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Production and characterization of chitosan-based polymer particles with the precipitation collection method

Çöktürme toplama metodu ile kitosan esaslı polimerik partikül üretimi ve karakterizasyonu

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Research Article

Abstract

In this study, a chitosan-based polymer particle was produced to be used as a sorbent. Gel particle production was carried out using chitosan samples with different acetylation degrees and molecular weights. The produced particles were characterized. In the first phase of the study, chitosan samples were provided and structural analyses were performed. In the second stage, polymer particle production was carried out by the precipitation-collection method. The morphological, structural, and physicochemical properties of the produced gel particles were examined. In the last step, the sorption efficiency of the particles (distilled water, oleic acid) was investigated. As a result, it was measured that the polymer particle diameters were to be between 3.388 and 3.903 mm and the densities of the particles were to be 0.389-0.416 g/cm^3. Distilled water holding capacity of the particle which was produced with an 85 % DDA chitosan sample, was calculated as 0.523 g/g$_{\text{particles}}$, and the oleic acid holding capacity was determined as 0.286 g/g$_{\text{particles}}$. These values are approximately 20 % lower than the values obtained with the 75 % DDA chitosan sample. Low molecular mass chitosan sample sorbed 0.556 g distilled water per gram particle and 0.193 g oleic acid per gram particle. These values were calculated as 0.170 g/g$_{\text{particle}}$ and 0.381 g/g$_{\text{particle}}$ for the particles produced using high molecular weight chitosan samples, respectively. EDX analysis performed on the selected region, it was determined that the chitosan-based polymer particle consisted of 43.58 % C, and 49.83 % O.

Keywords: Chitosan, Polymer particle, Sorption, Distilled water, Oleic acid.

Özet

Bu çalışmada, sorbent olarak kullanılmak üzere kitosan bazlı bir polimer partikülü üretilmiştir. Jel partikül üretimi, farklı asetilasyon derecelerine ve moleküler ağırlıklara sahip kitosan numuneleri kullanılarak gerçekleştirilmiştir. Üretilen partiküller karakterize edilmiştir. Çalışmanın ilk aşamasında kitosan numuneleri temin edilerek yapısal analizleri yapılmıştır. İkinci aşamada çöktürme-toplama yöntemi ile polimer partikül üretimi gerçekleştirilmiştir. Üretilen jel partiküllerinin morfolojik, yapısal ve fizikokimyasal özellikleri incelenmiştir. Son aşamada partiküllerin (distile su, oleik asit) sorpsiyon etkinliği araştırılmıştır. Sonuç olarak, polimer partikül çaplarının 3.388 ile 3.903 mm arasında ve partiküllerin yoğunluklarının 0.389-0.416 g/cm^3 arasında olduğu ölçülmüştür. % 85 DDA kitosan numunesi ile üretilen partikülün distile su tutma kapasitesi 0.523 g/g$_{\text{partikül}}$, oleik asit tutma kapasitesi ise 0.286 g/g$_{\text{partikül}}$ olarak belirlenmiştir. Bu değerler, % 75 DDA kitosan numunesi ile elde edilen değerlerden yaklaşık % 20 daha düşüktür. Düşük moleküler kütleli kitosan numunesi, gram parçacık başına 0.556 g damıtılmış su ve gram parçacık başına 0.193 g oleik asit emdi. Bu değerler yüksek molekül ağırlıklı kitosan numuneleri kullanılarak üretilen partiküller için sırasıyla 0.170 g/g$_{\text{partikül}}$ ve 0.381 g/g$_{\text{partikül}}$ olarak hesaplanmıştır. Seçilen bölge üzerinde yapılan EDX analizinde kitosan bazlı polimer partikülün % 43.58 C ve % 49.83 O içerdiği belirlendi.

Anahtar kelimeler: Kitosan, Polimer partikül, Sorpsiyon, Distile su, Oleik asit.

1. Introduction

Polymer chemistry is one of the most advanced fields of chemistry. Polymers, which were previously used only in very basic applications in industry, recently are also used in different fields (such as research in space technology, biomedicine, artificial organ construction, and controlled release of fertilizers in agriculture). The using widespread use of synthetic

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polymeric products, the main raw material of which is petroleum, has brought environmental problems. It has been understood that the use of biodegradable natural polymers (which can self-degrade in nature) should become widespread instead of petroleum-based synthetic polymers that cannot self-degrade in nature. For this reason, studies have been carried out in recent years to develop natural polymeric products with biodegradable properties for areas where polymers are widely used, especially in packaging, agriculture, and medicine. Studies have focused on natural polymers such as starch, chitin, chitosan, carboxymethyl cellulose, hemicellulose, sodium alginate, xanthan gum, gelatin, etc. [1].

