***Original Research Article***

**The Effect of Skim Milk Addition in**

**Marshmallow Characteristics**

**ABSTRACT**

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| **Aims:** A common issue in marshmallow production is the suboptimal softness or chewiness of the texture. The purpose of this study was to determine the effect of adding skim milk on organoleptic and physicochemical of marshmallow.  **Study design:** Using a Completely Randomized Design (CRD).  **Place and Duration of Study:** The research was done at the Laboratory of Animal Product Technology, Faculty of Animal Science, Universitas Brawijaya, Malang. The research was done in January to March 2024  **Methodology:** The method used in this study was a laboratory experiment consisting of 3 treatments and 4 replications, namely T0 (0% skim milk and 100% water), T1 (25% skim milk and 75% water), and T2 (50% skim milk and 50% water). The data obtained were analyzed using analysis of variance (ANOVA), then if there was a significant difference continued with Duncan's Multiple Range Test (DMRT).  **Results:** The addition of skim milk to marshmallow gave a very significant difference (P<0.01) in the organoleptic parameters of color, aroma, and taste, and in the physicochemical parameters of ash content and elasticity, gave a significant difference (P<0.05) in the parameters of texture and protein content, and did not provide a significant difference (P>0.05) in density, yield, reduction sugar, and texture. The average value of the organoleptic including color (3.31–4.13); aroma (2.52–3.23); taste (3,83–4,21); texture (3.13–3.48). The density (0.48–0.59 g/cm3); yield (75.57– 79.09%); protein concent (4.23–5.1%); ash content (0.018–0.193%); reduction sugar (0.433–0.553%); texture (2.15–5.98N); and elasticity (9.17–77.5%).  **Conclusion:** It can be concluded that the addition of skim milk to marshmallow candy affected various quality parameters. It is recommended that marshmallow production incorporates 50% skim milk addition. |

*Keywords*: *Gelatin; skim milk; marshmallow candy; organoleptic; physicochemical.*

1. **INTRODUCTION**

**Candy is one of the most popular processed food products, especially among children, due to its sweet taste, bright colors, and unique texture.** Candies are generally classified into four types: hard candy, soft candy, chewy (gum) candy, and sugar-free candy (BSN, 2008). One of the most popular types of soft candy is marshmallow. Marshmallows are known for their soft, chewy, light, and foamy texture, and are available in various flavors and colors.

Traditionally, marshmallows are made from a mixture of granulated sugar, glucose, water, flavorings, and gelatin. Gelatin plays a crucial role as a gelling agent and foam stabilizer. It can be obtained through partial hydrolysis of collagen from animal sources such as skin, meat, or bones, with bovine bones being one of the potential sources. Bovine bones, a byproduct of the livestock industry, are rich in collagen and can be processed into high-quality gelatin. Gelatin derived from bovine bones has a high protein content, reaching up to 76.76% (Sugita et al., 2021), and has been proven effective in forming stable gel formulations (Rauf et al., 2020).

A common issue in marshmallow production is the suboptimal softness or chewiness of the texture (Azharuddin, 2023). To address this, texture-enhancing additives such as skim milk can be incorporated. Skim milk is milk that has had most of its fat content removed (<1%) and is rich in protein 34,11%, fat content 1.33%, and mositure content 3.19%. It is typically obtained through fat separation processes such as centrifugation or filtration (Handayani et al., 2014), (Andriani et al., 2020).

Skim milk holds great potential as a food additive due to its functional properties in enhancing protein content, water binding capacity, textural development, and stabilization (Putri et al., 2018), (Umaroh and Handajani, 2018). The incorporation of skim milk in marshmallow production is expected to improve texture and elasticity, as well as increase the nutritional value, particularly protein and reducing sugar content. Moreover, studies have indicated that the combination of gelatin and skim milk influences various physical and chemical properties, such as density, yield, ash content, and organoleptic attributes (Adi et al., 2022), (Hakiki et al., 2022).

The addition of skim milkis important for improving the quality especially protein content on mashmalllow production. Milk protein also help improve texture resulting in softer and mote stabel marshmallow. In addition, skim milk supprots the production of marshmallow without compromising organoleptic quality. Based on this background, it is essential to conduct a study on the addition of skim milk at varying concentrations in marshmallow production to evaluate its effects on organoleptic quality and physicochemical characteristics, including density, yield, protein content, ash content, reducing sugar, texture, and elasticity.

