

Effect of Xanthan Gum Concentration Variations on the Physical Properties of Breadfruit Leaf (*Artocarpus altilis*) Extract Serum

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Abstract

Breadfruit leaves (*Artocarpus altilis*) contain flavonoid with high antioxidant activity that neutralize free radicals and prevent premature aging. This study formulated breadfruit leaf extract (0.75%) into a serum using xanthan gum as a gelling agent. Serums are characterized by their ability to carry high concentrations of active ingredients and provide rapid skin absorption. Xanthan gum was selected due to its excellent stability across various pH levels and temperatures, as well as its compatibility with other pharmaceutical ingredients. This experimental study aimed to determine the effect of varying xanthan gum concentrations on the physical quality of the serum. Three formulas were tested: Formula I (0.5%), Formula II (1%), and Formula III (2%), with a constant breadfruit leaf extract concentration of 0.75%. Physical evaluations included organoleptic properties, homogeneity, pH, viscosity, spreadability, and adhesion tests. Results showed that all formulas were homogeneous and met standard pH requirements. Formula II was the only one to meet both viscosity and spreadability standards. ANOVA results confirmed that xanthan gum concentration significantly influences all physical quality parameters. Specifically, increasing the concentration of xanthan gum led to higher pH, viscosity, and adhesion values, but reduced the spreadability of the serum.

Keywords: Xanthan gum, serum, breadfruit, *Artocarpus altilis*, physical quality.

1. INTRODUCTION

Health and skin beauty become primary concerns in the modern era, where outward appearance often reflects an individual's health condition (Hasriyani *et al.*, 2022). As the largest organ of the body, the skin functions as a protective barrier against external hazards such as bacteria, radiation, and harmful substances. The skin also plays a crucial role in maintaining body temperature balance and managing the nervous system (Dąbrowska *et al.*, 2016). Exposure to environmental factor can trigger oxidative stress due to elevated levels of Reactive Oxygen Species (ROS) that cannot be neutralized by the body's natural antioxidants, leading to reduction of collagen production and the appearance of fine lines on the skin (Gragnani *et al.*, 2014). Additionally, UV-B exposure can penetrate into the dermal layer, damaging DNA structures. The DNA damage caused by UV-B is a key factor in wrinkle formation and increases the risk of skin cancer (Matsuda *et al.*, 2013).

Free radicals can be neutralized by compounds known as antioxidants (Utami et al., 2023). The human body is equipped with antioxidant mechanisms to counteract naturally occurring free radicals; however, under certain conditions, the body is unable to counteract all free radicals. Thus, an intake of external antioxidants is required to inhibit excessive and damaging free radical reactions (Malinda & Syakdani, 2020). In the field of healthcare, flavonoids play an important role due to their wide range of biological activities, including as antioxidants, antivirals, and antimicrobials, as well as providing protection against severe diseases as anticancer, anti-proliferative, and antiangiogenic agents (Ullah *et al.*, 2020).

Breadfruit leaves (*Artocarpus altilis*) show therapeutic potential for human health. Research by Rahmat *et al.* (2025) reported that breadfruit leaves contain tannins, flavonoids, alkaloids, and steroids. Among these compounds, flavonoids play a vital role in neutralizing free radicals due to their function as natural antioxidants (Nugraha *et al.*, 2022; Budiawan *et al.*, 2026). The high levels of flavonoids in plants correlate with relatively high Sun Protective Factor (SPF) values, due to the ability of flavonoid chromophore groups to absorb ultra violet (UV) radiation (Kirana *et al.*, 2023). Furthermore, flavonoids also exhibit effective antioxidant properties in preventing oxidative stress, protecting the skin from premature aging, and reducing cancer risks. The antioxidant content of breadfruit leaves is considered high, as indicated by an IC₅₀ value of 45.7 ppm (Rahmasari *et al.*, 2024). These advantages have encouraged the use of breadfruit leaves as an active ingredient in anti-aging cosmetic formulations.

