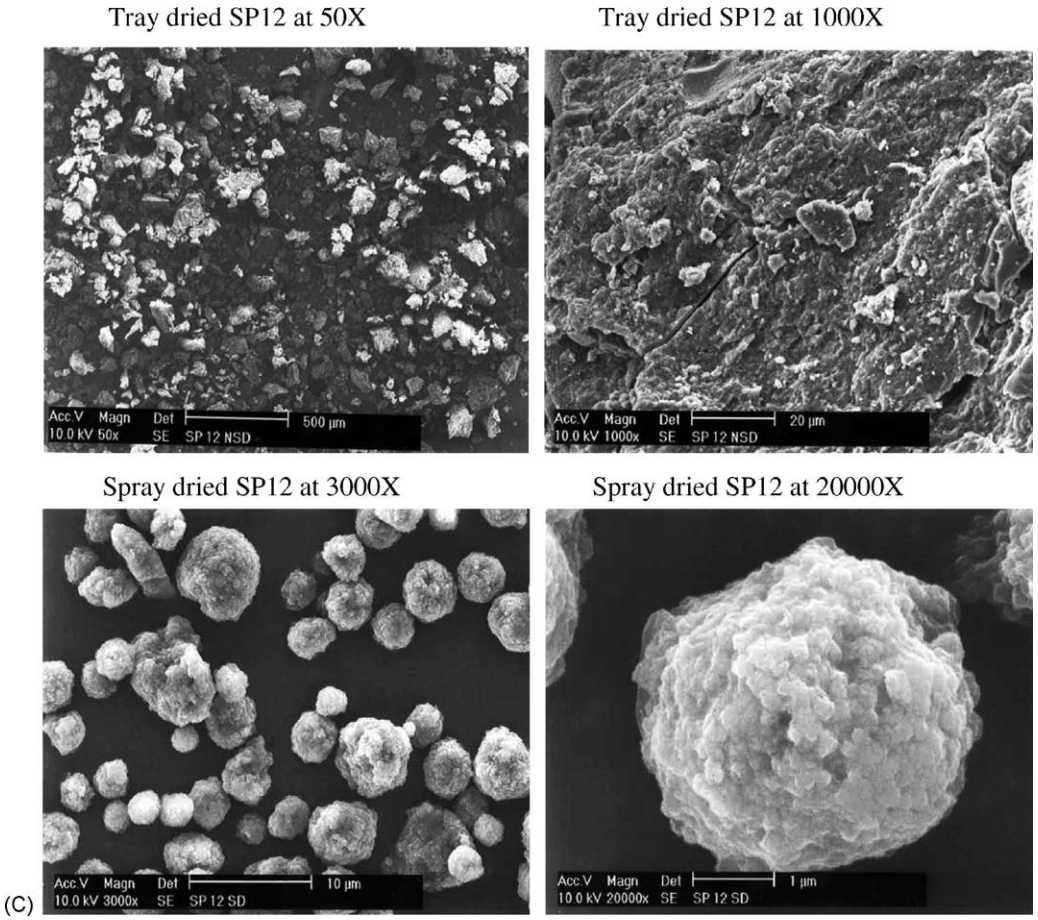


Fig. 1. (*Continued*).

Table 3
Bulk and tap densities and flow properties of chitinosans used in this study

| Chitinosan | Density[a] | | Compressibility (%) |
|---|---|---|---|
| | Bulk | Tap | |
| FLMW spray dried | 0.315–0.316 | 0.416–0.430 | 25.3 |
| FLMW tray dried[b] | – | – | |
| FHMW spray dried | 0.350–0.358 | 0.503–0.516 | 30.5 |
| FHMW tray dried | 0.310–0.316 | 0.398–0.407 | 22.1 |
| SP spray dried | 0.255–0.266 | 0.350–0.351 | 25.8 |
| SP tray dried | 0.241–0.242 | 0.396–0.397 | 39.0 |
| SP12 spray dried | 0.474–0.504 | 0.504–0.543 | 6.5 |
| SP12 tray dried | 0.640–0.641 | 0.844–0.845 | 24.3 |
| SP21 spray dried | 0.387–0.406 | 0.439–0.449 | 10.8 |
| SP21 tray dried | 0.645–0.654 | 0.859–0.876 | 25.1 |
| SF11 spray dried | 0.467–0.451 | 0.485–0.511 | 7.8 |
| SF11 tray dried | 0.691–0.693 | 0.918–0.933 | 25.0 |
| SF22 spray dried | 0.541–0.542 | 0.612–0.620 | 11.9 |
| SF22 tray dried | 0.679–0.702 | 0.845–0.881 | 20.1 |

[a] Range, $n = 2$.
[b] Insufficient sample; data not available.

