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The Effect of Corn Silk (*Zea Mays* L) Extract Variation in Making Marshmallows on Chemical and Organoleptic Properties

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A B S T R A C T

Marshmallows are soft, chewy candies characterized by their light, foamy texture. They are typically formulated with gelling agents such as gelatin, pectin, or starch and have a water content of 12-20%. Their composition primarily includes sucrose and liquid glucose, resulting in a mildly sweet taste. This study explores enhancing marshmallows' nutritional value by incorporating corn silk extract, an inexpensive and abundant corn by-product that is often underutilised. Corn silk is rich in antioxidants and possesses a subtle aroma and flavor, making it an ideal natural additive. This research aimed to evaluate the impact of corn silk extracts on the chemical and organoleptic properties of marshmallows and identify the selected formulation. Using a completely randomized design (CRD) was used with five concentrations of corn silk extracts (P1: 10%, P2: 20%, P3: 30%, P4: 40%, and P5: 50%) and four repetitions. The study analysed water content, ash content, sucrose content, pH, and organoleptic properties (colour, texture, and taste). Results indicated that adding corn silk extracts significantly affected all tested parameters ($P < 0.05$). The selected formulation was P1 (10% corn silk extracts). This formulation yielded marshmallows with a water at 16.18%, an ash at 0.91%, a sucrose content of 31.78%, and a pH at 6.80. Organoleptically, P1 marshmallows scored highly for color (6.32, very much like-very much like), texture (5.32, like-very much like), and taste (5.20, like-very much like). Corn silk extracts potential to enhance marshmallow characteristics and provide an innovative use for this agricultural byproduct.

Contribution to Sustainable Development Goals (SDGs):

SDG 6: Promotes the sustainable use of agricultural resources to reduce environmental pollution that affects water quality.

SDG 11: Supports sustainable communities through value-added utilization of agricultural by-products.

SDG 13: Helps reduce agricultural waste and supports climate-friendly food production.

SDG 15: Encourages sustainable land resource management through the utilization of corn silk waste.

1. INTRODUCTION

1.1. Research Background

Marshmallow is a type of candy characterized by its soft, lightweight, and chewy foam-like texture. Marshmallow candy is

a popular sugar-based confection enjoyed by people across demographic groups [1]. It is a soft confectionery product widely favoured by consumers, typically made from a mixture of gelatin, sugar, and various sweeteners [2]. It's a gelling agent-based confection, often made with gelatin or pectin, and has a water content of approximately 12% to 20%. Marshmallows come in



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various shapes, scents, tastes, and colors. Their distinct flavor, often described as not overly sweet, is attributed to a combination of sucrose and liquid glucose [3].

Research has explored expanding the value of marshmallow candy by adding natural ingredients such as corn silk. Corn silk is an abundant, inexpensive byproduct of corn cultivation that is currently underutilised by communities [4], [5], [6], [7]. However, [8] note that corn silk possesses a very uncharacteristic aroma, flavor, and aftertaste in sensory evaluations. Despite this, corn silk is rich in compounds with antioxidant properties, including phenolic acids, tannins, and ascorbic acid [9], [10]. It's also a good source of minerals such as Na, K, Fe, Zn, Mg, and Cu [11].

[12] demonstrated the utilization of corn silk in jelly candy production. Their findings indicated that adding corn silk extract at a 25% concentration (150 ml of corn silk extract within 263 g of total material) and 15-25g of gelatin resulted in jelly candy with a water content of 13%–18%, consistent with SNI standards. [13] reported the addition of corn silk extract to marshmallow candy at a concentration of 25% (40 ml of corn silk extract per 160 g total material). They also varied gelatin content from 4 g to 8 g. This resulted in marshmallows with an elastic texture and a brownish-white to slightly brown color. Building on this and considering the potential benefits of corn silk, our current study aimed to develop marshmallows with varying concentrations of corn silk extract (10%-50%). We sought to determine the best formulation based on sensory evaluation, ensuring it meets quality standards and consumer preferences.

In our process, the formed foam was poured into a mold and refrigerated at approximately 5°C for 8 hours. Subsequently, the marshmallows were cut into 2 x 2 cm pieces and coated with roasted cornstarch. Finally, the corn silk extract marshmallows were analyzed.

2. MATERIALS AND METHODS

2.1 Materials and Tools

This study used fresh super-sweet corn harvested approximately 85 days from Bandungan District, Semarang Regency, along with glucose syrup, edible gelatin, granulated sugar, and Rose Brand cornstarch. The equipment employed consisted of digital scales (SF-400), an analytical balance (Radwag AS 110.R2 plus), various glassware including Pyrex weighing bottles, porcelain cups, funnels, Erlenmeyer flasks, measuring cups, and reflux condensers, as well as volumetric flasks, boiling stones, furnaces, ovens, desiccators (As One 280K200), a Brookfield Texture Analyzer CT3, pH meters, knives, pipettes, cutting boards, mold pans, mixers, bowls, basins, and refrigerators.