Currently, one type of cosmetic experiencing rapid growth is serum. The primary advantages of serum lie in its lower viscosity compared to other topical products, high concentration of active substances, faster skin absorption, more comfortable texture during application, and ease of spreading across the skin surface (Ekawati & Hariningsih, 2023). In serum formulation, excipient materials such as good and appropriate thickening agents are required to achieve desirable consistency and stability. The selection and characteristics of excipients are important aspects in serum formulation and must be adjusted to the type of preparation.

Xanthan gum is a commonly used polysaccharide hydrocolloid obtained through the fermentation process of the bacterium *Xanthomonas campestris* (Rowe *et al.*, 2009). One advantage of xanthan gum as a gelling agent is its ability to produce formulations with high viscosity levels even when used at low concentrations (Sawiji et al., 2024). Xanthan gum is frequently utilized in oral pharmaceutical products, topicals, cosmetics, and foods, and is

generally recognized as safe and non-irritating at the concentrations used as a pharmaceutical additive. Xanthan gum demonstrates superior stability and viscosity properties across various pH levels and temperatures, as well as high compatibility with almost all other pharmaceutical ingredients (Rowe *et al.*, 2009).

Previous research by Octavia *et al.* (2025) produced serum formulations containing breadfruit leaf extract using xanthan gum as a thickening agent. However, that study focused on determining the most effective extract concentration, while the xanthan gum concentration used was kept constant. This highlights a research gap in the serum formulation process. Research on the effect of variations in xanthan gum concentration on the physical quality of breadfruit leaf extract serum has never been conducted, considering that xanthan gum is an excipient that plays a role in determining the physical quality of the serum. The physical quality of the serum preparation is a primary determinant of comfort and effectiveness when applied to the skin. Precision in xanthan gum concentration is essential to identify a concentration that is too high can cause the preparation to be too thick and difficult to spread, while a low concentration can make the preparation too thin, which may reduce the comfort aspect for the user. Accordingly, this study aims to evaluate the effect of variations in xanthan gum concentration on the physical quality of breadfruit leaf extract serum that meets testing standards, including spreadability, adhesion, pH, viscosity, organoleptic, and homogeneity tests.

2. METHOD

Tools and Materials

The tools used in this research were a digital balance (Acis-AD 600i), maceration vessel, glass funnel, stand and clamp, filter paper, flannel cloth, 20-mesh sieve, porcelain dish, moisture balance, stirring rod, spatula, grinder (Huang cheng), water bath (Biostellar), room thermometer (HTC-2), oven (Mettler), petri dish (Anumbra), mortar, pestle, measuring cylinder (Iwaki), beaker glass (Iwaki), hand mixer (Ocooker), dropper pipette, adhesion test apparatus, spreadability test apparatus, Brookfield viscometer (NDJ-9s), pH meter (Hanna HI 2210), and glass plates.

The materials used in this study included breadfruit leaf (*Artocarpus altilis*) simplicia and 96% ethanol solvent (Technical Grade) at the extraction stage. The preparation of breadfruit leaf extract serum was formulated with the addition of excipients, including xanthan gum (Cosmetic Grade), propylene glycol (Pharmaceutical Grade), Na₂EDTA (Pharmaceutical Grade), sodium benzoate (Pharmaceutical Grade), strawberry essence, and distilled water

The plant samples used in this study were breadfruit leaves (*Artocarpus altilis*) obtained from Guyung Village, Gerih District, Ngawi Regency, East Java. The botanical identification and determination of the plant were conducted at the Biology Laboratory of Widya Mandala Catholic University Surabaya, Madiun Campus.

Extraction

The process of making breadfruit leaf extract was carried out using the maceration method with 96% ethanol solvent. A total of 400 g of weighed breadfruit leaf powder was placed into a maceration vessel. Then, 1.6 L of ethanol solvent was added until completely submerged. Subsequently, the mixture was soaked for 3 days, with stirring every 24 hours, and kept away from sunlight. After the first maceration, the simplicia was re-macerated using 96% ethanol for 2 days. The liquid extracts obtained from both maceration and re-maceration stages were combined, then evaporated using a water bath at a temperature of 50°C. This was followed by drying in an oven at 50°C for 36 hours until a thick extract was obtained (Tapalina *et al.*, 2022). The yield of the thick extract was then calculated. The good yield of breadfruit leaf extract is more than 9.9% (Ministry of Health of the Republic of Indonesia, 2017)

Preparation of Formulation

The serum preparation formula used in this study is a modification of previous research conducted by Octavia *et al.* (2025)..