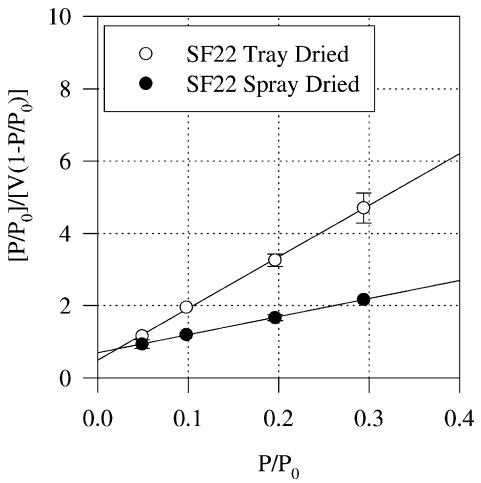


Fig. 2. Representative BET isotherm for chitinosan.

pack together closely leading to a lower volume to mass ratio, and, therefore, higher bulk density. Conversely, the large, irregular tray-dried particles would be expected to exhibit *poor* packing characteristics, a higher volume to mass ratio, i.e. *a* lower bulk density. Since particle density and particle packing affect the density of the powder, the observation that spray drying results in a decrease both in bulk density and tap density of the powder as compared to the effect of tray drying ($P < 0.05$) is not unexpected. The percent compressibility was subsequently calculated (Fiese and Hagen, 1986) and the values for the tray- and spray-dried material are reported in Table 3. Spray-dried chitinosans, in general, exhibited lower percentage of compressibility values, in contrast to tray-dried chitinosans, which correspond to improved flow properties of the spray-dried materials.

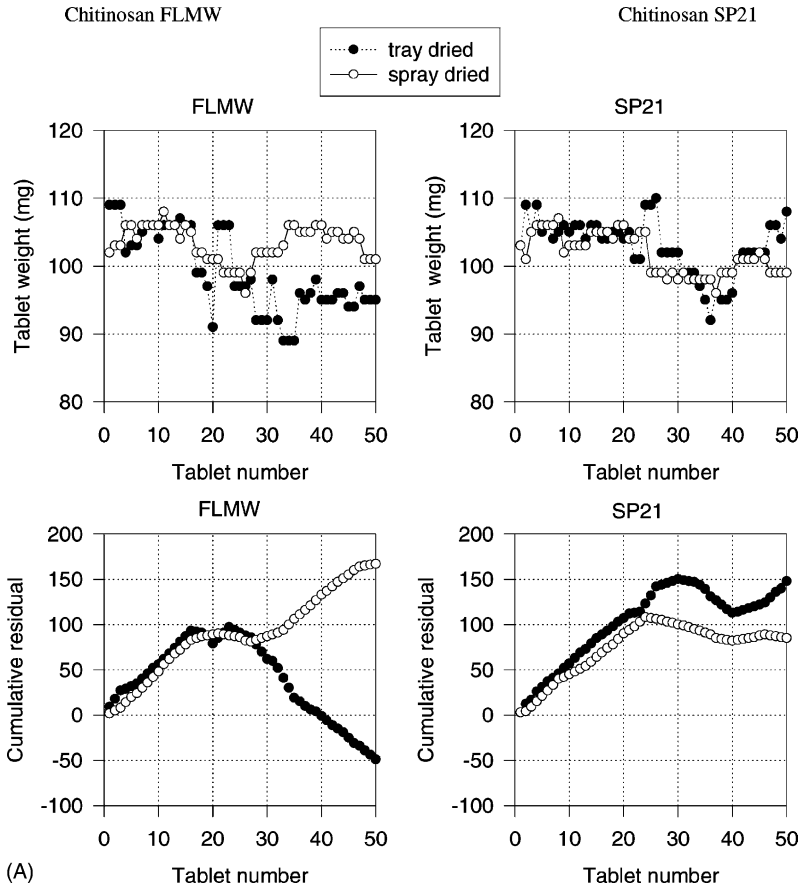


Fig. 3. Representative weight variation charts, cusum plots, and frequency histograms for chitinosan.