1. **MATERIAL AND METHODS**
2. **Materials**

The study was conducted at the Laboratory of Animal Products Technology, Faculty of Animal Science, Universitas Brawijaya. Sample analyses were carried out at the Laboratory of Food Quality and Safety Testing, Faculty of Agricultural Technology, Universitas Brawijaya. The research was conducted from January to March 2024.

The materials used in this study included bovine bone gelatin brand "Hakiki" (30 ml), skim milk powder brand "NZMP" (according to the treatment), granulated sugar brand "Gulaku" (375 g), cornstarch brand "Maizenaku" (as much as needed), and water (150 ml and according to the treatment). The equipment used for marshmallow production included a digital scale, plastic box containers, parchment paper, saucepan, gas stove, knife, mixer, sieve, wooden spatula, ladle, spoon, thermometer, nonstick pan, 5 ml measuring cup, and 200 ml beaker glass.

1. **Methods**

This research employed an experimental method using a Completely Randomized Design (CRD), consisting of three treatments with four replications. The treatments were as follows: T0 : without skim milk and 100% water

T1 : adding 25% skim milk and 75% water

T2 : adding 50% skim milk and 50% water

1. **Research Procedure**

The marshmallow production method, modified from Zulfajri et al., (2018), was conducted as follows:

1. All tools and ingredients were prepared.
2. Cornstarch was dry-roasted and then cooled.
3. Containers were lined neatly with parchment paper, and 5 grams of the roasted cornstarch was placed in each lined container.
4. Granulated sugar, gelatin, and skim milk were weighed according to the formulation.
5. A mixture of 375 grams of sugar and 150 ml of water was heated in a nonstick pan until melted and boiling.
6. Water was heated to 70°C; once it reached that temperature, gelatin and skim milk were added according to the treatment (P0 = 0% skim milk and 100% water, P1 = 25% skim milk and 75% water, P2 = 50% skim milk and 50% water).
7. The resulting mixture was placed into a mixing bowl and whipped using a high-speed mixer for 5 minutes until the mixture expanded and became fluffy.
8. The marshmallow mixture was poured into the prepared containers lined with parchment paper and then sealed.
9. The mixture was allowed to set for 12 hours.
10. The resulting marshmallow samples were packed and subsequently subjected to organoleptic, density, yield, and protein content analyses.
11. **Variables**

The variables observed in this study included organoleptic quality and physicochemical characteristics. The tests conducted consisted of organoleptic evaluation using 30 untrained panelists (Padmawati et al., 2022), (Iswahyudi et al., 2023), (Putra et al., 2021), density measurement (Bintoro et al., 2024), yield (%) (Nugroho et al., 2018), protein content (%) (AOAC, 2005), ash content (AOAC, 2005), reducing sugar content (Al-kayyis, 2016), texture (Devi et al., 2018), and elasticity (Devi et al., 2018).

1. **Statistical Analysis**

The collected data were analyzed using Analysis of Variance (ANOVA). Data on density, yield, protein content, ash content, reducing sugar, texture, and elasticity were analyzed using a Completely Randomized Design (CRD), while organoleptic parameters were analyzed using a Randomized Block Design (RBD). If significant differences were found, the analysis was followed by Duncan’s Multiple Range Test (DMRT) for post hoc comparison.

1. **RESULTS AND DISCUSSION**
2. **Organoleptic**

**Table 1. Average organoleptic test results for marshmallow with the addition of skim milk**

|  |  |  |  |
| --- | --- | --- | --- |
| **Organoleptic Test** | **Treatment** | | |
| **T0 ± SD** | **T1 ± SD** | **T2 ± SD** |
| Color | 4,13 ± 0,15b | 4,02 ± 0,04b | 3,31 ± 0,49a |
| Aroma | 2,52 ± 0,10a | 2,59 ± 0,11a | 3,23 ± 0,40b |
| Texture | 3,13 ± 1,00a | 3,48 ± 0,33b | 3,46 ± 0,57b |
| Taste | 3,83 ± 0,10a | 4,00 ± 0,21a | 4,21 ± 0,28a |

Notes:

1. Different superscripts in the columns for color, aroma, and taste indicate highly significant differences among treatments (P<0.01).
2. Different superscripts in the texture column indicate significant differences among treatments (P<0.05).

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| --- | --- |
| D:\red 9\red 9 hm\cameraa\IMG_20240124_115102.jpg  a) | D:\red 9\red 9 hm\cameraa\IMG_20240124_115312.jpg  b) |
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**Fig. 1. Marshmallow a) T0 (Treatment 0 as a control. 0 g skim milk),**

**b) T1 (7,5 g skim milk), and C (T2) (15 g skim milk )**

**3.1.1 Color**

The results of the analysis of variance showed that the addition of skim milk had a highly significant effect (P<0.01) on the organoleptic color of marshmallow candy, with average color scores ranging from 3.31 (slightly white) to 4.13 (white). The basic color of marshmallow candy is generally white (Padmawati et al., 2022).