Table. 1. Breadfruit Leaf Extract Serum Formulation

Composition	FI (% W/W)	FII (%W/W)	FIII (%W/W)
Breadfruit leaf extract	0,75	0,75	0,75
Xanthan gum	0,5	1	2
Propylene glycol	10	10	10
Disodium edetat	0,05	0,05	0,05
Sodium benzoate	0,5	0,5	0,5
Strawberry essence	5 drops	5 drops	5 drops
Aquadest	ad 100	ad 100	ad 100

Based on Table 1 the formulation of breadfruit leaf extract serum applied refers to research conducted by Setiawan *et al.* (2023) and Auranajwa *et al.* (2025). The procedure for making the serum began by weighing all materials according to calculations. The first stage was the preparation of the xanthan gum base. Hot distilled water weighing 20 times the weight of the xanthan gum was placed in a mortar, then xanthan gum powder was sprinkled evenly over it. The mixture was allowed to stand until fully expanded, then stirred vigorously until a homogeneous gel mass was formed. Separately, the preservative solution was prepared by dissolving sodium benzoate in distilled water at a 1:10 ratio. 0.75 g of extract was levigated

with 10 g of propylene glycol, added little by little into a separate mortar until completely dissolved. The extract solution was then added little by little into the xanthan gum gel base, then stirred vigorously until the gel mass was homogeneous. Then Na₂EDTA was added and stirred until even. Once homogeneous, the sodium benzoate solution was added and stirred until even. Distilled water was added, and 5 drops of strawberry essence were introduced and stirred until even. To ensure final homogeneity, the serum preparation was placed in a beaker glass and stirred using a hand mixer. The finished serum preparation was placed in a storage container and labeled.

Physical Quality Test of Serum

All physical quality test of breadfruit extract serum were conducted in triplicate for each formulation.

Organoleptic Test

The organoleptic test was performed by visual observation and the sensation felt on the skin. Aspects assessed included color, aroma, and texture (Hikmah *et al.*, 2023).

Homogeneity Test

The homogeneity test was performed by spreading the sample evenly on an object glass and covering it with another object glass. Observation of homogeneous or even conditions was indicated by the absence of coarse particles or grains visible on the glass (Wahyuningsih *et al.*, 2021).

pH Test

The pH test was performed by first calibrating the pH meter. After calibration, the electrode was rinsed with distilled water and waited until dry. Then, the electrode was dipped into the serum preparation. The measured pH value was then displayed on the tool's screen (Firmansyah *et al.*, 2022).

Viscosity Test

The viscosity test was performed using a Brookfield viscometer. After 200 g of the serum preparation was placed, the spindle was lowered until fully submerged. Spindle number 2 was employed for formulas FI and FII, while spindle number 4 was used for FIII. The device was operated at a rotational speed of 6 rpm until it reached a stable state, at which point the viscosity value was read directly from the Brookfield viscometer display (Slamet *et al.*, 2020).

Adhesion Test

The adhesion test was performed by placing 0.25 g of serum between two glass slides with a specified area. The glass was then pressurized by placing a 1 kg weight on top for 5

minutes. Then the weight was removed, and an 80 g weight was attached to the adhesion test apparatus. The 80 g weight was pulled simultaneously with the activation of a stopwatch. The length of time until the two glass slides separated was recorded as the measure of the serum's adhesion (Setiawan *et al.*, 2023).

Spreadability Test

The spreadability test was performed by placing 0.5 g of serum in the center of a scaled glass, covering it with another glass, and applying pressure using a 150 g weight. After letting it stand for 1 minute, the diameter of the serum spread was measured using a verniper caliper to determine spreadability (Rahmavika *et al.*, 2023).

