Quality Characteristics of Buffalo (*Bubalus bubalis*) Milk Candy as Affected by Different Ratios of Sucrose and Glucose Syrup as Humectant

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Abstract: *Background*: This research evaluates the effect of the different proportions of sucrose and glucose syrup (100:0, 85:15, 70:30, and 55:45) on the overall quality of buffalo milk candy. The objective was to identify the optimal ratio that enhances both its microbial stability and sensory appeal.

Methods: Buffalo milk candy was kept at room temperature, and samples were drawn for microbial testing, moisture, water activity (A_w), and sensory analysis.

Results: A visible mold growth was observed in 100:0 (Day 30), 85:15 (Day 40), and 70:30 (Day 52), and therefore, other analyses were discontinued. Moisture content and A_w of all the treatments were significantly different throughout the storage period. However, with the increase in glucose syrup, A_w decreases consistently with time, thus enhancing the product's safety and stability. On the other hand, sensory evaluation did not show significant differences across all parameters in all treatments during the storage period.

Conclusion: In conclusion, the addition of a higher proportion of glucose syrup, specifically 55:45, improved both the shelf-life and maintained the sensory quality of buffalo milk candy.

Keywords: Buffalo milk, sucrose, glucose syrup, humectant, milk candy.

INTRODUCTION

Buffalo milk, like any other milk source, is an excellent medium for microbial growth, making it highly perishable due to its high nutritional value. Various factors contribute to the deterioration of food quality, such as initial load of microorganisms, nutrient availability, pH, water activity (A_w), storage temperature, oxygen levels, and humidity [1]. Shelf-life is a critical aspect for consumers, affecting their purchasing behavior. Consumers often prioritize products with enhanced shelf life to minimize food waste and fewer market trips, and are mostly willing to pay a higher price [2].

One of the known sweet products in the Philippines is the milk-based sweets, one of which is *pastillas de leche*. However, these are perishable and need to be refrigerated. Candy products enjoy widespread popularity due to their innovative formulations and the diverse application of various ingredients [3]. Key factors influencing consumer acceptance include the shelf life and sensory characteristics of these treats; therefore, manufacturers should consider these factors [4].

Moisture content indicates the amount of water present in a product, while A_w represents the amount of free water available for chemical reactions and microbial growth. Moisture content alone cannot determine product stability; relatively, controlling A_w is crucial for extending shelf life and is a more reliable predictor of microbial activity in food. The incorporation of food additives, specifically humectants, can significantly slow product deterioration [5]. Common humectants used in food processing are sucrose, fructose, lactose, mannitol, honey, sorbitol, and glycerol. Humectants bind moisture by forming hydrogen bonds present in the food and regulate A_w by lowering it to below 0.9, enhancing food stability while preserving texture and flavor [6]. Soft candies typically have a moisture content of 8-22% and an A_w between 0.50-0.75 [6, 7].

Sugars and sweeteners, particularly sucrose (table sugar) and glucose syrup (corn syrup), are key components of candy products. Sucrose is most commonly used as a sweetener in milk candies. While sucrose has a relative sweetness of 1.0, glucose syrup offers a more cost-effective alternative at a sweetness level of 0.3 [8]. Adjustments in ingredient levels can significantly alter the physical and sensory characteristics of products, including their color, flavor, and texture, which are critical for consumer acceptance [4].

Given that many buffalo milk products currently have short shelf lives, this research aims to develop

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buffalo milk-based candies with extended shelf life and optimal sensory qualities with the use of humectants, sucrose, and glucose syrup in different ratios.

MATERIALS AND METHODS

Ingredients

Fresh buffalo milk (5.54% fat, 4.09% protein, 4.21% lactose, 13.3% total solids, pH 6.69, specific gravity 1.032) was obtained from the Central Dairy Collecting and Processing Plant (CDCPF), Nueva Ecija, Philippines. Skimmed Milk Powder was procured from a supplier in Metro Manila, Philippines. Glucose syrup, sucrose (refined sugar), and vegetable oil were procured from the local market in Science City of Muñoz, Nueva Ecija, Philippines.