Based on Table 1, the organoleptic color score of marshmallow candy decreased with increasing percentages of skim milk. This indicates that the higher the proportion of skim milk added, the less intense the white color of the marshmallow becomes. This can be attributed to the fact that the color of skim milk powder is off-white (Umaroh and Handajani, 2018). The off-white color of skim milk results from the absence of carotene and riboflavin, which are normally present in milk fat, and the fat content in skim milk is relatively low. The lowfat content in skim milk causes food products to appear slightly yellowish-white in color (Pamela et al., 2022).

**3.1.2 Aroma**

The analysis of variance also revealed that the addition of skim milk had a highly significant effect (P<0.01) on the aroma of marshmallow candy, with average aroma scores ranging from 2.52 (slightly strong) to 3.23 (moderately strong). Aroma is influenced by the scent of the raw materials used in the product formulation (Handayani et al., 2014).

The results showed that as the percentage of skim milk increased, the aroma of the marshmallow also became more pronounced. The addition of skim milk, which has a distinct dairy aroma, has been shown to alter the sensory profile of other products such as sweet corn yogurt (*Zea mays* L. *saccharata*), reducing the typical corn aroma and imparting a stronger milk-like scent (Diputra et al., 2016).

**3.1.3 Texture**

According to Table 1, the average texture scores of marshmallow candy ranged from 3.13 to 3.48 (slightly soft). Skim milk contributes to protein enrichment, which helps bind and form texture (Putri et al., 2018). As a binder, skim milk powder improves water-holding capacity and fat emulsification in food products, leading to gel formation and increased chewiness, as protein gel strength tends to increase with higher solid or protein concentrations (Sari et al., 2024).

Gelatin is a base ingredient in marshmallow that significantly contributes to texture and chewability (Jariyah et al., 2019). Specifically, gelatin aids in foam formation and stabilization during marshmallow production by increasing viscosity and reducing surface tension between air and sugar solution. This also helps prevent sugar crystallization, resulting in a softer texture (Cahyaningrum et al., 2021). Gel is formed through cross-linking of polymer chains, creating a continuous three-dimensional network capable of entrapping water, thus producing a firm and compact structure resistant to flow under pressure (Ardiansyah, 2021), leading to a marshmallow product that is aerated, soft, and elastic (Eddy and Editya, 2020).

The texture of marshmallow is influenced by the combination of ingredients used in its production (Sofyan et al., 2020). Water acts as a solvent for all components and contributes to textural formation. Marshmallows made using bovine gelatin have a soft texture characterized by a smooth surface, tenderness, and easy swallowability. This softness is attributed to the reversible nature of gelatin, which transitions from sol to gel through rapid air entrapment and absorption, leading to foam formation (Putra et al., 2014).

**3.1.4 Taste**

The variance analysis also showed that the addition of skim milk had a highly significant effect (P<0.01) on the taste of marshmallow candy, with average taste scores ranging from 3.83 to 4.21 (sweet). The sweet flavor in marshmallows is likely due to the presence of sugar and skim milk in the formulation (Sintasari et al., 2014). Skim milk and sucrose function primarily as sweetening agents. The sweetness in skim milk comes from lactose, while a slightly salty taste is derived from chloride content (Amen et al., 2020).

1. **Physicochemical**

**Table 2. Average physicochemical test results for marshmallow with the addition of skim milk**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Treatment** | | |
| **T0 ± SD** | **T1 ± SD** | **T2 ± SD** |
| Density (g/cm3) | 0,48 ± 0,09 | 0,59 ± 0,09 | 0,50 ± 0,10 |
| Yield (%) | 75,69 ± 8,26 | 79,09 ± 2,49 | 75,57 ± 5,81 |
| Protein Content (%) | 4,23 ± 0,13a | 4,49 ± 0,23ab | 5,10 ± 0,62b |
| Ash Content (%) | 0,018 ± 0,015a | 0,060 ± 0,027ab | 0,193 ± 0,026b |
| Reducing Sugar (%) | 0,433 ± 0,30 | 0,477 ± 0,16 | 0,553 ± 0,18 |
| Texture (N) | 5,98 ± 3,87 | 4,18 ± 0,83 | 2,15 ± 1,31 |
| Elasticity (%) | 54,17 ± 8,33b | 77,50 ± 5,69c | 9,17 ± 5,69a |

Notes:

1. Different superscripts in the ash content and elasticity column indicate highly significant differences among treatments (P<0.01).
2. Different superscripts in the protein content column indicate significant differences among treatments (P<0.05).
3. Different superscripts in the density, yield, reducing sugar, and texture column indicate no significant differences among treatments (P>0.05).