Data Analysis

Research data were analyzed qualitatively and quantitatively. Statistical analysis used the Statistical Product and Service Solution (SPSS) 25 with initial procedures of normality and homogeneity tests. Test results showed that all serum formulas had normally distributed and homogeneous data, except for the viscosity test where the data was not homogeneous. Therefore, the analysis was continued using the One-Way ANOVA parametric. Subsequently, a Post Hoc test was performed to determine the location of significant differences between each test group.

3. RESULTS AND DISCUSSION

Preparation of Extract

The extraction of breadfruit leaf simplicia was conducted using the maceration method. The determination of the extract's water content yielded an average result of 1.63%, which fulfills the requirement of a water content of less than 10% (Ministry of Health of the Republic of Indonesia, 2017). In this study, an extract yield of 9.50% was obtained. Similar results occurred in research by Efrilia (2025) and Suradnyana *et al.* (2025), where the yield of breadfruit leaf extract was below 9.9%, specifically 9.13% and 8.36%. A factor that can influence the extract yield being less than 9.9% is the choice of solvent.

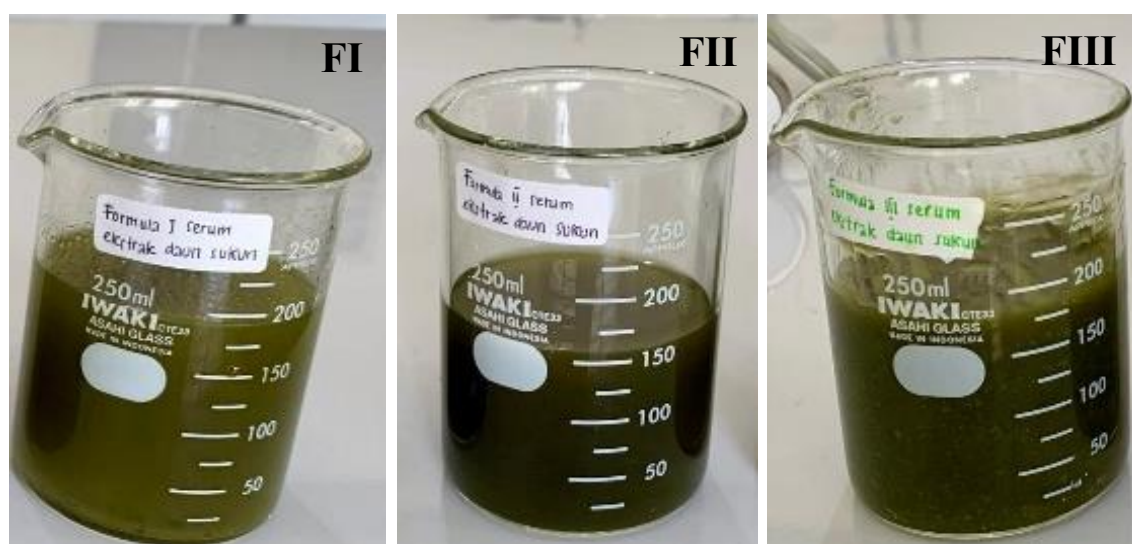
Physical Quality Testing of Breadfruit Leaf Extract Serum Preparation

Organoleptic Test

The initial testing of the serum preparation was the organoleptic test through observation of the color, form, and aroma of the preparation (Hikmah *et al.*, 2023).

Table 2. Organoleptic Test Results

Formula	Texture	Color	Odor
FI	Liquid	Dark green	strawberry
FII	Slightly Thick	Dark green	strawberry
FIII	Thick	Dark green	strawberry

**Figure 1.** Breadfruit Leaf (*Artocarpus altilis*) Extract Serum Formulations

Referring to Table 2 and Figure 1, all three serum formulas produced preparations with a dark green color. This is consistent with the research by Octavia *et al.* (2025), which also obtained a dark green result for breadfruit leaf extract serum. This coloration is caused by the natural pigment of the breadfruit leaf extract used as the active ingredient. The color intensity tends to appear darker as the viscosity of the preparation increases. This aligns with the study by Sawiji *et al.* (2024), which demonstrates that variations in xanthan gum concentration affect both the color consistency and the thickness of serum preparations. Physically, the difference in concentrations resulted in Formula I having a liquid consistency, while Formula II was slightly thick, and Formula III produced a thick preparation.