Chitin, which can be obtained from natural sources, is the second most common biopolymer on earth after cellulose. Chitin is obtained from the exoskeleton structures of shellfish such as crabs, lobsters and shrimps, insects, and the cell walls of fungi. Chitin is found in approximately 25 % of the shells of insects, and 15 % and 30 % in crabs and shrimps, respectively. Chitin has a stable structure and is insoluble in water, alcohol, dilute acid, and basic solutions [2]. To produce chitin from the waste shells of crustaceans, demineralization, deproteinization, and decolorization processes must be applied, respectively, to remove minerals, proteins, and pigments from the shell (Figure 1) [3-6]. While dilute sodium hydroxide solution is commonly used for the removal of proteins, dilute hydrochloric acid solution is preferred for the removal of mineral substances [7]. The decolorization treatment is ethanol, sodium hypochlorite solution, pure acetone, hydrogen peroxide, etc. carried out using chemicals. In this context, there are many studies on the production of chitin and its derivatives from waste shells and the recovery efficiency and product characterization depending on the process parameters [8-10].

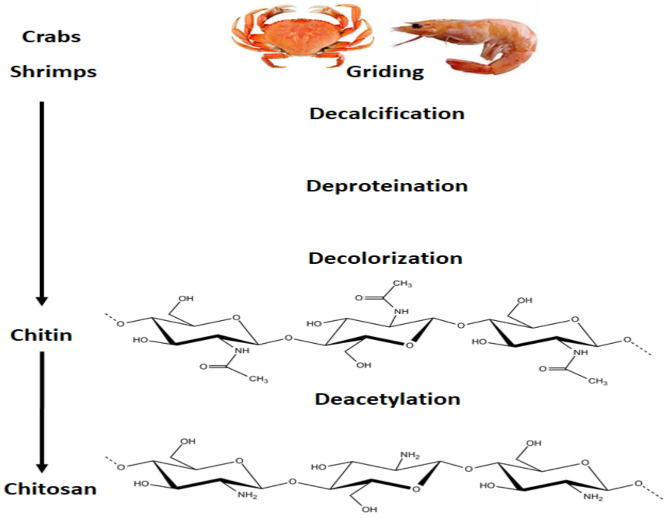


Figure 1. Chitosan production process [11]

Chitosan (poly-[β-(1,4)-2-amino-2-deoxy-β-D-glucopyranose]) is a linear polysaccharide. It is a deacetylated derivative of chitin and is the second most abundant biopolymer in nature after cellulose. Chitosan is a biobased macromolecule ie. polymer. It is considered to be an environmentally friendly material, due to biodegradable. In addition, chitosan renewable and hydrophilic exhibit the properties [12]. Unlike other natural polymers, chitosan macromolecules are positively charged (due to weakly basic groups) and are cationic polysaccharides. For this reason, chitosan macromolecules can easily interact with negatively charged polymers, macromolecules, and polyanions. Chitosan macromolecule can bond with many bioactive substances such as protein and lipid. And it can participate in network or matrix formation with many polymers such as negatively charged alginate. It is also compatible with important functional carbohydrates (hyaluronic acid, mucopolysaccharides) in the body. Chitosan and its derivatives have anti-cancer [13], antioxidant, anti-microbial, anticoagulant, antihypertensive, antidiabetic, antiobesity, antiallergic, anti-inflammatory, neuroprotective, and matrix metalloproteinase inhibitory effects. They are renewable, biocompatible, biodegradable, and non-toxic compounds with biological activity [14]. Chitosan contains three functional reactive groups. They are an amino group at the C-2 position and primary and secondary hydroxyl groups at the C-3 and C-6 positions [15]. Due to the presence of functional groups in its structure, being a cationic polymer and suitable for the production of particles of different sizes, chitosan has been used especially in biomedical applications, pharmaceutical, cosmetics, and food packing sectors [16, 17].