2.2 Experimental Design

This study used a Completely Randomised Design (CRD) with a single factor: varying concentrations of corn silk extract. The treatments were as follows:

P1: 10% corn silk extracts
P2: 20% corn silk extracts
P3: 30% corn silk extracts
P4: 40% corn silk extracts
P5: 50% corn silk extracts

Each treatment was repeated 4 times, and the data were analysed using the Duncan Multiple Range Test (DMRT) at the 5% significance level.

2.3 Research procedure

The marshmallow-making process starts with preparing corn silk extracts. This involves several key steps: sorting the corn silk to remove dirt and unwanted materials, weighing it according to the specified treatment for accuracy and consistency, washing it with running water to remove any remaining dirt, reducing the size to about ± 5 cm to increase surface area and process efficiency, brewing it with 400g of water at 50°C for 10 minutes to extract desired components, and finally filtering it with filter paper to produce a clean extract ready for marshmallow formulation.

Marshmallows were prepared by first mixing 50g of corn silk extract with 20g of gelatin until uniformly blended, followed by a 5-minute resting period. Concurrently, 45g of sugar and 15g of glucose syrup were cooked with 50g of corn silk extract at about 100 °C for 5 minutes, with continuous stirring. The resulting hot sugar-glucose syrup solution was then incorporated into the gelatin mixture. This combined solution was whipped using a mixer at medium speed for 5 minutes to create a foamy marshmallow batter. The foamed batter was poured into a mold and chilled in a refrigerator at approximately 5°C for 8 hours. Afterwards, the marshmallow was cut into 2 x 2 cm squares, dusted with roasted cornstarch, and analysed.

3. RESULT AND DISCUSSION

3.1 Water

Analysis of variance results showed that adding corn silk extracts significantly affected the water content of the produced marshmallows ($p < 0.05$). The average water content ranged from 16.18% to 16.52%. Table 1 presents the specific water content values for marshmallows with corn silk extracts.

Table 1. Water Content of Marshmallows

Treatment	Water content (%)
P1 (10%)	16.18 $\pm$ 0.05 ^a
P2 (20%)	16.33 $\pm$ 0.13 ^{ab}
P3 (30%)	16.38 $\pm$ 0.11 ^b
P4 (40%)	16.48 $\pm$ 0.19 ^b
P5 (50%)	16.52 $\pm$ 0.11 ^b

Note: Different superscripts within the same column indicate a significant difference at the 5% significance level ($p < 0.05$).

The water content of samples P1-P5 increased progressively with the addition of corn silk. This indicates a positive correlation: a higher proportion of corn silk in the marshmallow formulation leads to greater water content. This is due to corn silk's relatively high inherent water content and its hydrophilic properties, which facilitate water absorption and binding. According to [14] corn silk consists of fine, elongated fibrous strands with a porous internal matrix. This microstructure increases the available surface area for water interaction and facilitates capillary action [15] Water can penetrate and be retained within the fiber network, further reinforcing its hydrophilic nature [16].

Additionally, corn silk can interact with other marshmallow components, such as sugar and gelatin, forming a more complex

structure that helps retain water. Corn silk can interact synergistically with other marshmallow components to form a more complex, water-retentive network, enhancing moisture stability and texture. According to [17] corn silk is rich in polysaccharides and cellulose-based fibers containing numerous hydrophilic functional groups ($-\text{OH}$ and $-\text{COOH}$). These groups readily form hydrogen bonds with hydroxyl groups from sugars (such as sucrose or glucose) and with polar amino acid residues along gelatin chains.

[18] and [19] both reported that increasing the addition of corn silk leads to a higher water content, attributing this to corn silk's water-binding capacity. Specifically, a 10% increase in corn silk reportedly raises water absorption by 0.1 g.

Water content significantly impacts the shelf life and water activity of marshmallows. Corn silk enhances marshmallow structure by integrating with gelatin's protein network [20] and sugar's hygroscopic matrix, forming a composite system that efficiently binds and retains water. This interaction produces a more stable, elastic, and moisture-resistant confectionery structure, which is particularly beneficial for improving texture and shelf life.

