e-ISSN 2581-0405
Asian Journal of Applied Research for Community Development and Empowerment
Journal home page: http://ajarcde-safe-network.org ISSN 2581-0405

Effect Of Gelatin And Egg White Addition on the Characteristics of Marshmallow Made from Siwalan and Red Dragon Fruit Peel

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ARTICLE INFO

Article History:
Received: 01 May 2025
Final Revision: 02 June 2025
Accepted: 07 June 2025
Online Publication: 10 June 2025

KEYWORDS

Siwalan, Marshmallow, Egg White, Gelatine, Dragon Fruit

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A B S T R A C T

Marshmallow is a confectionery with a soft, light and chewy texture made from fruits, including siwalan and red dragon fruit skin. In its manufacture, treatment is needed, namely the addition of gelatin and egg white. In this study, marshmallow siwalan and red dragon fruit skin will be made by adding gelatin and egg whites. This study aimed to determine the effect of gelatin and egg white addition treatment on the physicochemical and organoleptic characteristics of marshmallows produced and the best treatment of marshmallows with the addition of gelatin and egg white favored by panellists. This study used a completely randomized design (CRD) factorial pattern with two factors and two replicates. Factor I adds gelatin (10%, 12%, 14% b/v) and factor II is the addition of egg white (6%, 8%, 10% b/v). If there is a significant difference, it will be continued with the 5% DMRT test. The best treatment results were obtained in the treatment (A2B3) with the addition of gelatin (12%) and egg white (10%), namely Moisture Content 59.44%, Aw Value 0.63, Color Test (a*) 11.63, Chewiness 61.78%, Antioxidant 30,45% and organoleptic values which include Color 5.40, Aroma 4.44, Taste 4.76, Texture 4.28 producing marshmallow siwalan and red dragon fruit skin with the best quality and best panelist acceptance.

Contribution to Sustainable Development Goals (SDGs):
SDG 2: Zero Hunger
SDG 3: Good Health and Well-being
SDG 9: Industry, Inovation, and Infrastructure

1. INTRODUCTION

1.1. *Research Background*

Borassus flabellifer L., commonly known as siwalan and classified under the Arecaceae family, is widely distributed across Southeast Asia. It is recognized for its potential applications in food, health, and industrial sectors due to its rich nutritional profile. Per 100 grams of edible pulp, siwalan contains approximately 0.35 g of protein, 0.54 g of minerals, 13.25 g of vitamin C, 3.9 g of vitamin B1, 0.14 g of phosphorus, and 0.4 g of iron [1]. Moreover, the fruit is abundant in bioactive compounds such as polyphenols, carotenoids, and flavonoids, which are associated with anti-inflammatory properties, immune enhancement, and cardiovascular protection [2].

Marshmallow is a sugar-based aerated confection characterized by its soft, elastic texture. It is typically formulated using sucrose, glucose syrup, gelatin, and foaming agents. The product is produced by whipping the mixture at high speed to incorporate air, forming a stable foam matrix. Multiple parameters, including precise temperature control during sugar heating, whipping time, and the roles of hydrocolloids influence the overall quality of the marshmallow. In addition, water activity (aw), pH, and color properties significantly affect product stability and consumer acceptability [3]–[5].

Gelatin and egg white serve as functional ingredients essential to marshmallow structure development. Gelatin, acting as a gelling agent, forms a three-dimensional gel network by binding water molecules, thereby contributing to the product's elasticity and chewiness. Meanwhile, egg white is a foaming agent that reduces surface tension and stabilizes air bubbles during whipping. Synergistic use of both components enhances foam stability and structural integrity [6], [7]. Optimization of gelatin concentration is critical, as deviations can alter textural properties. Overuse may result in excessive hardness, whereas insufficient gelatin can yield a product that lacks structural cohesiveness [8], [9]. Given its multifaceted roles as a stabilizer, emulsifier, and texture modifier, gelatin remains a key hydrocolloid in confectionery formulations.

Red dragon fruit (Hylocereus polyrhizus) peel extract presents a viable natural colorant alternative due to its high anthocyanin content, reported at 38.33 mg/100 g [10]. Anthocyanins impart a vibrant red hue while offering antioxidative benefits, aligning with current industry trends toward clean-label and functional food development. Their application in marshmallow production enhances aesthetic appeal and contributes additional health-promoting properties [11].