Processing of Milk Candies

In a pan, raw buffalo milk was heated at 60˚C, then glucose syrup was added and mixed until dissolved. After dissolving the glucose syrup, dry ingredients were added and mixed until lump-free. The ratio of sucrose and glucose syrup used in the study was 100:0 (as the control), 85:15, 70:30, and 55:45. The mixture was stirred over low to medium heat until the temperature reached 93-103˚C, then was allowed to cool. The temperature of the milk candy mixture ranged from 40 to 50 ˚C before molding. The mixture was then cut into 3.5 grams per piece, molded, and rounded manually. Afterward, each piece was wrapped with a glassine paper, and then twelve pieces of milk candies were packed and sealed in a stand-up pouch. The milk candies were then stored in a dry room at ambient temperature.

Microbiological Analysis

First, 10 g of the milk candy was added to 90 mL of buffered peptone water and then homogenized in a stomacher until completely dissolved. The subsequent serial dilutions (10^{-2} and 10^{-3}) were prepared by transferring 1 mL from the previous dilution into 9 mL buffered peptone water and mixing well. Samples were tested for Aerobic Plate Count (APC), Coliform Count (CC), Yeast and Molds Count (YMC) using a dry rehydratable film method on Days 0, 10, 20, 30, 40, 45, and 52 of the milk candies stored at room temperature. The incubation period and temperature were as follows: APC at 32 ± 1°C for 48 ± 3 hours, CC at 32 ± 1°C for 24 ± 2 hours, and YMC at 20-25°C for 5 days [9, 10]. The results were evaluated against the Food and Drug Administration (FDA) Circular No. 2022-012 for sugar confectionery.

Moisture Content and Water Activity (A_w)

The moisture content and A_w were analyzed on Days 0, 10, 20, 30, 40, 45, and 52 of the milk candies stored at room temperature. Milk candies were analyzed for moisture content using the oven-drying method. The sample (2-5g) was placed in a pre-dried aluminum dish and dried in an oven at 110°C for 6 hours. The dried sample was placed in a desiccator and cooled for 30 minutes to room temperature. The weight was recorded, and the percentage of moisture based on the initial wet weight was calculated [11]. A_w was measured at room temperature using the Aqualab PRE water activity meter. The sample was placed in the sample cup and immediately inserted into the water activity meter for measurement, thereby restricting moisture transfer from the air to the samples.

Sensory Evaluation

Acceptance testing was used to measure the magnitude of like or dislike for the final product [11]. The test was held in the sensory laboratory under ambient temperature (22±2˚C) in the Philippine Carabao Center National Headquarters and Gene Pool. 30 non-trained panelists evaluated samples of milk candies with a criterion of having no allergies to wheat, milk, or soy. All participants provided their written informed consent form before participating in the sensory sessions.

Each sample was presented with a three-digit code, and their order of presentation was randomized entirely for each panelist [11]. Sensory characteristics such as appearance, sweetness, creaminess, chewiness, mouthfeel/texture, and overall acceptability were evaluated based on a 9-point hedonic scale, where 9 = like extremely and 1 = dislike immensely. Sensory evaluation was conducted on Days 0, 10, 20, 30, 40, 45, and 52 of the milk candies stored at room temperature.

Product Yield and Formulation Cost

Yield was computed based on the cooked weight divided by the initial batch size multiplied by 100. The formulation cost was calculated based on the costs incurred in all products, specifically the materials used.

Statistical Analysis

Data were analyzed using Analysis of variance (ANOVA) in a completely randomized design (CRD). Significant differences in the treatments were compared using Fisher's Least Significant Difference test. All the data were analyzed using the Minitab Statistical Software® (version 19).

