

CHARACTERISTICS OF BODY LOTION FROM CHITOSAN AND ALGINATE (*Sargassum* sp.) NANOPARTICLES

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Abstract

Chitosan and alginate have great potential in the cosmetics industry; therefore, both were processed into chitosan alginate nanoparticles and added to body lotion formulas to increase their effectiveness. This study aimed to investigate the effect of chitosan alginate nanoparticles on the characteristics and antioxidant activity of body lotions. Body lotion formulas with additional concentrations of 0, 1, 2, and 3 g of chitosan alginate nanoparticles. This study used a completely randomized design (CRD) with chitosan alginate nanoparticle concentrations of 0, 1, 2, and 3 g. The body lotion appeared homogeneous, with no clumped particles. The characteristics of body lotion with the addition of chitosan-alginate nanoparticles are viscosity of 4596.73-6931.77 cps, spreadability of 52.4-68.9 cm, and pH value of 6.00-6.98 which are in accordance with body lotion standards. The antioxidant activity was 19.82-21.59 μM Fe^2. The addition of chitosan-alginate nanoparticles with particle sizes of 100-500 nm to body lotion increased the antioxidant activity.

Keywords: antioxidant activity, degree of deacetylation, nanoparticle formula, viscosity, zeta potential

Karakteristik Produk Body Lotion dari Nanopartikel Kitosan dan Alginat (*Sargassum* sp.)

Abstrak

Kitosan dan alginat berpotensi dalam industri kosmetik sehingga keduanya diolah menjadi nanopartikel dan ditambahkan ke formula body lotion untuk meningkatkan efektivitasnya. Penelitian ini bertujuan menentukan pengaruh penambahan nanopartikel kitosan alginat berdasarkan karakteristik dan aktivitas antioksidan body lotion. Penelitian menggunakan rancangan acak lengkap (RAL), yaitu konsentrasi tambahan nanopartikel kitosan alginat 0, 1, 2, dan 3 g. Kitosan yang ditambahkan dan nanopartikel alginat tidak mengubah karakteristik sensoris. Body lotion tampak homogen karena tidak ada partikel yang menggumpal. Karakteristik body lotion dengan penambahan nanopartikel kitosan-alginat, yaitu viskositas 4596,73-6931,77 cps, daya sebar 52,4-68,9 cm, dan nilai pH 6,00–6,98 yang sesuai dengan standar body lotion. Aktivitas antioksidan, yaitu 19,82-21,59 μM Fe^{2+}/g. Penambahan nanopartikel kitosan-alginat dengan ukuran partikel 100-500 nm ke dalam body lotion meningkatkan aktivitas antioksidan.

Kata kunci: antioksidan, derajat deasetilasi, formulasi, viskositas, zeta potensial

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INTRODUCTION

Exposure to ultraviolet (UV) radiation, especially from sunlight, along with pollution and other environmental factors, can increase the formation of free radicals. These reactive molecules contribute to premature aging, inflammation, dry and cracked skin, pigmentation disorders, and even increase the risk of skin cancer (D'Orazio *et al.,* 2013; Letsiou *et al.,* 2024). Body lotion is a liquid emulsion that contains protective ingredients to moisturize, soften, and maintain the health of the skin (Al-Momani *et al.,* 2022). Antioxidants play a particularly crucial role among these protective components. Found in many skincare products, including body lotions, antioxidants help neutralize free radicals and protect the skin from oxidative damage (Sipahutar *et al.,* 2019).

Building on this, researchers have explored natural materials that exhibit strong antioxidant activity. Seaweed (*Sargassum* sp.) and chitosan from shrimp shells are two of the many natural materials containing secondary metabolites that exhibit antioxidant activity. Both *Sargassum* sp. and chitosan extracted from shrimp shells can produce phenolic compounds that act as natural antioxidants for various applications (Mutmainnah *et al.,* 2024; Onodenalore *et al.,* 2024**;** Eskander *et al.,* 2020**;** Hu *et al.,* 2019). Antioxidants can be obtained from the extraction of natural ingredients into nanoparticles, which have the potential to be developed according to needs. Nanomaterials, with a size of 1 to 100 nanometers, are part of a large group of materials with applications in various fields, including cosmetics, which have attracted much attention due to their unique physicochemical properties.

Natural antioxidants are often modified into nanoparticles to further enhance their performance. The integration of nanotechnology into the cosmetics industry has opened new avenues for innovation in this field. Nanotechnology and the application of its concepts in the cosmetics industry create new opportunities that pave the way for further innovation and collaboration in various fields with wider impacts and benefits for society and the environment (Mihranyan *et al.,* 2012; You *et al.,* 2012**;** Shang *et al.,* 2019). Nano-based products have been developed using a variety of nanomaterials with different compositions, shapes, and sizes (Fytianos *et al.,* 2020; Carrouel *et al.,* 2020). These ingredients were chosen because of their ability to overcome the limitations of cosmetics, namely, increasing penetration, controlling the release of active ingredients, and acting as active ingredients (Salvioni *et al.,* 2021).