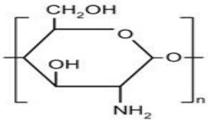
Chitosan, which had been used in limited areas such as plant growth and water treatment until the early 1990s, was described as a new generation polymer thanks to its specific properties discovered with the increase of studies on chitosan in the following years. However, the use of chitosan biopolymer in Turkey is very low compared to developed countries. Chitosan still maintains its feature of being a biopolymer whose usage area should be increased. In the last fifteen years, many studies (theses, articles) had been carried out mainly on the chitin and chitosan production methods [18-20]. Studies are concentrated in this area. However, it is emphasized that current studies should proceed in the direction of converting chitosan into products with high added value (production of chitosan-based polymeric nanoparticles and films). Especially in academic studies conducted at the international level in the last five years, chitosan has been used in the production of biomaterials, biotechnology/tissue engineering applications, and drug release applications [21-24].

Chitosan is thought that alternative sorbent. Recently, it is detailed studies are carried out to produce sorbents/ion exchangers (chitosan-based polymeric microparticles and film production) from chitosan for the removal of micropollutant, heavy metals, or dye molecules [25-29]. However, no study has been conducted to investigate the effect of chitosan DD and molecular weight on the efficiency of sorption. Therefore, in this study, firstly, chitosan samples with different deacetylation degrees and molecular weights were obtained from commercial enterprises and the samples were characterized. The chitosan particles were produced, then characterized and then sorption activity (distilled pure water, oleic acid) was investigated. There is no study in the literature examining the effect of acetylation degree and molecular weight on the physicochemical, structural, and sorption properties of the produced gel particles. It is thought that this study will contribute to the literature in this context.

2. Materials and Methods

The chemicals which were used in the chitosan-based polymeric polymer particle production step were purchased from Sigma-Aldrich (USA) and their properties were given in Table 1. All of the chemicals were high purity degrees. A total of five chitosan samples with three different molecular weights and two different deacetylation degrees (DDA) were purchased from Acros (New Jersey, USA).

Table 1. The main chemicals and their properties

Chemicals	Purity	Chemical formula
Acetic acid	≥99.85 %	CH_3CO_2H
Hydrochloric acid	ACS reagent, 37 %	HCI
Ethanol	absolute	CH_3CH_2OH
Sodium hydroxide	pellet	NaOH
Potassium hydroxide	pellet	KOH
Oleic acid (fatty acid)	ACS reagent	$CH_3(CH_2)_7CH{=}(CH_2)_7COOH$
Chitosan (Poly(D-glucosamine))	75 % and 85 % DDA Low, medium, high Mw	

2.1. Moisture content analysis

Moisture content analysis of chitosan samples was performed at 80 °C by the gravimetric method. For this purpose, the Mettler LJ16 brand moisture analyzer was used. The analysis experiments were performed using chitosan samples with a particle size of 154 μm (less than 100 mesh). All of the analysis was repeated at least three times, and the calculation results were presented by taking the average of the experiments.

2.2. Ash content analysis

The ash content analysis of chitosan samples had been performed appropriately to the ASTM-D1102 standard. The analysis experiments were performed using chitosan samples with a particle size of 154 μm (less than 100 mesh).

All of the analysis was repeated at least three times, and the calculation results were presented by taking the average of the experiments.

2.3. FTIR analysis

FTIR analysis was used to reveal the functional groups and chemical structure of chitosan samples. For this purpose, Shimadzu IR Spirit spectrophotometer was used and measurements were carried out using 45 scans in the range of 400 to 4000 cm^{-1}. A background scan was performed to prevent interference from airborne components, and then samples were scanned under the same conditions.

2.4. Determination of water and fatty acid holding capacity

Distilled water and fatty acid (oleic acid) holding (sorption) capacity of chitosan samples were determined by the gravimetric method. The experiments were carried out by the method of "The Japanese Industrial Standard K8150". For this purpose, 20 ml of distilled water or oleic acid was placed in 50 ml plastic beakers, and chitosan samples of which the initial mass was determined (W_d), were added. The samples were allowed to contact distilled water or fatty acid at 25 °C for 24 hours. At the end of the contact time, the chitosan samples were filtered and weighed, and the final weighing was recorded (W_s). The holding capacity of chitosan samples was calculated using Equation 1.

$$\mathrm{HC}\left(\frac{\mathrm{g}}{\mathrm{g}_{kitosan}}\right) = \frac{(W_s - W_d)}{W_d} \tag{1}$$

2.5. Determination of the viscosity of chitosan gel solutions

1±0.001 g of chitosan samples were solved in 2.5 % acetic acid solution. Before the production of polymer particles, the viscosity value of the chitosan solutions was measured using AND Vibro SV-10 brand viscometer. Thus, chitosan-based polymer particle production was made with gel solutions which is a standard viscosity range.