RESULTS

Microbiological Analysis

Milk candies were stored at a temperature range of 27-31℃ and a relative humidity of 45% - 55%. APC, CC, and YMC for 100:0, 85:15, 70:30, and 55:45 were within the standards of FDA 2022-012 for sugar confectionery until Day 20, 30, 45, and 52, respectively. However, visible mold growth was observed at 100:0 (Day 30), 85:15 (Day 40), and 70:30 (Day 52); thus, no APC and CC were conducted on that day and the succeeding storage periods.

Over time, 55:45 demonstrated better microbial stability, with APC remaining below 260 cfu/g throughout storage (Table **1**). Similarly, the higher glucose syrup ratios, particularly 55:45, demonstrate better microbial safety by consistently keeping coliform levels below detectable limits. However, the 100:0 formulation is more susceptible to fungal contamination, particularly at Day 30.

Moisture Content and Water Activity

In candy and sugar-based products, moisture plays a key role in providing insights into the water retention of the product, which ultimately affects texture, taste, and shelf-life. The moisture content and A_w readings were taken at various time intervals from Day 0 to Day 52.

Table 1: Microbiological Characteristics of Buffalo Milk Candy with Different Sucrose and Glucose Syrup Ratios during Storage

Item	Treatments			
	100:0	**85:15**	**70:30**	**55:45**
Aerobic Plate Count (cfu/g)				
Day 0	<250	<250	<250	<250
Day 10	<250	<250	<250	<250
Day 20	<250	<250	<250	<250
Day 30	-*	<250	<250	<250
Day 40	-	-	260	<250
Day 45	-	-	310	<250
Day 52	-	-	-	260
Coliform Count (cfu/g)				
Day 0	<10	<10	<10	<10
Day 10	<10	<10	<10	<10
Day 20	<10	<10	<10	<10
Day 30	-	<10	<10	<10
Day 40	-	-	<10	<10
Day 45	-	-	<10	<10
Day 52	-	-	-	<10
Yeast and Mold Count (cfu/g)				
Day 0	<10	<10	<10	<10
Day 10	<10	<10	<10	<10
Day 20	<10	<10	<10	<10
Day 30	-	<10	<10	<10
Day 40	-	-	<10	<10
Day 45	-	-	<10	<10
Day 52	-	-	-	<10

*"-" means no further microbiological testing was conducted due to a visible mold presence in the product.

Table 2: Moisture Content and Water Activity of Buffalo Milk Candy with Different Sucrose and Glucose Syrup Ratios during Storage

Item	Treatments			
	100:0	85:15	70:30	55:45
Moisture Content (%)				
Day 0	10.38 ± 0.102^{a*}	10.14 ± 0.144^{a}	9.94 ± 0.200^{a}	10.17 ± 0.169^{a}
Day 10	9.90 ± 0.204^{b}	9.55 ± 0.405^{b}	9.77 ± 0.027^{ab}	9.79 ± 0.245^{a}
Day 20	9.29 ± 0.144^{c}	9.12 ± 0.014^{c}	9.49 ± 0.166^{bc}	9.16 ± 0.160^{b}
Day 30	-**	9.04 ± 0.102^{c}	9.28 ± 0.232^{cd}	9.11 ± 0.361^{b}
Day 40	-	-	9.18 ± 0.165^{d}	9.12 ± 0.217^{b}
Day 45	-	-	8.87 ± 0.049^{e}	8.93 ± 0.225^{b}
Day 52	-	-	-	8.85 ± 0.146^{b}
Water Activity (A_w)				
Day 0	0.78 ± 0.005^{a}	0.75 ± 0.001^{a}	0.70 ± 0.001^{a}	0.68 ± 0.002^{a}
Day 10	0.76 ± 0.001^{b}	0.74 ± 0.001^{a}	0.69 ± 0.006^{ab}	0.67 ± 0.002^{b}
Day 20	0.76 ± 0.000^{c}	0.72 ± 0.006^{b}	0.68 ± 0.002^{abc}	0.67 ± 0.001^{b}
Day 30	-	0.75 ± 0.006^{c}	0.69 ± 0.005^{ab}	0.67 ± 0.001^{b}
Day 40	-	-	0.68 ± 0.005^{bc}	0.65 ± 0.006^{c}
Day 45	-	-	0.67 ± 0.014^{e}	0.65 ± 0.005^{d}
Day 52	-	-	-	0.64 ± 0.001^{d}

*Mean values ± standard deviation bearing different superscripts per column differ significantly ($p < 0.05$).
** "-"means no further microbiological testing was conducted due to a visible mold presence in the product.