Homogeneity Test

The homogeneity test aims to ensure that the preparation is evenly dispersed, characterized by the absence of coarse particles or lumps (Arifin *et al.*, 2023).

Table 3. Results of Formula Homogeneity Test

Formula	Homogeneity
FI	Homogeneous
FII	Homogeneous
FIII	Homogeneous

Referring to Table 3, the serum preparations in all three formulas were homogeneous, as evidenced by the absence of coarse particles or precipitates. This indicates that the active ingredients and the vehicle were uniformly mixed. In line with the research by Henrirallez et al. (2025) regarding carrot extract serum, which obtained homogeneous results for the preparations. Furthermore, in a study by Fauzah et al. (2024) on pumpkin peel extract serum, all three formulas were also found to be homogeneous.

pH Test

pH testing is conducted to ensure the safety of the preparation and to minimize the risk of skin irritation during application (Chandra & Rahmah, 2022).

Table 4. Results of Formula pH Test

pH		
FI	FII	FIII
5.64 ± 0.01	5.87 ± 0.01	5.96 ± 0.01

Referring to Table 4, the breadfruit leaf extract serum preparations FI, FII, and FIII comply with the acidity requirements. The safe pH range aligns with the physiological pH of the skin, which is within the range of 4.5 to 6.5 (Happe et al., 2024). According to Rowe (2009), the pH of xanthan gum ranges from 6.0 to 8.0. The pH testing of the serum using a pH meter yielded results of 5.64 for FI, 5.87 for FII, and 5.96 for FIII. The ANOVA test results yielded a p-value of $0.00 < 0.05$), indicating a significant difference. The post-hoc test further revealed that there were statistically significant differences among all three formulations. The results of this study show an increase in serum pH as the concentration of xanthan gum used increases. This is in line with the research by Octavia et al. (2025), which demonstrates that increasing the concentration of xanthan gum causes the pH value level to rise. In the study conducted by Nugrahaeni et al. (2021) and Ezera et al. (2019) pH test results showed an increase toward neutral or alkaline levels as the concentration of xanthan gum increased.

Viscosity Test

Viscosity testing is performed to determine the thickness level of a preparation, which represents its flowability (Fikayuniar *et al.*, 2021).

Table 5. Viscosity Test Results

Viscosity(cPs)		
FI	FII	FIII
68.40 ± 1.26	2014.67 ± 27.01	85266.00 ± 746.85

Referring to Table 5, the breadfruit leaf extract serum preparation FII meets the serum viscosity requirements, which fall within the range of 2000-50000 cPs (Hanifah & Amalia, 2023). Meanwhile, serum preparations FI and FIII do not meet the viscosity test requirement range, as results were 68.40 cPs and 85266.00 cPs, respectively. The ANOVA test results yielded a p-value of $0.00 < 0.05$, indicating a significant difference. The post-hoc test further revealed that there were statistically significant differences among all three formulations. The research results show that the higher the concentration of xanthan gum used, the higher the level of thickness. This is in line with the research conducted by Auranajwa (2025) regarding matoa leaf extract serum, which shows that the increase in xanthan gum concentration is directly proportional to the viscosity value of the preparation. In the formulation of *keji beling* leaf extract serum, an increase in viscosity also occurred as the xanthan gum concentration increased (Happe *et al.*, 2024). Increasing the xanthan gum concentration can enhance the viscosity of the preparation through a water absorption mechanism that causes the polymer molecules to swell. Xanthan gum contains high molecular weight components; these interconnected polymer chains form the viscous property. The bound networks form a three-dimensional structure capable of binding and trapping water molecules within. As a result, the initially liquid fluid transforms into a thick gel (Silvia & Dewi, 2022).

Spreadability Test

Spreadability testing aims to determine the ability of the serum preparation to spread on the skin surface and to ensure ease of application when used (Fikayuniar *et al.*, 2021).