Natural antioxidants are often modified into nanoparticles to further enhance their performance (Yang *et al.,* 2020), increase their bioavailability and solubility (Kumari *et al.,* 2022), and absorption in biological systems (Khalil *et al.,* 2019). They also improve stability (Wen *et al.,* 2025), thereby protecting the compounds from degradation and maintaining their antioxidant activity. They also have better penetration and targeting, allowing targeted penetration into specific tissues or cells, thereby maximizing antioxidant action where it is needed most. Smaller particle sizes can increase the reactivity and interaction of antioxidants with free radicals, thereby enhancing their antioxidant capacity (Charlton *et al.,* 2023). These modifications optimize the use of natural antioxidants in pharmaceutical, nutraceutical, and cosmetic applications.

Among natural sources, chitin and chitosan are versatile biomaterials with wide-ranging potential (Komi & Hamblin, 2016). Derived from by-products of the shrimp processing industry, chitin and chitosan can provide raw materials for health innovations and broader biopolymer applications in the future (Hussain *et al.,* 2013). Chitin and chitosan are biopolymers whose structures can be modified chemically and mechanically to produce new properties, functions, and applications (Crini, 2019; Alves *et al.,* 2021; Fatullayeva *et al.,* 2022; Al-Rooqi *et al.,* 2022), biomedical fields (Adhikari & Yadav, 2018; Wu *et al.,* 2023), plant protection (Yadav *et al.,* 2022; Kumar *et al.,* 2022), antibacterial (Badawy & Rabea, 2016; Canama *et al.,* 2023), cosmetic product applications (Mihranyan *et al.,* 2012; Kulka & Sionkowska, 2023), antioxidant (Ayoka *et al.,* 2022; Cakasana *et al.,* 2014), and food additives (Hamed *et al.,* 2016).

Various studies have shown that chitosan and its derivatives can enhance various activities, and it is obtained from an affordable natural source, namely fishery waste. Owing to their natural origin, biodegradability, and biocompatibility, chitosan and its derivatives have gained increasing attention across various sectors, including agriculture, pharmaceuticals, and cosmetics (Velásquez, 2023). It has many functions, including antioxidant, antihypertensive, anti-inflammatory, anticoagulant, antitumor, anticancer, antimicrobial, hypocholesterolemic, and antidiabetic effects, the most important of which is its antioxidant effect. The antioxidant activity of chitosan and its derivatives is associated with free radical scavenging activity in vitro and in vivo (Ngo & Kim, 2014).

Similarly, *Sargassum* sp., a brown seaweed rich in antioxidants, nutrients, and bioactive compounds, has emerged as a promising natural source for cosmetic and health applications (Pakidi & Suwoyo, 2016), with great potential for use in health, agricultural, and cosmetic products (Sumandiarsa *et al.,* 2022; Xie *et al.,* 2024). Alginate is a hydrocolloid compound that is a polysaccharide derived from brown seaweed (*Phaeophyceae*) (Khajouei *et al.,* 2022a). It has many benefits and applications in food, cosmetics, and medicine, and is an environmentally friendly material that can be used sustainably (Diharningrum & Husni, 2018; Khajouei *et al.,* 2022b). Alginate is used in various products because it is biocompatible, biodegradable, low-toxicity, thickener, stabilizer, emulsifier, oil-resistant thin film former, and antioxidant with unique biological and pharmacological characteristics (Pradhan *et al.,* 2022; Hoan *et al.,* 2023; Muhammad *et al.,* 2023). Several studies have shown that encapsulated alginate nanoparticles contribute to increased antioxidant activity (Silva *et al.,* 2023). Other studies have also shown that the use of film-based alginate nanoparticles modified with kiwi peel extract has good UV barrier properties, as well as increased antioxidant properties and significant antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* (Sun *et al.,* 2021).

Both chitosan and alginate have attracted considerable interest in nanoparticle-based cosmetic formulation. The cosmetics industry was one of the first sectors to adopt nanotechnology, and its application has changed the way skin care and beauty products are formulated and used (Santos *et al.,* 2019). The cosmetics industry was one of the first sectors to adopt nanotechnology and its application has changed the way skin care and beauty products are formulated and used (Santos *et al.,* 2019). The use of chitosan and alginate nanoparticles in cosmetic cream preparations provides many benefits, including safety, stability, and good absorption ability. The ability of chitosan alginate nanoparticles to increase the effectiveness of active ingredients and provide hydration and skin protection benefits has the potential to produce innovative and effective cosmetic products (Bilal & Iqbal, 2020; Raj *et al.,* 2012).

The use of chitosan and alginate nanoparticles in body lotions has great potential because of their antioxidant properties, which can benefit skin health. The cosmetics industry was one of the first sectors to adopt nanotechnology. Its application has changed the way formulations are made for skincare and beauty products (Santos *et al.,* 2019). The use of chitosan and alginate nanoparticles in cosmetic creams offers numerous benefits, including safety, stability, and good absorption properties. The ability of chitosan-alginate nanoparticles to enhance the effectiveness of active ingredients and provide hydration and skin protection makes this combination a potential source of innovative and effective cosmetic products (Raj *et al.,* 2012; Bilal & Iqbal, 2020). The use of chitosan and alginate nanoparticles in body lotions also has great potential because of their antioxidant properties, which can benefit skin health.

The development of innovative cosmetic products that are beneficial for skin health remains wide open. Comprehensive research on the physicochemical aspects of chitosan and alginate nanoparticles can provide deeper insights into the potential use of natural ingredients in cosmetics and facilitate the development of effective, safe, and environmentally friendly products. This study aimed to determine the additional effect of chitosan alginate nanoparticles based on the characteristics and antioxidant activity of body lotion. It is hoped that the results of this study will help better understand the potential and limitations of using nanoparticles in cosmetics and facilitate innovation in the beauty industry.