1.2. Literature Review

Marshmallow is a type of soft candy classified as a confectionery product, with unique characteristics of a smooth, light, and chewy foamy texture. It is produced from a mixture of sucrose, glucose, egg white, gelatin, and flavor, giving it a sweet taste and acting as a binding agent. Its sugar content makes it a natural sweetener, while gelatin is important in providing an elastic structure through its ability to melt when heated and re-gel when cooled. Marshmallows are available in various shapes, aromas, flavors, and colors, making them versatile and attractive product in the food industry [12].

According to Ref. [3], marshmallow is a type of confectionery made from hydrocolloid components such as carrageenan and gelatin, characterized by a soft, chewy, light, and foam-like texture, with the ability to maintain shape and stability during storage and distribution, making it suitable for use in various food applications, including cake decoration and other innovative products.

Gelatin functions as a gelling agent that can bind water, form a foam structure, and increase the elasticity of marshmallows. According to Ann et al. [13], gelatin can stabilize the foam formed by increasing viscosity, lowering the surface tension between air and liquid, and preventing sugar crystallization resulting in a soft texture. The combination of sucrose and glucose syrup affects the texture and chewiness of marshmallows.

Glucose syrup inhibits sugar crystallisation, increases viscosity, and produces a chewy texture and preferred sweetness. According to Boland, Delahunty, and van Ruth [14], adding sucrose also affects the hardness of candy. High sugar content can cause the gel to become hard and decrease the texture of the marshmallow. The role of egg white as an additional ingredient in making marshmallows, functions as an emulsifying and foaming agent. Egg white contains albumin protein, which can form a stable froth structure during shaking. According to Ref. [15], egg white improves froth stability because it can create an elastic thin protein film around air bubbles, keeping the structure stable when cooled. The siwalan tree, also known as the siwalan tree (Borassus flabellifer), is a type of palm (like areca nut) that grows in Southeast Asia and South Asia [1].

The siwalan fruit grows in clusters, with about 20 grains per cluster. Each grain contains 3–7 seeds of brownish flesh, covered by a thick and hard shell [16]. Siwalan fruit contains functional compounds in natural pigments, namely carotenoids, which also function as a source of natural antioxidants. According to research by Ref. [17], the carotenoid amount in siwalan fruit reached 8324.63 µg/100 mg, with β-carotene content of 6217.48 µg/100 mg. In addition, siwalan fruit is also rich in dietary fiber. The soft physical structure of siwalan fruit, its fragrant aroma, and its natural orange color make it very potential to be developed as a functional food beneficial for health.

Red dragon fruit peels, often considered organic waste, actually contain very useful bioactive compounds, one of which is betasianin. Betasianin is a type of powerful antioxidant that plays an essential role in counteracting free radicals in the body.

This compound provides health benefits and contributes to the distinctive red-purplish color pigment in red dragon fruit [18]. Apart from betasianin, red dragon fruit skin also contains other compounds that are no less important, namely anthocyanins. Anthocyanins, which belong to the flavonoid group, are natural pigments that can be used as natural dyes to replace synthetic dyes [19].

Fig. 1. Raw material siwalan and red dragon fruit peel

1.3. Research Objective

The purpose of this study was to provide information to the public regarding the utilization of siwalan fruit in the method of making marshmallows of siwalan fruit and dragon fruit extract. And create food innovation by adding nutritional and economic value to the utilization of siwalan fruit and dragon fruit extract.

2. MATERIALS AND METHODS

2.1. Material and tools

The materials used in this study include siwalan fruit obtained from Edu Wisata Siwalan Sewu, red dragon fruit obtained at Manukan Market Surabaya, and Green Valley brand bovine gelatin which is halal certified by MUI. Other ingredients used were water (Aqua), sucrose, fructose syrup, cornstarch (maizena), and citric acid obtained from Arvian Margerjo Surabaya Store. For analysis, the materials used included 0.01N methanol solution, 1% amylum solution, distilled water, as well as various chemical reagents namely Diphenyl picrylhydrazyl, Nelson A reagent, Nelson B, Arsenomolybdat, and glucose.

The tools used in this study consisted of processing equipment and analysis equipment. Processing equipment includes a mixer, stove, mortar, measuring cup, digital scale, container/basin, mold, baking pan, spoon, and stirrer. Meanwhile, the analytical equipment used includes tools for chemical analysis, namely spectrophotometer, desiccator, oven, water bath, texture analyzer, color reader, 50 ml burette, stative, volumetric flask, 250 ml erlenmeyer, 250 ml beaker glass, digital scale, analytical balance, drop pipette, micron pipette, volumetric pipette, test tube, stirring rod, measuring cup, filter paper, watch glass, weighing bottle, porcelain chair, funnel, and knife.