2.6. Production procedure of chitosan-based polymer particles

The chitosan-based polymer particle was produced by the precipitation-collection method. Deacetylation degree, molecular weight, alkali type, and alkali concentration were determined as variable parameters. The effects of these parameters on particle production and particle properties were investigated. 1 ± 0.002 gram chitosan sample was dissolved in 25 ml of acetic acid solutions (2.5 % (v/v)).

To obtain homogeneous gel solutions, an ultrasonic homogenizer of Bandelin HD 2070 was used. The homogenizer was operated with 50 % amplitude, 5 seconds spraying, and 1 second dwell time. The prepared homogeneous gel solutions were dropped with an injector to the NaOH or KOH solutions (0.5-1-5-10-20-40 g/L). The process was carried out that a maximum of 3 particles per minute was produced. The speed of the magnetic stirrer was kept at 400 rpm so that the particles did not break up. The chitosan particles were kept in the alkaline solution for one day, then filtered. It was washed with distilled water until it reached neutral pH. At the end of the washing process, the chitosan particles were taken into the 50 % distilled water-ethanol mixture.

Figure 2. A photograph of a chitosan-based polymer particle

2.7. Characterization of Chitosan Based Particles

Size determination of chitosan-based polymer particle: The diameter of the chitosan-based particle produced in a standard size by the precipitation-collection method was determined using a digital thickness gauge (caliper/micrometer). For this aim, the diameter of the particles was measured using a digital thickness gauge (caliper/micrometer) with ±0.001 mm accuracy. Measurements were repeated for at least five particles and the measurements were averaged. Average particle diameter was used to calculate particle densities. All analyzes and tests applied for the characterization of polymer particles were carried out using the particles of standard diameter.
Distilled water and oleic acid holding capacity: Distilled water and fatty acid (oleic acid) holding (sorption) capacity of chitosan samples were determined by the gravimetric method. The experiments were carried out by the method of "The Japanese Industrial Standard K8150". The analysis details were given in the raw material analysis section.

2.8. Morphological analysis (SEM)

To reveal the surface morphology of networked particles, SEM analyses were performed using the EVO/MA10. Before SEM analysis, all particles were coated with gold.

3. Results and Discussion

3.1. Charectirization of chitosan samples

In the study, firstly, chitosan samples with different deacetylation degrees and molecular weight obtained from commercial enterprises were characterized. The ash and moisture contents of the chitosan samples were given in Table 2. The moisture content of chitosan samples was found to be between 6 % and 10 %. Although the ash contents of the samples are within the expected limits, the ash content of the chitosan with 85 % deacetylation degree chitosan samples was much higher (about 4 %) compared to the other samples. The ash and moisture contents of chitosan samples were consistent with Fawzya et al (2018)'s [30] and Yuan et al (2011)'s [31] studies. In addition, according to previous studies, the molecular weight (MW) is an important parameter in chitosan properties such as crystallinity, degradation, tensile strengths, and moisture content [32-37] reported that the moisture sorption of chitosans with high MWv's (600–1000 kDa) was significantly greater than those with similar DDA's but lower MWv's (50–60 kDa).

The distilled water and fatty acid (oleic acid) holding capacities of chitosan samples were given in Table 3. It has been determined that the deacetylation degree of chitosan is inversely proportional to the distilled water and fatty acid holding capacity. The distilled water and oil sorption capacity decreased as the deacetylation degree increased. Besides, it was observed that the molecular weight and the distilled water holding capacity were inversely proportional, but the oil holding capacity changed in direct proportion. As the molecular weight of chitosan samples increased, the water holding capacity decreased, but the oil holding capacity increased.