MATERIALS AND METHODS

Chitosan Production

Shrimp shells were obtained from PT First Marine in Muara Baru, North Jakarta, Indonesia. Chitosan production was carried out in this study following the research conducted by Imtihani and Permatasari (2020) with three stages of making chitosan: demineralization, deproteination, and deacetylation. Water-soluble chitosan (WSC) was manufactured following the procedure described by Permadi *et al.* (2022). Chitosan production begins with demineralization to remove inorganic minerals, such as calcium carbonate, using acid, deproteinization to remove protein using a strong base, and ends with the deacetylation of chitin into chitosan by removing acetyl groups using a strong base (Choiriyah *et al.,* 2025). WSC is produced using acetic acid solvent, which is used to make chitosan, which is initially insoluble and soluble in water by modifying its chemical structure through protonation of the amine group (Silvia, 2021).

Water Soluble Chitosan (WSC) and Alginate Test

WSC was tested for solubility (Tungtong *et al.,* 2012), moisture content (BSN, 2015a), ash content (BSN, 2010a), total nitrogen, and degree of deacetylation (Czechowska-Biskup *et al.,* 2012). The solvent materials used in the chitosan manufacturing process included distilled water (Onemed, Indonesia), HCl (Merck, Germany), technical NaOH (Merck, Germany), acetic acid (Merck, Germany), H_2O_2 (Onemed, Indonesia), and ethanol (Merck, Germany).

Alginate was prepared by modifying the alginic acid pathway adopted from Sumandiarsa *et al.* (2020) and Hartono *et al.* (2021). The production of sodium alginate from natural sources begins with the extraction of alginate using an alkaline solution, followed by immersion in 4% HCl to form alginate. This acid is then oxidized by NaOCl for bleaching and neutralized with $NaHCO_3$ to form alginate salt, which is then precipitated using isopropyl alcohol (IPA) to obtain sodium alginate (SA). Alginate was tested for moisture content (BSN, 2015b), ash content (BSN, 2010b), pH, and viscosity (Langit *et al.,* 2019a). *Sargassum* sp. from the coast of Nglolang, Kemadang Village, Gunung Kidul, Indonesia. The materials used in the extraction of alginate included Na_2CO_3 (Merck, Germany), NaOCl (Onemed, Indonesia), $NaHCO_3$ (Merck, Germany), and isopropyl alcohol (IPA) (Merck, Germany).

Production of Nanoparticles from Chitosan and Alginate

The preparation of nanoparticles from chitosan alginate and their characteristics, such as stability, turbidity, particle size, polydispersity index, and zeta potential, were based on research conducted by Salsabila *et al.* (2020). Chitosan nanoparticles were produced using 1% acetic acid solvent, which was stirred constantly at a temperature of 40^{o}C using a homogenizer at a speed of 1,000 rpm for 1 h. Alginate nanoparticles were prepared by dissolving them in distilled water and sizing them using a hot plate magnetic stirrer at 40 °C for 1 h. While stirring, 96% ethanol was added to the solution to prevent the agglomeration of the nanoparticles. At certain times To produce chitosan alginate nanoparticles, both were mixed together by homogenizing using a hot plate magnetic stirrer at a speed of 500 rpm at a temperature of 40 °C until nanoparticles were formed or the solution formed looked clear.

Formulation of Chitosan Alginate Nanoparticles into Body Lotion

After the chitosan alginate nanoparticles were produced, the next step was to formulate the body lotion, based on the method described by Salsabila *et al.* (2020), with modifications. The modifications involved the addition of 0, 1, 2, and 3 g of chitosan alginate nanoparticles. The experiment was performed in triplicate. The formulation of the body lotion is presented in (Table 1). This body lotion was produced based on the research by Erungan *et al.* (2019), where the process began with making the first and second formulas, each in a different beaker. The ingredients were then combined when they were dissolved and homogeneous at the appropriate temperature and stirring time, where the ingredients were modified. After producing the chitosan alginate nanoparticles, the next step was to formulate them based on the modifications (formulation) made by Salsabila *et al.* (2020) to produce a body lotion. The formula was prepared by adding 0, 1, 2, and 3 g of chitosan alginate nanoparticles, and the experiment was replicated three times, as illustrated in Table 1.

This body lotion was produced based on the research of Erungan *et al.* (2019), which began by creating the first (oil) and second (water) phases, each in a separate beaker. Once the ingredients were dissolved, they were mixed and homogenized until the appropriate temperature and stirring time were reached.

Body Lotion Characteristics Analysis

The body lotion was analyzed using the hedonic test (BSN, 2015b) with 30 untrained panelists, using a score of 1-5 which indicates the level of liking, a score of 1 if you really do not like it, 2 if you do not like it, 3 if you quiet like, 4 if you like it, and 5 if you like it very much, homogeneity (Pratasik *et al.*, 2019), viscosity (Langit *et al.*, 2019b), spreadability, pH (BSN, 2019), stability (BSN, 1996), and FRAP antioxidant assay (Benzie & Szeto, 1999).