On Day 0, milk candy with no glucose syrup (100:0) had the highest moisture content of 10.38% while 70:30 had the lowest content with 9.94% (Table **2**). All treatments had a statistically significant decrease throughout the storage period. This is expected as water is lost during storage. 100:0 had a substantial reduction in moisture content from 10.38% on Day 0 to 9.29% on Day 20. Similarly, 85:15 and 70:30 had a significant decrease until Day 30 and Day 45, respectively. However, 55:45 had a significant decrease in moisture content between Day 10 and 20 was observed, but no further significant decrease from Day 20 to Day 52. Higher glucose syrup ratios tend to retain moisture slightly better over time compared to those with higher sucrose formulations.

Correspondingly, all treatments had a significantly decreasing trend in the A_w throughout the storage period. This is desirable as lower A_w helps in preventing microbial growth and extending shelf-life. A_w measures the amount of free water available for microbial growth and chemical reactions. On Day 0, 0.78 is the highest A_w observed in 100:0, while the milk candy with the highest concentration of glucose syrup had the lowest A_w observed with 0.68. There was an inverse relationship observed between the A_w and the glucose syrup concentration. Throughout the storage period, the lowest recorded A_w of milk candy was observed on Day 52 with the highest glucose syrup concentration. As the proportion of glucose syrup increases (55:45), A_w decreases more consistently over time, leading to safer and more stable products.

Sensory Evaluation

The different sensory qualities of milk candies, such as appearance, chewiness, sweetness, creaminess, overall taste, and general acceptability, were evaluated by 30 panelists using a 9-point hedonic scale.

Figure **1** shows the mean sensory score on the sensory characteristics of milk candies through the storage period. No sensory evaluation was conducted on Day 30, Day 40, and Day 52 for 100:0, 85:15, and 70:30, respectively, as visible mold growth was observed on these days for the specific treatments.

All treatments showed minimal changes in appearance, creaminess, and chewiness over time.