All physicochemical properties of chitosan samples vary depending on the raw material source (shellfish or mushroom type), the production methodology, and the deacetylation degree of the chitosan and molecular weight of the chitosan. It is known that the solubility of chitosan samples and viscosity value of gel solution are some of the physicochemical properties. These properties generally affect occurring the particle and diameter of the particle. Thus, the viscosity of the chitosan gel solution was measured and these values were presented in Table 4. As result, it was determined that the viscosity values of the gel solution viscosity have changed a range from $1.13x10^3$ to $2.83x10^3$ cP. It was determined that the viscosity value of the chitosan gel solution changed inversely with the degree of deacetylation but was directly proportional to its molecular weight. Besides, considering the amount of acetic acid solution used while preparing gel solutions, it was determined that the solubility of the chitosan samples increased and the viscosity decreased as the degree of DDA increased. The experimental results obtained in this context are by the literature [38, 39].

Table 2. Ash and moisture content (wt %) of chitosan samples

Chitosan Samples	**Moisture %**	**Ash %**
75 % DDA chitosan	9.910	1.480
85 % DDA chitosan	5.670	4.400
Low molecular weight chitosan	6.000	1.750
Medium molecular weight chitosan	8.330	0.891
High molecular weight chitosan	9.000	0.255

Table 3. Distilled water and oleic acid holding capacities of chitosan samples

Chitosan Samples	**Distilled water** $g/g_{partikül}$	**Oleic acid** $g/g_{partikül}$
75 % DDA chitosan	1.274	0.911
85 % DDA chitosan	1.078	0.715
Low molecular weight chitosan	3.393	0.962
Medium molecular weight chitosan	3.072	2.384
High molecular weight chitosan	2.819	3.808

Table 4. The viscosity values of chitosan gel solutions

Chitosan Samples	**cP**	**Acetic acid (ml)**
75 % DDA chitosan	$1.27x10^3$	25
85 % DDA chitosan	$1.13x10^3$	9
Low molecular weight chitosan	$1.56x10^3$	20
Medium molecular weight chitosan	$1.76x10^3$	25
High molecular weight chitosan	$2.83x10^3$	30

FTIR spectra of the chitosan sample are provided in Figure 1. Peaks at 3000-3500 cm^{-1} indicate the presence of the $–NH_2$ (νNH) and the –OH. It is known that these two peaks coincided in this region. The apparent peak observed in the 2850-2720 cm^{-1} region is due to the symmetric or asymmetric $–CH_2$ stretching vibration attributed to the pyranose ring (νC-H). Besides, it was observed that the other main peaks; at 1640 cm^{-1} are due to expressing the vibration of the –C=O in the acetamide group (amide I band); at 1590 is due to $–NH_2$ bending vibration in the amino group (δNH); at 1420 and 1320 cm^{-1} are due to vibrations of -CH in the ring, at 1250 cm^{-1} is due to C–O group, at 1152 cm^{-1} is due to –C–O–C in a glycosidic linkage, at 1020 cm^{-1} is due to C–O stretching in acetamide (νC-O), and at 899 cm^{-1} is due to corresponds to saccharide structure. The spectrum obtained agreed with the previous studies [40-42].