Data Analysis

The experimental design used in this study was a completely randomized design (CRD) with chitosan alginate nanoparticle concentrations of 0, 1, 2, and 3 g. Quantitative data on the physical testing values, antioxidant, and pH of the body lotion were analyzed using analysis of variance (ANOVA) with the IBM Statistical Package for the Social Sciences (SPSS) version 22. If significant differences were found, Tukey's test was performed. The verification data for chitosan, alginate, and chitosan alginate nanoparticles were analyzed descriptively and presented in tabular form. Hedonic body lotion data were analyzed using the Kruskal-Wallis test.

RESULTS AND DISCUSSION

Water Soluble Chitosan (WSC) and Alginate Characteristics

The production of chitosan from shrimp shells is carried out in three stages: demineralization, deproteination, and deacetylation. However, chitosan has low

Table 1 Formulation of body lotion preparations

Materials	Addition of chitosan alginate (g)			
	0 (F1)	1 (F2)	2 (F3)	3 (F4)
Oil phase				
Cetyl alcohol	1	1	1	1
Lanolin	3	3	3	3
Stearic acid	6	6	6	6
Water phase				
Glycerin	4	4	4	4
Triethanolamine	0.5	0.5	0.5	0.5
Methyl paraben	0.2	0.2	0.2	0.2
Aquadest add	100	100	100	100
Mix phase				
Chitosan alginate nanoparticles	0	1	2	3

solubility in neutral media and can only dissolve in acids; therefore, its use is limited. Therefore, to expand the use of chitosan, it needs to be degraded into water-soluble chitosan with a lower molecular weight (Nuryadin *et al.,* 2020). The characteristics of WSC from this study are shown in (Table 2), and chitosan (Figure 1A). Alginate was tested using yield parameters, water content, ash content, viscosity, and pH, as shown in (Table 3) and alginate (Figure 1B). All parameters showed better results than the standards. This shows that the process of making *alginate from Sargassum sp.* met the standards.

Chitin, chitosan, and alginate, produced by shrimp shells and *Sargassum* sp., are three of the most interesting natural polymers for various applications in their nano forms (Niculescu & Grumezescu, 2022). Chitosan in this study must go through a process of demineralization, deproteination and deacetylation to be free from inorganic compounds, high solubility with low molecular weight. The molecular weight of chitosan can affect its psychochemical properties, meaning that the higher the molecular weight, the more difficult its solubility and limited its use (Gonçalves *et al.,* 2021). Chitosan that can dissolve in water and acid is called water-soluble chitosan (WSC) (Yusharani *et al.,* 2019). The future perspective of alginate has also been considered in research to date because it has the potential for innovation that can expand its benefits in the pharmaceutical, food, and cosmetic fields (Letocha *et al.,* 2022).

(A) (B) (C)

Figure 1 Appearance of (A) chitosan; (B) alginate; and (C) chitosan alginate nanoparticles

Table 2 Characteristics value of water-soluble chitosan from shrimp shells

Parameter (%)	Value	(BSN, 2013)
Solubility		
Acid	92.5±0.71	Min. 99
Water	88.5±0.71	Min. 99
Water	4.04±0.90	<12
Ash	0.20±0.21	<12
Nitrogen	0.01±0.002	<5
Deacetilation degree	79.01±0.63	>75

Table 3 Alginate characteristics derived from *Sargassum* sp.

Parameter	Average value	U.S. Pharmacopeial Convention (2020)
Water (%)	8.65±0.37	5-12 %
Ash (%)	26.98±0.48	18-27%
pH	7.1±0.16	3.5-10
Viscosity	53.08±0.52	>27 cps

Sargassum sp. is a brown seaweed with potential in the field of cosmetics that has a function in skin care because it contains many kinds of bioactive compounds such as fucoidan, fucosantin, terpenoids and flavonoids (Lee *et al.,* 2022). Alginate extraction was carried out using the acid pathway, as described by Sumandiarsa *et al.* (2020), through the soaking stage in 4% HCl solution to make it purer because it dissolves dirty particles, dyes, reduces mineral salts, and destroys cell walls to make it easier to extract (Kamisyah *et al.,* 2020). Soaking in Na_2CO_3 alkaline solvent helps tissue cell swelling, facilitating alginate release from the tissue. WSC and alginate were characterized to determine whether the treatment during the manufacturing process was optimally achieved, so that their physicochemical properties could be determined.

The solubility of WSC is strongly influenced by its degree of deacetylation, molecular weight, and chitosan structure. The solubility of WSC in acetic acid is easier than water with a solubility rate of 92.5±0.71, and 88.5%±0.71 in distilled water solvent. The solubility value of WSC in water in this study was 88.5±0.71, which was lower than the results of the study conducted by Permadi *et al.* (2022), which produced a solubility value of WSC in water of 91.72±0.4, even though both studies used the same H_2O_2 concentration of 30%. In fact, this study had a higher degree of deacetylation (DD), namely 79.01±0.63 compared to the study by Permadi *et al.* (2022), which was 75.08±0.12.