Table 1. The treatment combination of marshmallow

Gelatine (%)	Egg White (%)		
	B1	B2	B3
A1	A1B1	A1B2	A1B3
A2	A2B1	A2B2	A2B3
A3	A3B1	A3B2	A3B3

Description :
A1B1 = 10% gelatin addition and 6% egg white addition
A1B2 = 10% gelatin addition and 8% egg white addition
A1B3 = 10% gelatin addition and 10% egg white addition
A2B1 = 12% gelatin addition and 6% egg white addition
A2B2 = 12% gelatin addition and 8% egg white addition
A2B3 = 12% gelatin addition and 10% egg white addition
A3B1 = 14% gelatin addition and 6% egg white addition
A3B2 = 14% gelatin addition and 8% egg white addition
A3B3 = 14% gelatin addition and 10% egg white addition

The data obtained were processed using Analysis of Variance (ANOVA) and continued with Duncan's Multiple Range Test (DMRT) to determine the differences between treatments. The results of all tests were analyzed using the De Garmo method to determine the product with the best treatment results.

2.1.1. Making of marshmallow

The preparation process began by weighing all required ingredients, including gelatin (10%, 12%, and 14% b/v), egg white (6%, 8%, and 10% b/v), 25 mL of siwalan fruit extract, 5 mL of red dragon fruit peel extract, 25 g of sucrose, and 15 mL of fructose syrup. A sugar solution was prepared by mixing sucrose, fructose syrup, and water in appropriate proportions, followed by heating at approximately 80°C for 10 minutes until fully dissolved. The gelatin solution was prepared by adding 15 mL of hot water at 75°C to the gelatin, then allowing it to sit for 5 minutes to ensure complete hydration. Foam formation was achieved by whipping the egg whites at high speed using a mixer for approximately 10 minutes until a stable, soft, and fine foam was formed. All components, including the siwalan extract, dragon fruit peel extract, gelatin solution, sugar solution, and whipped egg whites, were combined in a mixer and homogenized for about 15 minutes to obtain a uniform mixture without clumps or imbalance. The resulting aerated mixture was poured into a mold lined with cornstarch to prevent sticking and facilitate removal. The aging process was carried out at 5°C for 8 hours to achieve the desired chewy and firm marshmallow texture. After aging, the marshmallow was cut into cubes measuring 3 × 3 × 3 cm.

2.2. Research Analysis

2.2.1. Raw Material Evaluation

The raw material analyzed was siwalan fruit. The analysis included moisture content, reduction sugar, and antioxidant.

2.2.2. Physicochemical evaluation of marshmallow

The final product underwent several analyses, including moisture content, color measurement, water activity (Aw), and texture profiling (chewiness) to evaluate its physical quality.

2.2.3. Evaluation sensory of marshmallow

Organoleptic evaluation was also conducted to assess sensory attributes such as color, taste, aroma, and texture.

3. RESULT AND DISCUSSION

3.1. Raw material characteristic

In this study, an analysis of raw materials was carried out on siwalan fruit. The results of the raw material analysis can be seen in Table 2.

Table 2. Chemical analysis of siwalan fruit

Analysis	**Result**	
	Analysis	**Literature**
Moisture Content (%)	95.52 ± 0.086	93.75%
Reduction Suagar (%)	0.97 ± 0.014	1.49%
Antioxidant (%)	38.32 ± 1.759	38.42%

The statistical analysis results (Table 2) show that the water content of siwalan extract is 95.52%, while according to Rosyida and Sulandri [20], the water content in siwalan fruit is 93.75%. This slight difference in analysis results with the literature is due to differences in fruit maturity and storage levels. The level of fruit maturity will affect the moisture content of a material; the higher the level of fruit maturity, the higher the moisture content.

This follows Sutrisno et al. [21], who stated that the water content will increase with increasing fruit maturity due to the fruit respiration reaction, where the final result is water. Table 2 also shows the reducing sugar value of siwalan fruit extract at 0.97%. According to the literature from James Ngginak [22], the reducing sugar content in siwalan fruit extract is around 1.49%. This difference is due to the different maturity levels of the fruit. Tampubolon et al. [23] stated that sugar content will increase as the fruit gets riper, making it taste sweeter. Factors in reducing sugar formation can depend on the temperature, time, and physiological maturity of agricultural products.