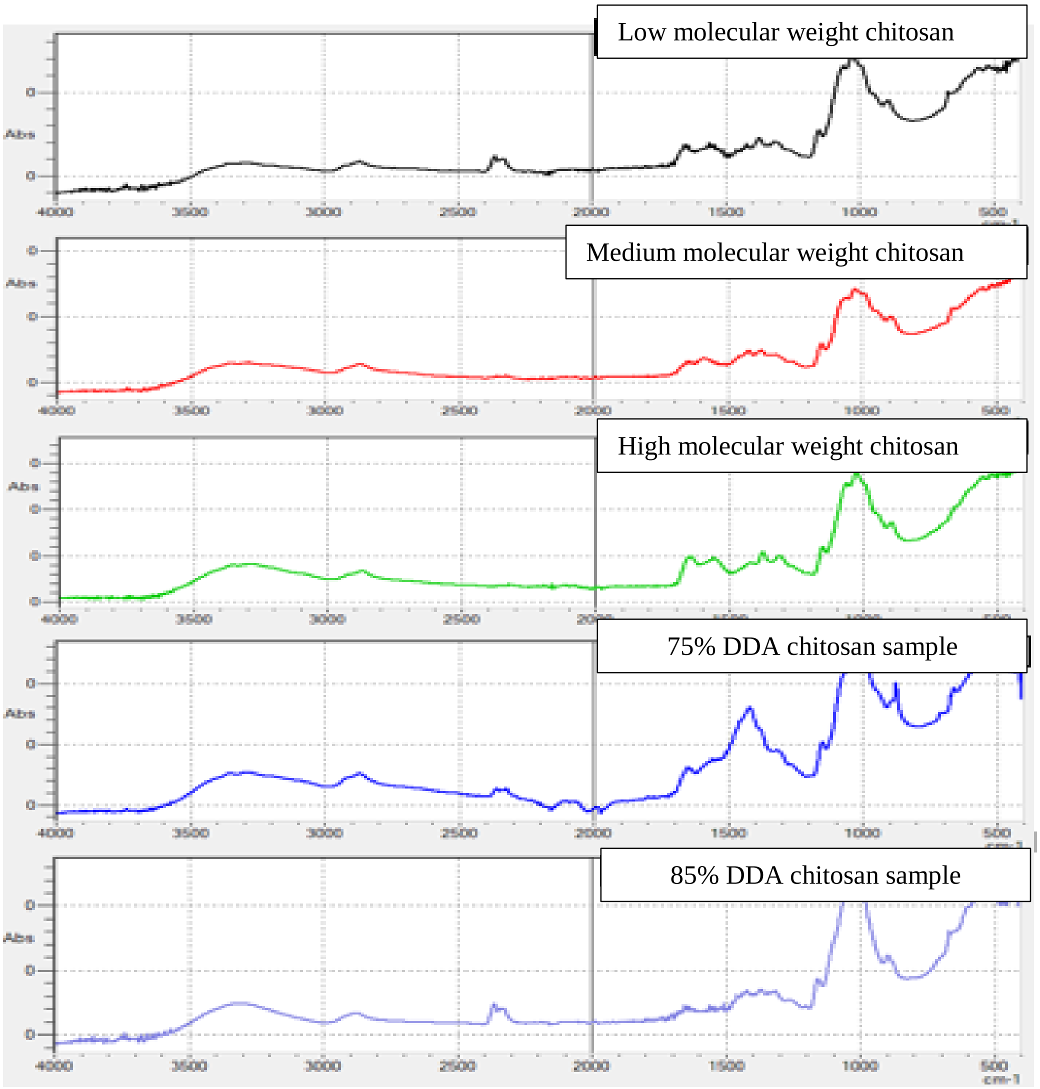


Figure 3. FTIR spectrum of chitosan samples

3.2. Characterization of chitosan particles

3.2.1. The average particle size, particle density, and particle weight

The prepared in different circumstances chitosan particle's physical properties (particle's diameter, density of the particles, particle mass) are presented in Table 5. The mass of the particles has changed the range from 0.036 to 0.047 g. The particle diameters were measured between 3.388-3.903 mm. Depending on these parameters, the densities of the particles were calculated as 0.389-0.416 g/cm^3.

Besides, it was observed that there is a nonlinear increase in the diameter and mass of the particles as the alkali concentration increased. In addition, the particles which were prepared using KOH solution as an alkaline medium, have a relatively higher diameter and mass compared to the particles prepared using NaOH solution. And their physical strength was higher than the particles prepared with NaOH.

Table 5. Sizes, masses, and densities of chitosan particles

Alkaline	Alkaline con.	Particle weight (g)	Particle diameter (mm)	Particle density (g/cm^3)
NaOH	1 g/L	0.036	3.388	0.400
	5 g/L	0.037	3.470	0.391
	10 g/L	0.038	3.495	0.396
	20 g/L	0.042	3.588	0.416
	40 g/L	0.043	3.598	0.423
KOH	1 g/L	0.036	3.388	0.400
	5 g/L	0.038	3.470	0.402
	10 g/L	0.044	3.797	0.389
	20 g/L	0.047	3.870	0.400
	40 g/L	0.047	3.903	0.393

3.2.2. Distilled water and fatty acid holding capacities of chitosan particles

Distilled water and fatty acid (oleic acid) holding capacities of chitosan particles are presented in Table 6. It was determined that the deacetylation degree was inversely proportional to the distilled water and fatty acid holding capacity. As the deacetylation degree increased, the sorption capacity decreased. Distilled water holding capacity of the particle which was produced with an 85 % DDA chitosan sample, was calculated as 0.523 g/g particles, and the oil holding capacity was calculated as 0.286 g/g particles. These values are approximately 20 % lower than the values obtained with the 75 % DDA chitosan sample.