Therefore, the molecular weight (MW) is one of the factors that determine the level of WSC solubility in water. Du and Vuong (2019) stated that chitosan with an MW of 18–90 kDa has good water solubility. Choi *et al.* (2024) also stated that low-MW chitosan (LMW chitosan, <10 kDa) has significant potential for biomedical applications (e.g., antimicrobial and gene/drug delivery) because of its higher water solubility at pH values ranging from 3.0 to 8.5 compared to that of high-MW chitosan (>100 kDa). Santoso *et al.* (2020) stated that an increase in the degree of deacetylation can decrease the molecular weight of chitosan. The depolymerization of chitosan can reduce its molecular weight and shorten its molecular chain (Tanasale *et al.,* 2019). Chitosan with a lower molecular weight tends to be more soluble in water because of its shorter chains and ease of dissociation. The moisture and ash content of WSC in this study were 4.04±0.90% and 0.20±0.21%, respectively. Low ash content is crucial for improving the quality of WSC, as high ash content can reduce the solubility and functionality of chitosan in pharmaceutical and cosmetic applications. The ash content of WSC is influenced by the amount of organic matter that reacts with chitosan during the conversion of water-soluble chitosan (Basmal *et al.,* 2007).

The total nitrogen content obtained was 0.01±0.002%, which is a low value, indicating that the deproteination process in the preparation of chitosan was successful, causing the amino acid chain to be overhauled and protein denaturation to occur properly. The total remaining nitrogen content is an indicator of the deproteination process (Natalia *et al.,* 2021). The use of higher NaOH concentrations accelerates deproteination by increasing protein breakdown reactions, resulting in lower nitrogen levels (Sudianto *et al.,* 2020). The degree of deacetylation (DD) value obtained was 79.01±0.63%, indicating that the deacetylation process was successful, resulting in WSC with high purity.

Nadia *et al.* (2014) explained that a high deacetylation degree indicates good chitosan purity. The high concentration of NaOH in the solution is very important in the deacetylation process to substitute acetyl groups ($-COCH_3$) with amino groups ($-NH_3^+$) on chitin and increase activity so that more acetyl groups are removed, producing chitosan with a higher degree of deacetylation (Natalia *et al.,* 2021). Chitosan in an acidic solution of amino groups will be deprotonated, that is, the $-NH_2$ group will bond with hydrogen ions (H^+) from the acid and turn into a $-NH_3^+$ group. Protonated chitosan has a wide range of potential applications in the cosmetic, pharmaceutical, and food industries, utilizing its bioactive ingredients with specific activities such as antioxidant, antibacterial, antifungal, and antihyperglycemic (Yadav *et al.,* 2023).

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Characteristics of Chitosan and Alginate Nanoparticles

Chitosan alginate nanoparticles were prepared by mixing the two nanoparticles by gradually dripping all the chitosan nanoparticles that were formed onto all the alginate nanoparticles in a ratio of (5:1). The nanoparticles or solutions formed were clear. Its characteristics were tested using parameters of stability and turbidity, size and distribution of nanoparticles, and zeta potential (Table 4).

The characterization of sodium alginate includes parameters such as moisture content, ash content, pH, and viscosity. The water and ash contents in this study were 8.65%± 0.37 and 26.98%±0.48, respectively. Previous research has reported moisture content in alginate of 9.35% (Maharani *et al.,* 2017), 12.16%±0.4 (Sumandiarsa *et al.,* 2020). The ash content in this study was greater than 24.37%±0.5 (Sumandiarsa *et al.,* 2020), 12.8% (Hartono *et al.,* 2021), 21.90%±0.51 (Permatasari *et al.,* 2022). The pH of the research results was 7.1±0.16, which is in accordance with commercial standards, namely 6.1-7.8 (Kok and Wong, 2018). The pH of alginate extracted from *Sargassum* sp. is 7.45 (Jayanudin *et al.,* 2014), 7.28 (Sumandiarsa *et al.,* 2020), and 7.8 (Sulasmi *et al.,* 2020).

The alginate viscosity value obtained in this study was 53.08± 0.52 cP, which is lower than the results of Sugiono *et al.* (2019) which amounted–62.4-73.0 cP and Damayanti *et al.* (2019) (range–35-81.33 cP for the same species. Viscosity is influenced by the extraction process in the bleaching phase, where a higher level of bleaching material reduces the viscosity of the resulting alginate (Andriamanantoanina & Rinaudo, 2010). The intense bleaching process can cause chain breaks and a decrease in the molecular weight of alginate, which directly impacts the decrease in viscosity. Viscosity is a favorable characteristic of alginate that shapes its stability and gel effect.

The characteristics of chitosan and alginate nanoparticles include stability, turbidity, particle size, polydispersity index, and zeta potential. The stability test showed that the nanoparticle solution stored for seven days did not experience precipitation or separation; therefore, it was considered stable. The turbidity test yielded absorbance results of 0.037, 0.038, and 0.036, with a transmittance value of 94.20%, which is close to the absorbance value of distilled water, which is 0.033. Therefore, the solution reached the nanoparticle size and clear color because it was almost close to distilled water. Particle size, polydispersity index, and zeta potential are important parameters in the physical characterization of nanoparticles, especially in cosmetic, pharmaceutical, and other nanoparticle suspensions. Particle size analysis is essential for measuring the stability, texture, and perfection of cosmetic formulas.