Table 6. Spreadability Test Results

Spreadability (cm)		
FI	FII	FIII
7.44 ± 0.05	6.47 ± 0.14	4.24 ± 0.04

Based on Table 6, the spreadability test results for serum preparations FI and FIII did not meet the standard requirements, whereas FII met the spreadability requirements, which are in the

range of 5-7 cm (Slamet *et al.*, 2020). The statistical analysis results showed that the breadfruit leaf extract serum preparations FI, FII, and FIII had significant differences. The ANOVA test results yielded a p-value of $0.00 < 0.05$, indicating a significant difference. The post-hoc test further revealed that there were statistically significant differences among all three formulations. From the research results, the difference in xanthan gum concentration affected the spreadability value of the serum. The spreadability value is inversely proportional to the viscosity value of the preparation. A viscosity that is too high results in a decrease in spreadability. This condition will make the application of the preparation difficult and hinder the even distribution of the active ingredients (Hikmah *et al.*, 2023). A decrease in spreadability also occurred in the study by Astuti (2023) along with an increase in the concentration of xanthan gum used in sandalwood oil nanoemulgel preparations. The spreadability value in the study by Auranajwa (2025) also experienced a decrease with the increasing concentration of xanthan gum used. When applied to the skin, the rubbing pressure provides shear stress. Because of its pseudoplastic nature, the pressure causes the molecular structure of xanthan gum to temporarily break down, so its viscosity decreases, becoming thinner, and returns to being thick when left to rest (Silvia & Dewi, 2022). This is important for topical preparations the decrease in viscosity when rubbed makes it easier for the preparation to spread on the skin surface, while the return of thickness after being rubbed ensures the preparation remains attached to the desired area (Priani *et al.*, 2025). Spreadability directly influences the comfort and efficiency of a preparation's use. An optimal spreadability provides a light, smooth sensation and allows for easy application without causing pain, which is particularly crucial for irritated skin. Conversely, low spreadability as observed in Formula III tends to feel tacky, heavy, and inefficient, as it requires a larger amount of product to cover the same skin area. Superior spreadability ensures a thin yet uniform distribution of active ingredients across the target surface, ultimately enhancing both user satisfaction and patient compliance (Albarghouthy *et al.*, 2025).

Adhesion Test

The adhesion test was conducted to determine the duration the preparation adheres to the skin surface after application. A longer contact period between the preparation and the skin is necessary because it allows the active substance to be optimally delivered into the skin layers (Nurjanah *et al.*, 2025).

Table 7. Results of Adhesion Value Test.

Adhesion (second)		
FI	FII	FIII
0.68 ± 0.10	0.84 ± 0.03	1.14 ± 0.18

Based on Table 7, the adhesion value results for breadfruit leaf extract serum preparations FI and FII did not meet the requirement, which is >1 second. whereas FIII met the requirements because the adhesion was more than 1 second (Yusuf *et al.*, 2017). The statistical analysis results showed that the three formulas had a significant difference. The ANOVA test results yielded a p-value of $0.00 < 0.05$), indicating a significant difference. The post-hoc test further revealed that there were statistically significant differences among all three formulations. The research results showed that as the concentration of xanthan gum increased, the serum adhesion value also became higher. This is in line with the research by Nugrahaeni *et al.*, (2021) regarding hair dye gel from sappan wood oil, and research showing that an increase in xanthan gum concentration is directly proportional to the adhesion of the preparation, the longer the adhesion time on the skin surface. In the cassava leaf extract serum preparation, a decrease in spreadability was obtained at low viscosity while at high viscosity, an increase in spreadability value was obtained (Setiawan *et al.*, 2023).

4. CONCLUSION

Based on the research results, it can be concluded that variations in the concentration of xanthan gum affect the physical quality of breadfruit leaves extract serum. An increase in the concentration of xanthan gum can increase the pH value, viscosity, and adhesion of the preparation, but it can provide a decrease in the spreadability value of the breadfruit leaf extract serum preparation. Currently, none of the formulations have met all the physical quality standards. While Formula II fulfilled most criteria, its adhesion properties remained below the required standards. Consequently, future research should focus on formula optimization specifically to enhance adhesive properties. Furthermore, this study is limited by the absence of sensory evaluation and long-term safety profiles; thus, it is highly recommended that subsequent studies incorporate hedonic and irritation testing to ensure both user acceptance and clinical safety.

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