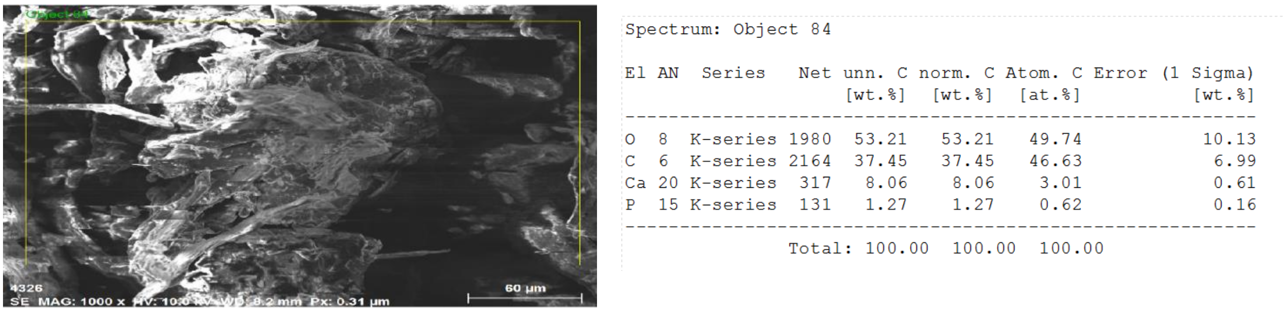
It was determined that as the molecular weight of chitosan samples increased, their oleic acid holding capacity increased, and distilled water holding capacity decreased. Low molecular mass chitosan sample sorbed 0.556 g distilled water per gram particle and 0.193 g oleic acid per gram particle. These values were calculated as 0.170 g/g$_{\text{particle}}$ and 0.381 g/g$_{\text{particle}}$ for the particles produced using high molecular weight chitosan samples, respectively. The results are in agreement with the data obtained from the chitosan samples given in Table 3.

Table 6. Water and fatty acid (oleic acid) sorption capacities of chitosan particles

Chitosan polymer particle	Distilled water (g/g$_{\text{partikül}}$)	Oleic acid(g/g$_{\text{partikül}}$)
75 % DDA chitosan-based particle	0.523	0.286
85 % DDA chitosan-based particle	0.647	0.381
Low molecular weight chitosan-based particle	0.556	0.193
Medium molecular weight chitosan-based particle	0.298	0.222
High molecular weight chitosan-based particle	0.170	0.381

3.2.3. SEM analysis of chitosan and chitosan-based polymer particle

The SEM images of the 75 % DDA chitosan sample and the chitosan particle which was produced using the 75 % DDA chitosan sample are given in Figure 4 and Figure 5, respectively. According to the 1000 times magnified image, it is understood that chitosan has a layered structure in the macro sense. However, in some parts of these layer fragments, a whitish sheen was noted. The presence of calcium (Ca) was detected in the structure as a result of the EDX analysis performed in a region that will include these whitish sheen. According to the spectrum obtained from the EDX analysis performed on the selected region in Figure 4, it was determined that the chitosan sample consisted of 37.45 % C, 53.21 % O, and 8.06 % Ca. According to Figure 5, it is understood that chitosan-based polymer particle has a homogenous, nonporous, and smooth structure in the macro sense. EDX analysis performed on the selected region in Figure 5, it was determined that the chitosan-based polymer particle consisted of 43.58 % C, and 49.83 % O.