Higher water content generally leads to a shorter shelf life [21]. Foods with high moisture content provide a favourable environment for the growth of microorganisms such as bacteria, yeasts, and moulds [22]. Water enables microbial metabolism, cell division, and enzyme activity, accelerating spoilage [23]. In addition, high moisture increases the rates of chemical reactions such as lipid oxidation, Maillard browning, and enzymatic degradation, all of which degrade product quality over time. However, the marshmallow water content in this study meets the maximum 20% requirement stipulated by SNI 3547-2-2008 for Jelly Candy Quality.

3.2 Ash

The addition of corn silk extracts significantly impacts ($p < 0.05$) the ash content of marshmallows, as revealed by variance analysis. Details of the marshmallow ash content with corn silk extract are provided in Table 2.

Table 2. Ash Content of Marshmallows

Treatment	Ash content (%)
P1 (10%)	0.91 ± 0.00^a
P2 (20%)	0.98 ± 0.02^b
P3 (30%)	0.98 ± 0.01^{bc}
P4 (40%)	0.99 ± 0.02^{bc}
P5 (50%)	1.00 ± 0.01^c

Note: Different superscripts within the same column indicate significant difference at the 5% significance level ($p < 0.05$).

The addition of corn silk to formulations P1-P5 resulted in a significant increase in the marshmallow's ash content. This outcome is attributed to the inherent mineral composition of corn silk, which includes potassium, magnesium, calcium, phosphorus, and iron. Ash content is a critical parameter for characterizing natural materials and processed products [24]. More specifically, the ash content can reflect the mineral absorption capacity of natural materials, such as corn silk, and the degree of impurity introduced during the manufacture of processed products (e.g., gelatin, glucose syrup, sucrose). Furthermore, it can indicate the successful fortification of products with minerals or other nutrients. Consequently, ash

content is instrumental in assessing product quality and safety, as well as in guiding the development of nutritionally optimized products.

An increase in corn silk addition leads to a corresponding increase in ash content, because corn silk is a natural source of inorganic minerals [25], [26]. According to some studies conducted by [27] and [28] corn silk contains essential minerals such as: potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu). As the level of corn silk in the marshmallow formulation increases, more of these minerals are incorporated into the product, resulting in a higher ash content. Therefore, the relationship between corn silk addition and ash content is directly proportional, indicating enhanced mineral contribution and successful mineral fortification of the marshmallow product. The studies reported corn silk ash content ranging from 3.74% [29] to 5.69% [30]. The marshmallow's ash content in this study still met the SNI 3547-2-2008 Jelly Candy Quality Requirements, with a maximum of 3%.

3.3 Sucrose

Analysis of variance results indicate that adding corn silk extract significantly affects ($p < 0.05$) the sucrose content of the produced marshmallows. The average sucrose content of these marshmallows ranges from 27.28% to 31.78%. Table 3 presents the sucrose content of marshmallows with corn silk extract.

Table 3. Sucrose Content of Marshmallows

Treatment	Sucrose (%)
P1 (10%)	31.78 ± 0.09^d
P2 (20%)	32.10 ± 0.73^d
P3 (30%)	30.93 ± 0.36^c
P4 (40%)	29.11 ± 0.34^b
P5 (50%)	27.28 ± 0.18^a

Note: Different superscripts within the same column indicate significant difference at the 5% significance level ($p < 0.05$).

It is known that the sucrose content decreased gradually from P1 to P5. Corn silk primarily contains monosaccharides such as glucose and fructose rather than significant amounts of sucrose, which explains the relatively low sucrose levels observed [29], [31]. These sugars are often strongly bound to other compounds, such as saponin-type flavonoids. As the level of corn silk increases, the proportion of non-sucrose sugars in the formulation increases, diluting the relative sucrose content in the final product. Moreover, reducing sugars in corn silk are thermally unstable. During marshmallow processing, according to [32], [33], [34], [35], heating can break the chemical bonds between sugars and their associated compounds, promoting degradation or caramelisation reactions. As a result, part of the sugar is no longer present or detected as sucrose during analysis. Therefore, increasing the addition of corn silk results in a relative dilution of sucrose, dominance of non-sucrose sugars, and thermal degradation, collectively explaining the observed decrease in sucrose content. Despite this, the sucrose content of the marshmallows in this study met the Quality Requirements for Jelly Candy SNI 3547-2-2008, which mandates a minimum sucrose content of 27%.

3.4 pH

Based on the results of the analysis of variance, show that the addition of corn silk extracts has a significant effect ($p < 0.05$) on the pH of the marshmallow produced. The average pH of marshmallows ranges from 5.53 to 6.80. The pH of marshmallows with the addition of corn silk extract can be seen in Table 4.