**3.2.1 Density**

The results of variance analysis in Table 2 indicate that the addition of skim milk to marshmallow candy had no significant effect (P>0.05) on density, with average values ranging from 0.48 to 0.59 g/cm³. A higher material mass results in a higher density, whereas a larger volume reduces the density of marshmallow candy (Zulfajri et al., 2018).

A lower density indicates a lighter marshmallow product, which is due to the greater amount of air trapped during the whipping process in marshmallow preparation (Zulfajri et al., 2018). Higher amounts of gelatin increase the product’s capacity to entrap air, making it lighter and yielding a lower density value (Bintoro et al., 2024).

**3.2.2 Yield**

The analysis of variance in Table 2 also shows that the addition of skim milk to marshmallow candy had no significant effect (P>0.05) on yield, with average yield values ranging from 75.69% to 79.09%. This result is likely due to inconsistent heating temperatures during cooking. Fluctuations in heating temperature can affect yield values (Pratiwi et al., 2020). Higher temperatures cause more water evaporation, reducing yield. Conversely, lower temperatures result in less water loss, yielding a higher final product weight (Abustang and Sushanti, 2022).

Yield is an important economic parameter (Firdaus et al., 2022). A higher yield indicates a greater economic value or material efficiency. Yield depends on both formulation and the solubility properties of the components (Dewatisari, 2020).

**3.2.3 Protein Content**

The analysis of variance showed that the addition of skim milk significantly affected (P<0.05) the protein content of marshmallow candy, with values ranging from 4.23% to 5.1%. Based on Table 2, protein content increased with higher percentages of skim milk. This is due to the use of “NZMP” branded skim milk, which contains 32.9% protein, 54.5% lactose, 7.9% minerals, 3.8% moisture, and 0.9% fat—contributing to the increased protein content in marshmallow candy. The higher the addition of skim milk in a product, the higher its protein content (Diputra et al., 2016). Skim milk enhances both protein and fat content, which help bind and form texture (Putri et al., 2018). According to SNI 01-2970-2006, skim milk powder must have a maximum moisture content of 5%, maximum fat of 1.5%, and minimum protein content of 30%. Skim milk typically contains 35–37% protein (Hakiki et al., 2022).

**3.2.4 Ash Content**

Variance analysis also revealed that the addition of skim milk had a highly significant effect (P<0.01) on the ash content of marshmallow candy, with values ranging from 0.018% to 0.193%. Previous studies reported ash content of banana peel marshmallows (Musa textilia) with variations of gelatin and egg whites ranging from 0.85% to 2.52% (Sarofa et al., 2019), and dragon fruit marshmallows between 0.25% and 0.37% (Zulfajri et al., 2018). The increase in ash content is due to the high mineral content of skim milk, including calcium, phosphorus, magnesium, and potassium (Kaombe et al., 2015), which directly contributes to the ash value of the product.

Ash content is also influenced by gelatin, derived from demineralized animal bones that naturally contain minerals such as phosphorus and calcium (Wandita and Rosida, 2023). In this study, the ash content of all treatments remained within the maximum limit of 3% for soft candy, as stated in SNI 3547.2-2008 (BSN, 2008). The high mineral content and dry matter (98%) of skim milk lead to a denser final product and, consequently, increased ash content in marshmallows.

**3.2.5 Reducing Sugar**

The results also showed that the addition of skim milk had no significant effect (P>0.05) on reducing sugar content in marshmallow candy, with values ranging from 0.433% to 0.553%. For comparison, reducing sugar content in marshmallows with chayote juice and butterfly pea extract ranged from 3.142% to 5.538% (Wandita and Rosida, 2023), while instant rice porridge with skim milk had reducing sugar values of 3.5–5.1% (Ni’mah et al., 2018). In marshmallow with skim milk, reducing sugars originate from lactose—a disaccharide composed of glucose and galactose. Higher concentrations of skim milk, as in treatment P2 (15 g skim milk), yielded the highest reducing sugar content of 0.533%.