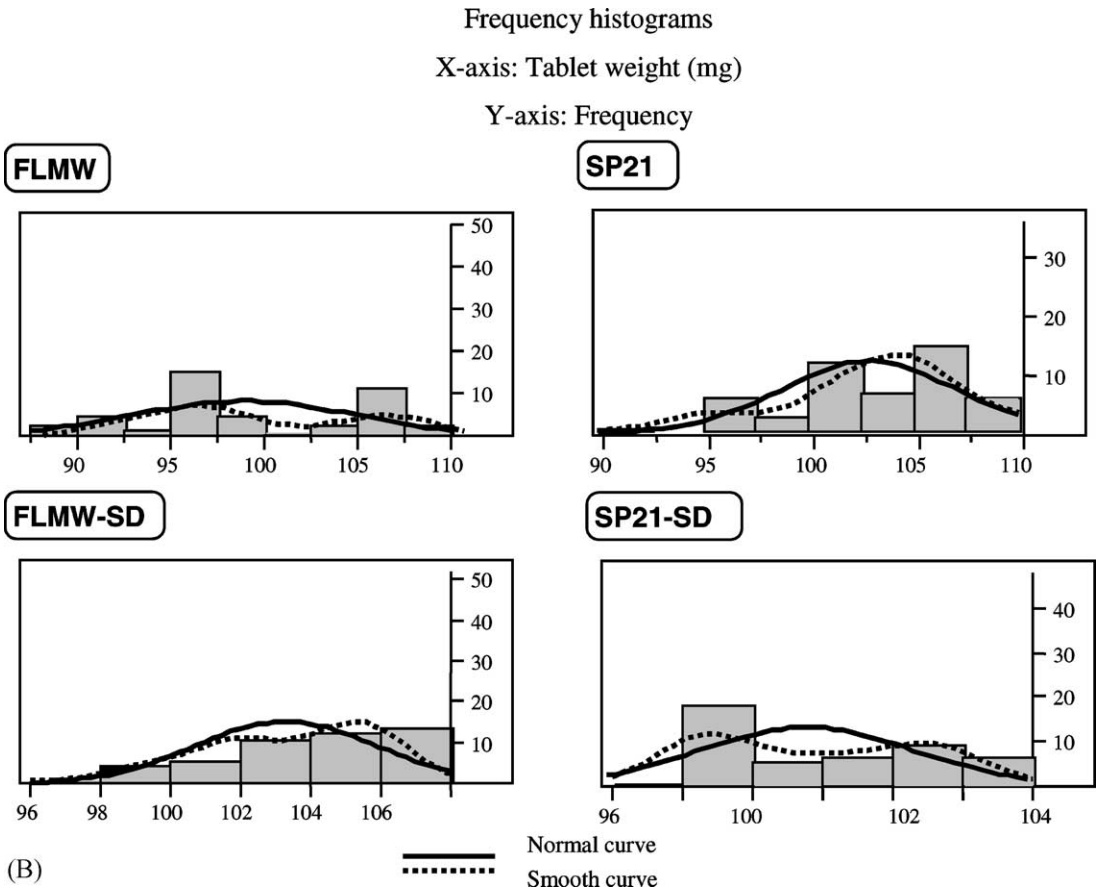


Fig. 3. (*Continued*).

### *3.6. Effect of drying method on the flow properties of the resultant chitinosan powders*

The flow properties of the chitinosans were evaluated by studying the weight variation of the tablets compressed from the various chitinosans. The chitinosans were compressed, as is, without the addition of other ingredients or lubricants. Fifty tablets were serially collected and weighed. The weights were then plotted against the tablet number to examine if there were any trends in the tablet weights over time. Furthermore, polar coordinate graphs were generated to determine if any trend resulting from a particular tablet station could be identified. Representative weight variation charts, cusum plots, and the frequency distributions are shown in Fig. 3. In general, although the cusum plots show trends in the data, the weight variation plots indicate that tablet weights over the collection range were, in most cases, within ± 10% of the target weight. The histograms of the tablet weight suggest that in most cases the tablet weights followed a bi-modal distribution. The drying process affected the powder flow properties: spray-dried materials, in general, consisted of spherical particles and demonstrated better flow (i.e. lower weight variation) than their tray-dried counterparts.

## 4. Conclusions

Although chitin and its derivatives (chitinosan and chitosan) have been commercially available for some time, their physicochemical properties have not been fully elucidated to date. The incomplete

characterization of these carbohydrate polymers and the variability of commercial materials have discouraged pharmaceutical formulators from adopting it as a pharmaceutical excipient. Previous research in our laboratory focused on the use of chitinosans as excipients for implantable delivery systems, as well as for electrically modulated gel delivery systems. Our intention in these studies is to further characterize the chitinosans and facilitate their incorporation into drug dosage forms and delivery systems.

In this paper, we have evaluated the effect of the drying method used in chitinosan manufacture, i.e. spray drying or tray drying, on the physicochemical and micromeritic properties of the resultant chitinosans. Although the drying methods did not significantly influence chitinosan's physicochemical properties, they did significantly affect the micromeritic properties of the resultant chitinosans.

Spray drying resulted in a free-flowing powder, which exhibited improved compressibility, thereby suggesting the potential of spray-dried chitinosan as an excipient for directly compressible formulations.

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