It is known that increasing corn silk extract in a mixture leads to a lower pH. The decrease in pH with increasing addition of corn silk extract can be explained by the chemical composition of the extract. According to [36], [37], [38], [39], [40], [41] corn silk extract contains various organic acids, phenolic compounds, and other acidic constituents that contribute hydrogen ions (H^+) when dissolved in the mixture. As the concentration of the extract increases, the total amount of these acidic components also rises, leading to a higher release of hydrogen ions and, consequently, a lower pH value. In addition, bioactive compounds in the extract may interact with other ingredients in the system, influencing buffering capacity and promoting reactions that further shift the equilibrium toward a more acidic environment. Therefore, a greater proportion of corn silk extract results in a progressive reduction in pH. Additionally, the sugar caramelization process also contributes to the decrease in marshmallow pH [42].

Table 4. pH of Marshmallows

Treatment	pH
P1 (10%)	6.80 ± 0.02^d
P2 (20%)	6.78 ± 0.15^d
P3 (30%)	6.41 ± 0.07^c
P4 (40%)	6.17 ± 0.07^b
P5 (50%)	5.53 ± 0.04^a

Note: Different superscripts within the same column indicate significant difference at the 5% significance level ($p < 0.05$).

The sugar caramelization process at high temperatures simultaneously involves breakdown and dehydration, which subsequently leads to polymerization and the formation of various acids. [40] classify amino acids, fatty acids, and phenolic compounds as organic acids that lower the pH of corn silk. Examples of amino acids include phenylalanine, leucine, isoleucine, and arginine, while fatty acids include oleic, linoleic, and palmitic acids.

3.5 Color Sensory

Based on the analysis of variance results presented in Appendix 5, it was found that the addition of corn silk extracts significantly affected ($p < 0.05$) the sensory color score of the marshmallows produced. The average marshmallow color scores ranged from 3.08 (dislike) to 6.32 (like very much). The specific color scores for marshmallows with corn silk extracts are detailed in Table 5.

Table 5. Color Sensory of Marshmallows

Treatment	Color Score	Description
P1 (10%)	6.32 ± 0.90^d	Really like–Very much like
P2 (20%)	5.28 ± 0.74^c	Like – like
P3 (30%)	4.36 ± 0.91^b	Somewhat like –Like
P4 (40%)	4.12 ± 1.33^b	Somewhat like –Like
P5 (50%)	3.08 ± 1.68^a	Dislike–Somewhat like

Note: Different superscripts within the same column indicate a significant difference at the 5% significance level ($p < 0.05$).

The color score of the marshmallow with corn silk extracts gradually decreased from P1 to P5, indicating that a higher concentration of corn silk extract negatively impacts the marshmallow's sensory color. The marshmallow's color is influenced by both the cooking process and the raw materials. Specifically, sucrose and glucose syrup turn brownish-white when treated at high temperatures, while corn silk itself contributes a brownish hue due to the Maillard reaction. When its concentration increases, more amino groups ($-NH_2$) are available to react with reducing sugars (from glucose syrup or hydrolyzed sucrose). A higher number of Maillard reactions results in greater formation of melanoidins, the brown-colored end products [43], [44]. It is known that P1 has the highest color score. This indicates that P1 is the marshmallow that best meets the panelists' preferences. The high score given by the panelists to P1 is likely due to its brighter color compared to other treatments. This is because P1 contains only a small amount of color pigment, resulting in a brighter marshmallow.

The low color score in P5 is likely attributed to the high concentration of corn silk extracts. Corn silk contains chlorophyll (63.7–69.5 $\mu\text{g}/100\text{ g}$), carotene (106.1–187 $\mu\text{g}/100\text{ g}$), beta-carotene (18.4–19.7 $\mu\text{g}/100\text{ g}$), and xanthophyll (86.8–133.84 $\mu\text{g}/100\text{ g}$) [45]. These pigments cause the marshmallows to appear dark brown, which is unfavorable to the panelists. According to [46] marshmallows are typically associated with a bright white color, making dark-colored marshmallows less recognizable to consumers.

3.6 Texture Sensory

Based on the analysis of variance results in Appendix 6, the addition of corn silk extract significantly affects ($p < 0.05$) the sensory texture score of the resulting marshmallows. The average marshmallow texture score ranges from 4.24 to 5.32, indicating a range of 'like' to 'like'. Specific texture scores with corn silk extracts are presented in Table 6.