Different maturity levels cause differences in physicochemical properties, especially reducing sugars [21]. Based on Table 2, the antioxidant inhibition value of siwalan fruit is 38.32%. This result follows the literature from Sarofa et al. [6], which states that the antioxidant value of siwalan fruit extract is 38.42%. This similarity may be because the maturity level of siwalan fruit used in this study is nearly the same as in the literature. The higher the level of maturity, the more it affects the physical and chemical changes in the fruit [24].

3.2. Physicochemical characteristic of marshmallow

3.2.1. Moisture content

Based on the analysis of variance (Table 3), a significant interaction ($p \leq 0.05$) was observed between the treatments of gelatin and egg white addition. Each treatment showed a significant effect on the moisture content of the marshmallow. The average moisture content of the siwalan and red dragon fruit peel marshmallows ranged from 54.92% to 60.60%. The lowest moisture content was recorded in the treatment with 10% gelatin and 6% egg white (54.92%), while the highest moisture content was found in the treatment with 14% gelatin and 10% egg white (60.60%). The increase in moisture content was influenced by the higher levels of gelatin and egg white incorporated into the

https://doi.org/10.29165/ajarcde.v9i2.678

formulation. This finding is consistent with Sarofa et al. [6], who stated that gelatin readily absorbs and binds water by forming a stable matrix during gel formation, which helps retain water within its structure. Furthermore, Nisa [25] reported that increasing gelatin concentration leads to an increase in moisture content.

Table 3. Physicochemical characteristics of marshmallow

Samples	Moisture Content (%)	WHC (%)	Colour (a*)	Chewiness (%)
A1B1	54.92 ± 0.283	0.99 ± 0.001	7.58 ± 0.389	56.67 ± 0.462
A1B2	56.24 ± 0.035	0.93± 0.005	8.52 ± 0.332	57.92 ± 0.090
A1B3	58.26 ± 0.099	0.85± 0.006	9.42 ± 0.332	58.95 ± 0.030
A2B1	56.60 ± 0.007	0.79± 0.004	10.20 ± 0.247	59.54 ± 0.122
A2B2	58.00 ± 0.064	0.70± 0.013	10.98 ± 0.240	60.35 ± 0.244
A2B3	59.44. ± 0.297	0.63 ± 0.007	11.68 ± 0.255	61.78 ± 0.072
A3B1	58.49. ± 0.417	0.50. ± 0.018	12.45 ± 0.318	63.97 ± 0.079
A3B2	59.21 ± 0.177	0.47 ± 0.009	13.25 ± 0.240	66.09 ± 0.088
A3B3	60.60 ± 0.078	0.41±0.011	14.03 ± 0.247	69.13 ± 0.028

3.2.2. Water Holding Capacity

The analysis of water activity (Aw) (Table 3) revealed a significant interaction ($p \leq 0.05$) between the addition of gelatin and egg white on the Aw values of marshmallows made from siwalan fruit and red dragon fruit peel. Each treatment significantly affected the Aw of the marshmallows. The average Aw values (Table 3) ranged from 0.41 to 0.98. The lowest Aw was observed in the sample containing 14% gelatin and 10% egg white (0.41), while the highest Aw was found in the sample with 10% gelatin and 6% egg white (0.98). Increasing the concentration of gelatin and egg white led to a decrease in Aw values. This trend aligns with the findings of Karim and Bhat [26], who stated that gelatin forms a three-dimensional network that traps water molecules, converting free water into bound water and thereby significantly reducing water activity in gel-based products. Additionally, Novitasari et al. [27] reported that higher concentrations of gelatin reduce the amount of free water, leading to a lower Aw value. It is important to note that Aw is inversely related to moisture content—lower Aw values are typically associated with higher total moisture content.