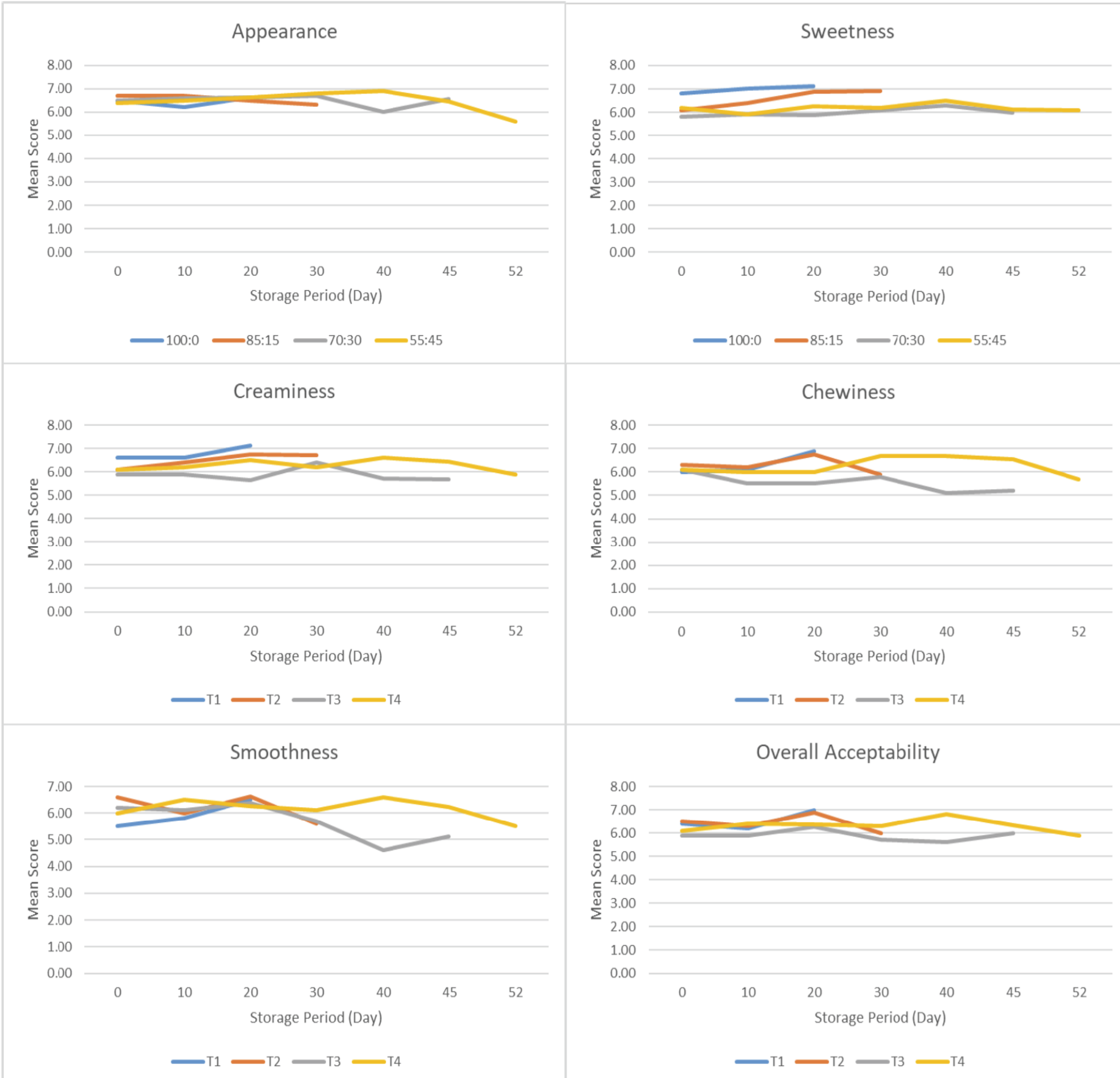

Figure 1: Mean sensory score on the sensory characteristics of buffalo milk candy with different sucrose and glucose syrup ratios during storage. *Mean values with no superscript indicate no statistical difference throughout the storage period per treatment at α=0.05.

100:0 reflected the highest mean sensory score in terms of overall acceptability, sweetness, and creaminess during storage. For appearance and chewiness, 55:45 has the highest mean score with 6.90 and 6.70, respectively. However, using ANOVA at 5% level of significance, it reveals that there was no significant difference in all treatments during the storage period for all parameters.

Product Yield and Formulation Cost

The percentage yield of the buffalo milk candy ranges from 75.47% to 76.20%. Notably, the 100:0 formulation has the highest percentage yield, but it also has the highest computed cost of Php 12.93 per 42g pack of milk candies. On the other hand, 55:45 has the lowest yield but has the lowest calculated cost of Php 11.95. The amount of sucrose is directly proportional to the percentage yield of buffalo milk candy; however, no significant difference with each treatment was observed.

DISCUSSION

The increasing consumption of candy products is due to the versatility in different formulations as well as the various ways in which components or additives can be incorporated into a product [3]. Compared to cow milk, buffalo milk has higher levels of total solids, fat, and protein, resulting in a more concentrated and nutrient-rich base that is ideal for value-added processing. These characteristics contribute to a smoother, richer, and creamier mouthfeel [12]. Additionally, buffalo milk has high total solids and lower water content; with its lower heat capacity and higher thermal conductivity, it reduces cooking time while also getting a higher yield, which is an advantage for candy producers [13]. However, despite its nutritional value, buffalo milk is highly perishable, which requires the development of processes that extend its shelf life, such as milk candy. The shelf life and sensory characteristics of these products are critical factors for consumer acceptance [4].