The produced chitosan alginate nanoparticles had a particle size of 317.6 - 421.4 nm and could not been able to reach a smaller size below 100 nm, but could provide a smooth texture and good suspension stability in body lotion products. Nanoparticles of 100-500 nm provide benefits in terms of formulation stability and even distribution, although penetration into deeper skin layers may be limited compared to smaller nanoparticles. The results showed particle sizes ranging from 100 to 500 nm, as described by Alshawwa *et al.* (2022), which are optimal for cosmetic and pharmaceutical applications because they tend to better moisturize and protect the skin, making them suitable for body lotion products

Table 4 Characteristics value of chitosan alginate nanoparticles

Parameter	Results
Stability	Stable
Transmit (%)	91.6±1.06
Particle size (nm)	375.97±53.9
Polydispersity index	0.47±0.05
Zeta potential (mV)	60.80±1.18

that focus on skin surface treatment (Melo *et al.,* 2023). Friedman *et al.* (2012) found that the average hydrodynamic diameter of the diameter particles was 341.6±11.1 nm. The nanoparticle chitosan alginate was effective in inhibiting bacterial growth.

The polydispersity index in the range of 0.414-0.521 in this study indicates a good size distribution of the nanoparticles, although slightly higher than the ideal range of 0.1-0.3 (Reddy & Gubbiyappa, 2022). The size distribution was fairly uniform with low size variation, which contributed to the stability and effectiveness of the formulation. Values above 0.5, as described by Danaei *et al.* (2018), may indicate greater size variation within the suspension and may lead to instability and particle aggregation, which affects product performance, such as the texture, absorption, and distribution of active ingredients. In the context of cosmetics, a small particle size is important for skin penetration and product effectiveness.

The zeta potential values have a range from to 59.8-62.1 mV indicating that the nanoparticles had excellent electrostatic stability. Values of ±30 mV already provide good stability, but higher values, such as ±60 mV, show excellent stability because the repulsive force between particles is large enough to inhibit particle agglomeration for a longer time, in accordance with Bhattacharjee (2016) and Altammar (2023). Potential zeta values above ± 30 mV and close to ± 60 mV make nanoparticles more ideal for application in cosmetics and pharmaceuticals, as their high stability ensures that product effectiveness is maintained and consistent texture makes them ideal (Guo *et al.,* 2014). Zeta potential values of nanoparticles exceeding + 30 mV or - 30 mv provide a higher level of stability to nanoparticle formulations. A high zeta potential (positive or negative) reflects a strong enough repulsive force between particles, which will not be able to agglomerate particles for a longer period (Akhtar *et al.,* 2012). Thus, the zeta potential indicates that the nanoparticles have a high degree of electrostatic stability.

Quality Characteristics of Body Lotion

The body lotion formula was tested to determine its hedonics (Table 5), physical

Table 5 Average hedonic value in body lotion formula

Parameter	Addition of chitosan alginate (g)			
	0 (F1)	1 (F2)	2 (F3)	3 (F4)
Appearance	4.00±0.62^{a}	3.84±0.70^{a}	4.04±0.60^{a}	3.90±0.69^{a}
Color	3.89±0.69^{a}	3.83±0.71^{a}	3.89±0.61^{a}	4.00±0.62^{a}
Aroma	3.36±0.87^{a}	3.17±0.82^{a}	3.32±0.86^{a}	3.26±0.82^{a}
Texture	3.57±0.78^{a}	3.50±0.77^{a}	3.63±0.77^{a}	3.70±0.68^{a}
Absorbency	3.41±0.89^{a}	3.32±0.87^{a}	3.40±0.88^{a}	3.49±0.88^{a}

The same superscripts in the same column show no significant differences (p<0.05)

Table 6 Physical testing value of body lotion formula

Parameter	Addition of chitosan alginate (g)			
	0 (F1)	1 (F2)	2 (F3)	3 (F4)
Homogeneity	Homogen	Homogen	Homogen	Homogen
Viscosity	6931.77 cps ±1194.18^{a}	5,468.55 cps ±1,397.32^{a}	5,008.47 cps ±1123.87^{a}	4596.73 cps ±960.67^{a}
Spreadability	52.4±1.95^{a}	67.5±4.64^{b}	68.9±2.24^{b}	65.2±6.15^{b}
pH	6.81±0.17^{a}	6.61±0.29^{ab}	6.35±0.21^{ab}	6.11±0.11^{b}

The same superscripts in the same column show no significant differences (p<0.05)

Table 7 Stability testing value of body lotion formula

Addition of chitosan alginate (g)	Weeks	Parameter		
		Color	Homogeneity	pH
0	0	White	Smooth without clumps/bubble	6.98
	1	White	Smooth without clumps/bubble	7.19
	2	White	A slight bubble	7.24
	3	White	A slight bubble	7.38
	4	White	A slight bubble	7.40
1	0	White	Smooth without clumps/bubble	6.80
	1	White	Smooth without clumps/bubble	7.09
	2	White	Smooth without clumps/bubble	7.10
	3	White	Smooth without clumps/bubble	7.12
	4	White	A slight bubble	7.21
2	0	White	Smooth without clumps/bubble	6.55
	1	White	Smooth without clumps/bubble	6.91
	2	White	Smooth without clumps/bubble	6.90
	3	White	Smooth without clumps/bubble	7.00
	4	White	Smooth without clumps/bubble	7.06
3	0	White	Smooth without clumps/bubble	6.23
	1	White	Smooth without clumps/bubble	6.70
	2	White	Smooth without clumps/bubble	6.74
	3	White	Smooth without clumps/bubble	6.83
	4	White	Smooth without clumps/bubble	6.85

properties, including homogeneity, viscosity, spreadability, pH (Table 6), stability (Table 7), antioxidant content (Figure 2), and appearance (Figure 3).