According to Table 6, adding corn silk extracts decreases the marshmallow's texture score. This is because excessive corn silk fiber can make marshmallows harder and less chewy, whereas marshmallows should be soft, light, and very chewy. P1 has the highest texture score due to the minimal addition of corn silk extract, resulting in a low fiber content. P1 marshmallows exhibited the softest, lightest, and chewiest texture, most closely aligning with the panelists' preferences. Conversely, P5 received the lowest texture score. This is likely because P5 marshmallows lacked the familiar sensory characteristics of typical marshmallow texture, possibly due to the high dietary fibre content from corn silk. According to [47] corn silk is rich in dietary fiber. It can reduce chewiness because the fiber interferes

with the formation of a strong structural network in the product. The dietary fibre in corn silk has a high capacity to bind water, limiting the availability of water for interactions among gelatin, starch, or protein molecules that normally contribute to a chewy texture. Moreover, the presence of fibre particles disrupts the matrix's continuity and elasticity, resulting in a weaker network. Consequently, the product exhibits lower chewiness as the amount of corn silk increases.

Table 6. Texture Sensory of Marshmallows

Treatment	Texture Score	Description
P1 (10%)	5.32±1.31 ^d	Like - Very much like
P2 (20%)	5.00±1.26 ^c	Like – Like
P3 (30%)	4.52±1.12 ^b	Somewhat like – Like
P4 (40%)	4.32±0.85 ^{ab}	Somewhat like – Like
P5 (50%)	4.24±1.42 ^a	Somewhat like – Like

Note: Different superscripts within the same column indicate significant difference at the 5% significance level ($p < 0.05$).

Excessive corn silk extract can reduce marshmallow chewiness. Furthermore, [48], [49] found that higher concentrations of corn silk extract decreased product elasticity, which they attributed to acidic conditions affecting the thickener's effectiveness.

3.7 Taste Sensory

The addition of corn silk extracts significantly affected ($p < 0.05$) the sensory taste score of the marshmallows. The average marshmallow taste scores ranged from 3.44 to 5.20, indicating a preference from dislike to really like. Table 7 presents the marshmallow taste scores with the addition of corn silk extracts.

Table 7. Taste Sensory of Marshmallows

Treatment	Taste Score	Description
P1 (10%)	5.20±1.31 ^d	Like-like
P2 (20%)	4.84 ± 1.26 ^c	Somewhat like-like
P3 (30%)	4.68 ± 1.12 ^b	Somewhat like-like
P4 (40%)	4.20 ± 0.85 ^{ab}	Somewhat like-like
P5 (50%)	3.44 ± 1.42 ^a	Dislike–Somewhat like

Note: Different superscripts within the same column indicate a significant difference at the 5% significance level ($p < 0.05$).

The addition of corn silk extracts is known to decrease the marshmallow taste score. This is attributed to the volatile compounds and flavonoids present in corn silk. Volatile compounds impart distinct flavors (e.g., sweet, bitter, or spicy), while flavonoids specifically contribute a bitter taste to the marshmallows. The increase in bitterness with the addition of corn silk extract is mainly attributed to the presence of volatile compounds and flavonoids in corn silk. Flavonoids and other phenolic compounds are well known for their intrinsically bitter taste, which becomes more pronounced as their concentration increases. When a higher amount of corn silk extract is incorporated into marshmallows, these compounds are present at levels that exceed the masking capacity of sugars, causing the

bitter taste to be more easily perceived. In addition, certain volatile compounds in corn silk contribute distinct flavour notes, including bitter, herbal, or slightly spicy notes. As the extract concentration increases, these flavour compounds become more dominant, leading to a noticeable increase in bitterness in the marshmallows.

P1 achieved the highest taste score because its low corn silk extract content resulted in a low flavonoid compound concentration. This allowed P1 to retain a characteristic marshmallow sweetness, which aligned with the panelists' preferences. This finding is consistent with Rizky et al. (2020), who reported that food products with minimal corn silk addition tend to receive high taste scores. Furthermore, Setiawan (2020) explained that marshmallows are inherently sweet, and adding non-saccharide natural raw materials can diminish this sweetness, thus negatively impacting P5 had the lowest taste score, likely because the significant amount of added corn silk extract introduced numerous volatile and flavonoid compounds, resulting in a bitter-sweet taste uncharacteristic of marshmallows. Taste evaluations by panelists.

4. CONCLUSION

The concentration of corn silk extracts significantly affected the water, ash, sucrose content, pH, and organoleptic properties (color, texture, and taste) of marshmallows ($p < 0.05$). The selected treatment was P1, which used 10% corn silk extracts. Marshmallows from this treatment had a water at 16.18%, an ash at 0.91%, a sucrose content at 31.78%, and a pH at 6.80. The organoleptic scores for P1 were 6.32 for color (highly preferred), 5.32 for texture (preferred to highly preferred), and 5.20 for taste (preferred to highly preferred).

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