3.2.3. Colour Measurement (a)*

Color analysis using a color reader revealed a significant difference ($p \leq 0.05$) between gelatin and egg white addition treatments. The color measurement was based on the a value, where higher a values indicate a redder color. The average values of the siwalan and red dragon fruit peel marshmallows ranged from 7.58 to 14.03. The lowest color intensity was observed in the sample with 10% gelatin and 6% egg white (7.58), while the highest was found in the sample with 14% gelatin and 10% egg white (14.03). The addition of red dragon fruit peel extract as a natural colorant significantly influenced the redness of the marshmallow products. This result is consistent with the findings of Ismanto et al. [28], who reported that incorporating red dragon fruit peel extract in chicken sausage enhanced the red color intensity of the product. The presence of red dragon fruit peel extract (Hylocereus polyrhizus) in marshmallow production plays a significant role in determining the final product's color characteristics due to its high content of betacyanin, a natural pigment responsible for the red to purple coloration in red dragon fruit.

3.2.4. Chewiness

The chewiness test (Table 3) showed a significant interaction ($p \leq 0.05$) between the addition of gelatin and egg white on the texture of siwalan and red dragon fruit peel marshmallows. Each treatment significantly influenced the chewiness parameter, which reflects the product's elasticity and resistance during mastication. In this study, increasing the concentrations of both gelatin and egg white positively affected the chewiness of the marshmallows. The average chewiness values (Table 3) ranged from 56.67% to 69.13%, with the lowest chewiness observed in the sample containing 10% gelatin and 6% egg white (56.67%), and the highest in the sample with 14% gelatin and 10% egg white (69.13%). The sample with 14% gelatin yielded the most optimal chewiness, aligning with the findings of Sarofa et al. [29], who reported that increasing gelatin concentrations up to 12% improved marshmallow texture by enhancing its elasticity and chewiness. This result is also supported by Sudaryati et al. [30], who found that the combination of gelatin and egg white increased moisture content and contributed to the formation of a stable three-dimensional gel matrix, thereby improving the textural properties of marshmallow.

3.3. Sensory characteristic

In this sensory evaluation, the tested product was marshmallow made with siwalan fruit and red dragon fruit peel, treated with two factors: Factor 1 was the addition of gelatin (10%, 12%, and 14%), and Factor 2 was the addition of egg white (6%, 8%, and 10%). These combinations resulted in nine treatment formulations, each expected to produce marshmallows with distinct sensory characteristics. The samples were evaluated using a hedonic test based on a 7-point preference scale (1 = dislike very much, 2 = dislike, 3 = slightly dislike, 4 = neutral, 5 = slightly like, 6 = like, 7 = like very much). A total of 25 semi-trained panelists participated in the sensory assessment. The essential components of the organoleptic test included the availability of product samples, the participation of panelists, and the requirement for honest responses to ensure reliable data collection (Table 4).

3.3.1. Color

The color analysis revealed a significant difference ($p \leq 0.05$) between the treatments involving gelatin and egg white additions. The hedonic evaluation of siwalan and red dragon fruit peel marshmallows, which included variations in gelatin and egg white concentrations, produced scores ranging from 3.88 to 5.56, indicating relatively consistent levels of panelist preference. The highest color score of 5.56 ("like") was obtained from the treatment with 12% gelatin and 8% egg white. This result is attributed to a more uniform color fading effect, which yielded a pink hue that was generally well-accepted by the panelists. The color fading occurred due to the whitening effect of gelatin and egg white, both of which are naturally white substances that dilute the original reddish-purple color of the red dragon fruit extract into a lighter pink tone. The red coloration originates from the red dragon fruit peel containing anthocyanins. Anthocyanins, classified as flavonoids, are natural pigments with potential as natural colorants to replace synthetic dyes [19].

Table 4. Organoleptic result of marshmallow

Samples	Colour	Aroma	Taste	Texture
A1B1	3.88	3.96	3.72	3.28
A1B2	4.84	4.08	4.44	3.80
A1B3	3.96	4.04	4.24	3.80
A2B1	4.88	3.96	4.52	3.88
A2B2	5.56	4.36	5.16	4.60
A2B3	5.40	4.44	4.76	4.28
A3B1	4.48	4.20	4.64	4.68
A3B2	4.76	4.12	4.52	4.68
A3B3	4.40	4.52	4.36	4.36

3.3.2. Aroma

The results of the organoleptic test showed that the addition of gelatin and egg white had no significant effect ($p \geq 0.05$) on the aroma preference of the marshmallow. The aroma scores ranged from 3.96 to 4.52 on the hedonic scale, with the highest preference observed in the sample containing 14% gelatin and 10% egg white, which received a score of 4.52. According to Lawless and Heymann [31], texture can indirectly influence aroma perception. Gelatin contributes to increased chewiness or viscosity, which can trap aroma compounds and release them more slowly during mastication, enhancing the sensory experience of aroma. As gelatin concentration increases, its ability to retain volatile aroma compounds also increases, resulting in a more gradual and consistent aroma release during chewing. This is supported by Ref. [32], who stated that aroma and flavor are interrelated, and a preferred texture—such as that provided by higher gelatin levels—can enhance the overall perception of aroma. For instance, if a chewy texture is liked, the aroma released in conjunction with that texture is more likely to be appreciated.