The characteristics of the body lotions were evaluated using hedonic parameters, homogeneity, viscosity, spreadability, pH, stability, and antioxidant content. A hedonic test was conducted on 30 untrained panelists. The results of the Kruskal–Wallis test on all hedonic test parameters showed a P value > 0.05; therefore, H0 was accepted. This means that there were no significant differences between the treatments with 0, 1, 2, and 3 g of chitosan alginate nanoparticles in terms of appearance, color, aroma, texture, moisture, and absorption of body lotion, and further testing could not be carried out to determine the differences in each sample. This indicates that the panelists' perceptions of the appearance, color, aroma, and texture of the body lotion remained unchanged, regardless of the presence or absence of alginate chitosan nanoparticles. These results indicate that alginate chitosan nanoparticles can be added to body lotions without altering their sensory characteristics.

In accordance with the study by Salsabila *et al.* (2020), the addition of chitosan nanoparticles and *Spirulina* sp. in the development of hand and body lotions did not show significantly different results. Physical testing of the homogeneity parameter showed homogeneous results because there were no clumped particles. According to Pratasik *et al.* (2019), cream preparations are said to be homogeneous if they do not show clumpy or unmixed particles. The viscosity parameter describes whether the body lotion base is diluted or viscous. Based on the ANOVA

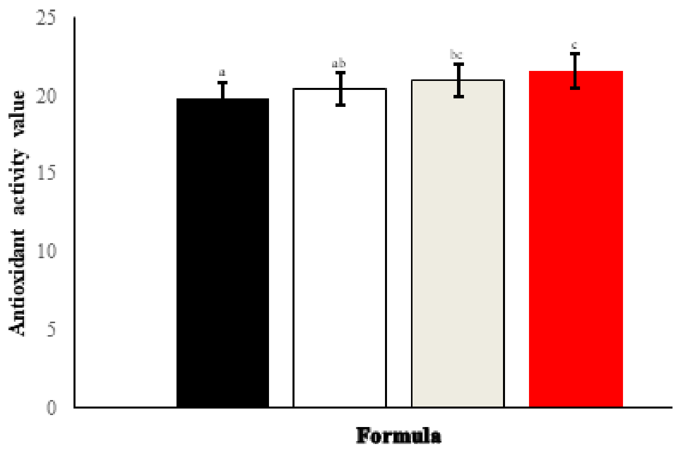

Figure 2 Average antioxidant value in body lotion formula with different addition of chitosan alginate (g); (■) 0, (□) 1,(□) 2, (■) 3;
Different superscripts show significant differences (p<0.05).

(A) (B) (C) (D) (E)

Figure 3 Body lotion appearance addition chitosan alginate nanoparticles (g); (A) 0, (B) 1, (C) 2, (D) 3, (E) commercial

test results at the 95% significance level (p > 0.05), the viscosity values of adding 0, 1, 2, and 3 g of chitosan alginate nanoparticles were 6931.77±1194.18, 5468.55±1397.32, 5008.47±1123.87, and 4596.73±960.67 cps, respectively. These values indicate that the addition of alginate chitosan nanoparticles has no effect on the viscosity of the lotion; therefore, there is no need for further testing to compare the formulas. The highest value was obtained with the addition of 0 g of nanoparticles, while the lowest value was obtained with the addition of 3 g; however, the value was still in accordance with SNI 16-4399-1996 standards, namely, the viscosity value of the preparation ranged from 2,000 - 50,000 cps.

Fransiska *et al.* (2021) in their research stated that in products that use hydrocolloids, viscosity is influenced by concentration, temperature, dispersion level, sulfate content, extraction techniques used, hydrophilic colloid content, type of substance, and molecular weight. In addition, Yuniar *et al.* (2023) stated that the thickening agent used, such as cetyl alcohol, also affects the viscosity of the lotion. The right viscosity value will make the lotion easy to apply on the body skin, so that it is easy to spread, evenly distributed, and absorbed into the skin.

Spreadability testing is required to determine the ability of the body lotion to be applied to the skin. The results of the spreadability test of adding 0, 1, 2, and 3 g of chitosan alginate nanoparticles were 52.4±1.95, 67.5±4.64, 68.9±2.24, and 65.2±6.15 cm, respectively. The ANOVA results at a significance level of 95% (p < 0.05) indicated that the addition of chitosan and alginate nanoparticles influenced the spreadability of the body lotion. Therefore, it was further tested using the Tukey test

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to determine the difference and found that adding 0 g was significantly different from adding 1, 2, and 3 g of chitosan alginate nanoparticles. The spreadability test results showed that all formulas experienced an increase in spreadability with the addition of the concentration in the formula (adding 0, 1, 2, and 3 g of chitosan alginate nanoparticles). This was influenced by the use of chitosan alginate nanoparticles, which could increase the spread and penetration of the active compounds in the skin.