Gelatin also contributes slightly to reducing sugars due to its carbohydrate content (approximately 14 g/100 g), consisting of glucose and galactose (Wijayanti et al., 2018). Sucrose, the main component of granulated sugar, is a non-reducing sugar that can hydrolyze into glucose and fructose, both reducing sugars. All treatments met the SNI 3547.2-2008 standard for soft candy, which sets a maximum reducing sugar limit at 20% (BSN, 2008). Reducing sugar is a critical parameter in marshmallow quality, as excessive levels can cause stickiness, poor setting, and reduced shelf life (Amir et al., 2017).

**3.2.6 Texture**

Analysis results indicated that the addition of skim milk had no significant effect (P>0.05) on marshmallow texture, with average force values ranging from 2.15 to 5.98 N**.** The texture tended to decrease (though not significantly) with increased skim milk concentration. In comparison, the texture of marshmallows containing gelatin and egg whites ranged from 1.3 to 3.6 N (Sarofa et al., 2019), while hard candy toffee with added skim milk yielded textures between 7.9 and 16.4 N at a skim milk concentration of 0.6% (Siswanto et al., 2021). The addition of skim milk softens the texture due to its protein components, such as casein and whey, which aid in stable foam formation and compact texture development (Trisnanigntyas et al., 2015).

The texture of marshmallow is strongly influenced by both formulation and processing. Proper heating of sugar to an optimal temperature (116°C) is necessary to dissolve sucrose evenly (Santoso et al., 2018). Thorough homogenization of water, gelatin, and skim milk is also crucial to prevent clumping and ensure uniform texture. The combination of granulated sugar, gelatin, and water plays a key role in achieving a firm and elastic structure, with gelatin acting as a stabilizer that forms gel layers to bind water molecules (Kirtil et al., 2017), (Jalasena and Anjani, 2016).

**3.2.7 Elasticity**

The variance analysis showed that the addition of skim milk had a highly significant effect (P<0.01) on the elasticity of marshmallow candy, with values ranging from 9.17% to 77.5%. Elasticity increased with initial skim milk addition but decreased at higher concentrations. Elasticity of marshmallow made from *Physalis* pulp and sweet orange juice ranged from 74.11% to 96.66% (Jariyah et al., 2019), while banana peel marshmallow showed elasticity between 13.34% and 30%, with optimal treatment using 12% gelatin and 5% egg whites (Sarofa et l., 2019). Gelatin acts as a stabilizer forming gels and providing foam stability, while its hydrocolloid nature imparts elasticity and chewiness (Pertiwi et al., 2018), (Cahyaningrum et al., 2021). Skim milk protein contributes to foam structure and enhances elasticity up to a certain point; however, excessive amounts can hinder gelatin’s function. Good marshmallow elasticity is necessary so that the marshmallow does not suffer significant damage when elastic deformation occurs (Nepovinnykha et al., 2018).

Water interaction with skim milk and gelatin plays a crucial role in marshmallow elasticity. In the control treatment (P0, no skim milk), all water interacted with gelatin, yielding an elasticity of 54.17%. In P1, with added skim milk, casein and whey proteins absorbed some water, helping gelatin form a stronger network and increasing elasticity to 77.5%. In contrast, in P2 (higher skim milk concentration), more water was absorbed by milk proteins, leaving insufficient water for optimal gelatin network formation, which reduced elasticity significantly to 9.17%. This shows the importance of optimizing skim milk levels to balance water interactions between gelatin and milk proteins. This is because gelatin can binding well with protein from skim milk, which allows marshmallows to withstand external pressure and return to their original shape once the pressure is removed (Eddy and Editya, 2020).

1. **CONCLUSION**

Based on the results of the study, it can be concluded that the addition of skim milk to marshmallow candy affected various quality parameters. The organoleptic evaluation showed average values for color ranging from 3.31 (slightly white) to 4.13 (white), aroma from 2.52 (moderately strong) to 3.23 (moderately strong), taste from 3.83 (sweet) to 4.21 (sweet), and texture from 3.13 (slightly soft) to 3.48 (slightly soft). In terms of physical and chemical properties, the density of the marshmallow ranged from 0.48 to 0.59 g/cm³, and the yield ranged from 75.57% to 79.09%. The protein content increased from 4.23% to 5.10%, while the ash content ranged from 0.018% to 0.193%. The reducing sugar content was between 0.433% and 0.533%, the instrumental texture ranged from 2.15 to 5.98 N, and elasticity values were observed between 9.17% and 77.50%. Based on these findings, it is recommended that marshmallow production incorporates 50% skim milk addition, as this concentration was shown to enhance overall quality, particularly by increasing protein and ash content in the final product.

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Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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