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Spectrum: Object 84

El AN  Series    Net unn. C norm. C Atom. C Error (1 Sigma)
                     [wt.%]  [wt.%]  [at.%]          [wt.%]
-----------------------------------------------------------
O   8  K-series 1980  53.21   53.21   49.74           10.13
C   6  K-series 2164  37.45   37.45   46.63            6.99
Ca 20  K-series  317   8.06    8.06    3.01            0.61
P  15  K-series  131   1.27    1.27    0.62            0.16
-----------------------------------------------------------
               Total: 100.00  100.00  100.00
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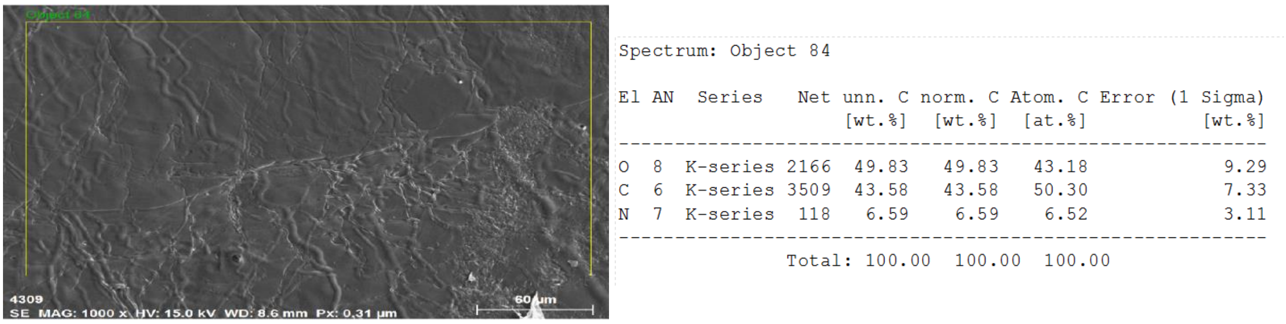
Figure 4. SEM image of 75% DDA chitosan samples



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Spectrum: Object 84

El AN  Series    Net unn. C norm. C Atom. C Error (1 Sigma)
                     [wt.%]  [wt.%]  [at.%]          [wt.%]
-----------------------------------------------------------
O   8  K-series 2166  49.83   49.83   43.18            9.29
C   6  K-series 3509  43.58   43.58   50.30            7.33
N   7  K-series  118   6.59    6.59    6.52            3.11
-----------------------------------------------------------
               Total: 100.00  100.00  100.00
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Figure 5. SEM image of chitosan particle produced with 75 % DDA chitosan sample

4. Conclusion

In this study, chitosan particles were produced by using chitosan samples with different deacetylation degrees and molecular weights obtained from commercial enterprises to be evaluated as sorbent.

- The moisture content of the chitosan samples was high and the ash content was within the expected limits, but the ash content of the chitosan samples with 85 % deacetylation degree was quite higher than the other samples.
- The water and oleic acid holding capacity were inversely proportional to the deacetylation degree, and as the deacetylation degree increased, the water and oleic acid sorption capacity decreased.
- The viscosity value of chitosan gel solutions changed inversely with the deacetylation degree of chitosan and was directly proportional to the molecular weight.
- It was determined that all chitosan samples show similar characteristic peaks in their FTIR spectra, mainly containing stretching vibrations and bands of $–NH_2$, $–C=O$, -OH, and –C–O–C.
- It was measured that the polymer particle diameters were to be between 3.388 and 3.903 mm and the densities of the particles were to be 0.389-0.416 g/cm^3. The diameter and weight of the particles increased as the alkali concentration increased.
- The particles prepared using the KOH solution have a relatively higher diameter and mass than the particles prepared using the NaOH solution.
- The physical strength of the particles prepared by using KOH solution was higher than the particles prepared with NaOH.
- The degree of deacetylation is inversely proportional to the distilled water and fatty acid holding capacity, and as the degree of deacetylation increases, the sorption capacity decreases. Distilled water holding capacity of the particle which was produced with an 85 % DDA chitosan sample, was calculated as 0.523 $g/g_{particles}$, and the oleic acid holding capacity was determined as 0.286 $g/g_{particles}$. These values are approximately 20 % lower than the values obtained with the 75 % DDA chitosan sample. Low molecular mass chitosan sample sorbed 0.556 g distilled water per gram particle and 0.193 g oleic acid per gram particle. These values were calculated as 0.170 $g/g_{particle}$ and 0.381 $g/g_{particle}$ for the particles produced using high molecular weight chitosan samples, respectively.

- According to the morphological analysis, chitosan has a layered structure. The chitosan-based polymer particle has a homogenous, nonporous, and smooth structure.
- EDX analysis performed on the selected region, it was determined that the chitosan-based polymer particle consisted of 43.58 % C, and 49.83 % O. It was obtained that the chitosan sample consisted of 37.45 % C, 53.21 % O, and 8.06 % Ca.

5. Author Contribution Statement

In the study, Author 1 experimental studies has carried out; Author 2 planned the process, interpreted the experimental results, and writing-original draft; Author 3 methodology, interpreted the experimental results, and writing-original draft; Author 4 investigation, interpreted the experimental results, and writing-original editing.

6. Ethics Committee Approval and Conflict of Interest

There is no need for any an ethics committee approval in the prepared article.

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