Chitosan alginate nanoparticles have biocompatibility, mucoadhesive properties, and the ability to interact with the stratum corneum in the skin to change the secondary structure of creatine, thereby increasing transdermal permeation and creating a looser skin structure. The greater the spread of the body lotion, the greater its ability to distribute evenly. According to Dominica and Handayani (2019), the factor that affects the diameter of spreadability is the amount of extract used in each formula. This statement is based on the fact that the lower the consistency of the body lotion, the lower the adhesion time, and the easier it is to spread the body lotion. In addition, the use of forming ingredients such as cetyl alcohol can cause the preparation to become thicker, so that the spread of body lotion will be longer, and the amount of lanolin will cause the preparation to become more liquid, so that the spread of body lotion will be faster (Salsabila *et al.,* 2020), thus affecting the viscosity of the body lotion preparation formed.

The pH of body lotions is measured to monitor any changes in pH during shelf life that may affect product stability. The pH value plays an important role in the stability of active substances, the effectiveness of preservatives, and their interactions with the skin. The results of the pH value test using ANOVA at the 95% significance level ($P < 0.05$) showed that the addition of alginate chitosan nanoparticles influenced the pH value of the lotion. Further testing using Tukey's test revealed differences in the pH value in each formula, where the lowest value was obtained in the formulation with 3 g of nanoparticles, while the highest was in the formulation with 0 g. The test results showed that adding 0 g was significantly different from adding 3 g but not different from adding 1 g and 2 g, and adding 1 g and 2 g were not different from adding 0 g and adding 3 g.

The test results showed that adding 0 g and 3 g were significantly different from each other, while adding 1 g and 2 g were not significantly different from each other but were different from adding 0 g and 3 g. This indicates that the body lotion without the addition of alginate chitosan nanoparticles had a significantly different pH value from the formulation with added nanoparticles. The results showed that the pH value of the body lotion ranged from 6.11±0.11-6.81±0.17, within the range suitable for the skin, which is 4.7-7.5. Sulasmi *et al.* (2020) reported that body lotion with the addition of alginate has a pH of approximately 6.3, which is consistent with the pH value obtained in this study. A pH value below 4.5 can cause irritation and itching, while a pH value above 8.0 can cause the skin to become slippery, dry, and lose elasticity (Safitri & Jubaidah, 2019). An appropriate pH range of body lotion not only avoids irritation but also keeps the skin healthy and comfortable while using the product.

The stability of the body lotion was determined by observing its color, texture, and pH weekly for 28 days. Stability refers to the ability of a product to retain its original form or condition over time. This was tested by storing the product for a certain period, during which its characteristics remained unchanged. Emulsion stability indicates that the emulsion in the material does not separate into layers (Rahmawanty *et al.,* 2020). The color of the body lotion remained stable, maintaining its initial white hue. However, the homogeneity parameter for adding 0 g was less stable, exhibiting slight bubbles on day 21, whereas the other formulations remained stable according to their initial state. The pH of all formulations changed but remained within the threshold of 4.5-8 according to SNI 16-4399-1996, which is safe for the skin (Purwaningsih *et al.,* 2014).

Antioxidant testing using ANOVA at a significance level of 95% ($p < 0.05$) showed that the addition of alginate chitosan nanoparticles influenced the antioxidant content. Therefore, it was further tested using the Tukey test and found that there were differences in antioxidant content in each formula, where the highest value was in adding 3 g and the lowest in adding 0 g chitosan alginate nanoparticles. As seen in the notation that symbolizes the difference of each treatment, where adding 0 g is significantly different from adding 2 g and 3 g but not different from adding 1 g, while adding 1 g is only significantly different from adding 3 g. Adding 2 g was not significantly different from adding 0 g, and adding 3 g was significantly different from adding 0 g and 1 g, but not different from adding 2 g. This indicates that the higher the concentration of alginate chitosan nanoparticles, the greater the antioxidant activity. The antioxidant values in the samples, which ranged from 19.82±0.07 – 21.59 ± 0.14 μM Fe^2/g, indicated the ability of the samples to reduce iron ions (Fe^{2+}) in the assay. This value is an indicator of antioxidant capacity, expressed in units of equivalent iron (Fe^{2+}) concentration per gram of the sample.

In comparison, research conducted by Abdullah *et al.* (2021) showed that *Sargassum* sp. alginate had an antioxidant capacity of 103.67 μmol Fe^{2+}/g, indicating high antioxidant activity. In addition, Sipahutar *et al.* (2019) showed that sunscreen cream containing *Sargassum* sp. seaweed was able to reduce free radicals at a concentration of 50% with an IC_{50} value of 105.42 μM. This indicates that *Sargassum* sp. contains phenolic components and natural antioxidants that are effective in fighting free radicals. Antioxidants can help protect human skin from exposure to air pollution and sunlight, which can damage the skin. Haerani *et al.* (2018) stated that the use of cosmetic products containing antioxidants and used for skin care by being applied on the surface of the skin can help prevent skin problems such as slowing down premature aging, preventing skin inflammation and increasing collagen production in the skin.

CONCLUSION

The development of chitosan and alginate nanoparticles in body lotion shows great potential and meets good homogeneity standards. Their addition did not affect homogeneity or viscosity but influenced spreadability, pH, and antioxidant activity. Nanoparticles sized 100–500 nm are ideal for cosmetic use, offering stability, a smooth texture, and effective skin penetration. These nanoparticles enhance antioxidant performance and protect the skin from free radicals. Further research should focus on reducing the particle size and optimizing the nanoencapsulation process to improve antioxidant efficacy.

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