The deterioration of food quality is affected by the internal characteristics and external factors of the food. Internal characteristics include the initial load of microorganisms in food, availability of nutrients, pH, and A_w. External factors are made up of storage temperature, oxygen availability, and humidity [1]. The buffalo milk candy in this study aligns with FDA standards in terms of microbial quality, indicating that it was processed and packaged under sanitary conditions. 100:0 exhibited an early onset of increased microbial load, suggesting that higher sucrose content leads to greater vulnerability to microbial growth and contamination. Conversely, formulations with higher glucose syrup content, particularly the 55:45 ratio, demonstrated better resistance to microbial growth. Similarly, a lower concentration of sugar used in pear candy not only enhanced the shelf life but also retained the overall acceptability [14]. The protective effect of glucose syrup is linked to its water-binding properties, which make it able to lower A_w levels, rendering conditions that are unfavorable to microorganisms [5, 6].

Sucrose, or table sugar, is one of the significant ingredients in candy products. It acts as a humectant, a hygroscopic substance that binds water through absorption and adsorption, leading to a decrease in A_w. This establishes an inverse relationship between A_w and sucrose concentration [8]. Glucose syrup, or corn syrup, serves as a cost-effective alternative to sugar in bakery products and candies, functioning as a softening agent [11].

It is worth noting that high water content does not directly mean high A_w, as shown with products such as marmalades that have a lot of water, yet possess low A_w because of high sugar levels [15]. Products with elevated moisture levels are more susceptible to microbial growth, underscoring the importance of moisture control in extending shelf life [16].

High-sugar products encompass a variety of items, including chocolates, marshmallows, and both hard and soft candies. For soft candies, the solution is typically heated to a range of 60-100°C, with a moisture content between 8-22% and an A_w of 0.50-0.75 [7]. Most bacteria that cause food spoilage are unable to grow below an A_w of 0.90, while mold and yeast growth can be inhibited at lower A_w levels, around 0.61 to 0.78 [17, 18]. Dissolved particles like sugars, salts, and humectants significantly influence A_w. Research indicates that adding humectants such as polydextrose and mannitol can further reduce water activity, enhancing the stability of candies and toffees against microbial growth [16]. Sugar-rich products are hygroscopic and can rapidly absorb moisture from the surrounding environment, causing significant changes in the product and leading to degradation [19].

The color (appearance), flavor (taste and aroma), and texture of soft candies are critical factors for consumer acceptance and the success of these products [4]. Beyond microbial stability, the 55:45 ratio preserves key sensory qualities such as appearance, sweetness, creaminess, and chewiness. Higher glucose syrup ratios prevent crystallization caused by moisture loss, maintaining a smooth texture and preventing degradation of flavor and structure over time [7, 20, 21]. The buffalo milk candies with higher glucose syrup also score better in sensory evaluations for smoothness, creaminess, and overall acceptability than higher sucrose formulations. No significant difference was found in the sensory preferences and texture of different concentrations of glycerol and sorbitol in chocolate dodol [22]. Furthermore, the addition of glycerol and glucose syrup increased balance with moisture content and reduced sugar crystallization in dried figs [23].

The 55:45 formulation retains more moisture and maintains a desirable texture longer than other formulations, which is particularly important for milk candies. This ratio helps keep the candies soft and creamy over time, preventing them from becoming too stiff or dry. Lower A_w in the 55:45 formulation also makes it more resistant to microbial growth, extending shelf life without relying heavily on preservatives. This is particularly attractive to consumers who prefer to buy such products that are free of unnecessary chemicals. Additionally, the inclusion of fats enhances texture and mouthfeel, providing lubrication and smoothness while controlling crystallization [24].