3.3.3. Taste

The taste analysis revealed a significant difference ($p \leq 0.05$) between treatments involving gelatin and egg white additions on the flavor preference of siwalan and red dragon fruit peel marshmallows. The panelists' average hedonic scores for taste ranged from 3.72 to 5.16. The lowest taste preference (3.72) was recorded in the sample with 10% gelatin and 6% egg white, which may be attributed to the lower gelatin concentration. With a lower gelatin content, the product's ability to retain and regulate the release of flavor compounds is reduced, causing the taste to dissipate quickly or lack intensity [33]. In contrast, the highest taste score (5.16) was found in the sample treated with 12% gelatin and 8% egg white. This suggests an optimal balance where gelatin concentration is sufficient to enhance texture while maintaining desirable flavor retention during mastication.

3.3.4. Texture

The texture analysis indicated a significant difference ($p \leq 0.05$) between the addition of gelatin and egg white on the texture preference of the marshmallow. Based on the sensory evaluation, the panelists' average scores for texture ranged from 3.28 to 4.68. The lowest texture score (3.28) was recorded in the treatment with 10% gelatin and 6% egg white, while the highest score (4.68) was found in the treatment with 14% gelatin and 8% egg white. The increased texture preference was observed to correlate with the increased levels of gelatin and egg white. Higher concentrations of these ingredients contributed to a firmer and more elastic marshmallow structure, which the panelists preferred. This finding is supported by Rahmi et al. [34], who stated that low gelatin concentrations result in a soft or even non-gelling structure, which is less preferred, whereas higher concentrations yield a more elastic gel that enhances panelist acceptance.

3.4. Characteristic of the Best Treatment (Antioxidant Activity)

Table 5 shows that the antioxidant activity of the best treatment in this study was 30.45%, while in the literature the antioxidant activity of the best treatment marshmallow was 35.52%. These results show that the antioxidant activity of siwalan fruit marshmallows and red dragon extract is not much different from the literature. In this study, the best treatment was obtained using the addition of 12% gelatin and 10% egg white, which is smaller than the literature that used 12% gelatin and 6% egg white. According to Ref. [35], there is a minimum threshold of antioxidant content in general that can be beneficial or effectively useful for the body. Less than 10% antioxidant content is considered low and thus has very limited effect on the body; 10–30% antioxidant content can begin to have a protective effect on body cells and tissues; more than 30% antioxidant content is considered biologically effective and potentially a functional antioxidant agent. In marshmallow siwalan and red dragon fruit skin, the antioxidant content of 30.45% indicates that this product can effectively serve as a natural antioxidant agent. This is also supported by Prior et al. [36], who state that antioxidant activity of 30% is already high and can ward off free radicals, prevent cell damage, provide protective effects against various chronic diseases, and is worth developing into functional food.

Table 5. Result of antioxidant best treatment sample

Analysis	**Gelatine (12%) and Egg White (10%)**	
	Antioxidant Activity	
	A2B3	**Literature**
Antioxidant Activity (%)	30,45 %	35,52%

4. CONCLUSION

The study revealed a significant interaction between the addition of gelatin and egg white on several parameters, including moisture content, ash content, water activity (Aw), texture, and organoleptic properties such as color, aroma, taste, and texture. However, no significant interaction was found for reducing sugar

https://doi.org/10.29165/ajarcde.v9i2.678

content in the marshmallow samples. The optimal formulation was achieved with 12% gelatin and 10% egg white, producing marshmallows with a moisture content of 59.44%, Aw value of 0.63, color measurement of 57.95, hardness of 59.19, and chewiness of 61.78%. Sensory evaluation results for this treatment showed favorable acceptance, with scores of 5.40 for color, 4.44 for aroma, 4.76 for taste, and 4.28 for texture. These findings indicate that this combination of gelatin and egg white yields marshmallows with desirable physical and sensory qualities.

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 https://doi.org/10.29165/ajarcde.v9i2.678