The higher the soluble solids content of the raw material used, the higher the production yield will be, resulting in lower manufacturing costs [25]. In the production of soft candy, glucose syrup is used due to its high production yield, good sweetness value, and it is more affordable than sucrose [7].

From a cost perspective, adding glucose syrup also offers a distinct advantage. While sucrose is the traditional sweetener in many high-sugar products, glucose syrup is generally more affordable. It has a relative sweetness value of approximately 0.45-0.5 compared to sucrose's 1.0, making it cost-effective for formulations where intense sweetness is not required [26]. In this study, the 55:45 formulation had the lowest unit cost per pack (Php 11.95) and a slightly lower yield. However, this trade-off was compensated for by better product shelf-life and quality. The economic advantage of glucose syrup results from its higher production yield, mainly when used in products with high soluble solids, like soft candies [7].

Moreover, the cost-effectiveness of glucose syrup may allow manufacturers to invest in improved packaging while still maintaining profitability. This aligns with current consumer preferences for minimally processed foods with fewer additives and longer shelf-life [27]. The 55:45 formulation, therefore, addresses multiple goals: it extends shelf-life, improves or maintains sensory characteristics, and reduces production costs.

In summary, buffalo milk, with its exceptional nutritional profile, is well-suited for high-value dairy confections. However, its perishability requires strategic formulation approaches. The incorporation of glucose syrup at a 55:45 ratio with sucrose proved to be the most effective in enhancing microbial stability, maintaining sensory quality, and reducing production costs. This ratio improves product stability, reduces the need for preservatives, and potentially lowers packaging costs, making it a viable option for candy manufacturers aiming to enhance product quality and consumer satisfaction, particularly for items intended for extended storage or export.

CONCLUSION

The different proportions of sucrose and glucose syrup ratios affect the shelf life, microbial stability, and organoleptic properties of buffalo milk candy. Formulations containing larger portions of glucose syrup, particularly 55:45, exhibited higher inhibition of microbial growth and a lower water activity (A_w), thereby increasing shelf stability compared to the formulations having a larger proportion of sucrose. The study explains that glucose syrup binds water more effectively, reducing A_w and preventing microbial growth. While sucrose serves as a humectant, it also increases the candy's susceptibility to microbial contamination, especially mold growth, as seen in the 100:0, 85:15, and 70:30 formulations. Sensory evaluation showed no significant difference in all treatments during the storage period for all parameters, implying that glucose syrup preserves the desirable qualities of buffalo milk candy with no adverse effects on its taste or texture. The study concludes that using glucose syrup not only enhances product stability but also improves production efficiency and cost-effectiveness.

FUNDING

This research received no external funding.

LIST OF ABBREVIATIONS

CDCPF	=	Central Dairy Collecting and Processing Facility
APC	=	Aerobic Plate Count
CC	=	Coliform Count
YMC	=	Yeast and Molds Count
FDA	=	Food and Drug Administration
ANOVA	=	Analysis of Variance

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ACKNOWLEDGEMENTS

The authors would like to thank all people who have made substantial contributions to the work reported in the article (e.g., technical help, writing and editing assistance, general support) but who do not meet the criteria for authorship.

AUTHOR CONTRIBUTIONS

Conceptualization: M.A., T.B., and J.S.; Methodology: M.A., T.B., J.S., and P.C.S.; Investigation: M.A.,

T.B., J.S., and P.C.S.; Data Curation: T.B., J.S., and P.C.S.; Formal Analysis: T.B., J.S., and P.C.S.; Writing- Original draft preparation: T.B., J.S., and P.C.S.; Writing-review and editing: P.C.S. and J.S.; Supervision: M.A. and P.C.S.

INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

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Received on 04-06-2025 Accepted on 04-08-2025 Published on 12-08-2025

https://doi.org/10.6000/1927-520X.2025.14.13