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Shelf-life Evaluation of Mango Jelly Candy: Critical Moisture Content Method

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ABSTRACT

Using the critical moisture content method, this study investigated the shelf life of mango jelly candy made from over-ripe arum manis mango. The product's shelf life must be evaluated to determine its effect after combining with citric acid. Tests were conducted using 0.5%, 1%, and 1.5% concentrations of citric acid. The mango jelly was wrapped in polypropylene packaging at a relative humidity (RH) of 78% and a temperature of 290 °C. Based on the analysis results, adding 0.5% citric acid yields a product with a longer shelf life compared to concentrations of 1% and 1.5%. An increase in the pH of mango jelly candy causes this. An increase in pH can cause syneresis, thereby increasing the water content in the jelly, which ultimately increases the Aw, allowing it to become a growth medium for microorganisms and resulting in a decrease in the characteristics of the mango jelly candy. The characteristics of the mango jelly product at a concentration of 0.5% as the chosen product formulation concentration are water content 19.91%, ash content 1.3%, fat content 0.33%, protein content 0.71%, and carbohydrate content 77.77%, and IC_{50} value at 16.11, with hedonic test values for aroma at 3.56, color at 4.04, taste at 4.0, and texture at 3.56. All stored products, whether treated as A1, A2, or A3, will be damaged on the 4th day of storage. Based on Labudza's calculation analysis, mango jelly candies A1, A2, and A3 have shelf lives of 12, 8, and 6 days, respectively. And three days.

***Keywords**: Antioxidant activity, Bacterial activity, Functional food, Local food, Xylose.*

1. INTRODUCTION

Damage to fruit is typical because fruit has a reasonably high water content. One fruit that also spoils quickly is mango. One effort to increase the selling value of mangoes is to process them into products, thereby extending their shelf life. One of the processed products from mango fruit is jelly candy, which can increase its shelf life and selling value. Mango jelly candy has been processed to extend its shelf life. The results show that the sensory value of the product is increased compared to the raw material, mango (Tasiri et al., 2023). Mango jelly candy is produced from overripe mangoes with high carbohydrate and low acid content. This can increase consumers' hedonics about the product, but it also has the potential to reduce its shelf life (Farina et al., 2020). Acid is one component that can increase the shelf life of a product, although high sugar concentrations can also increase the shelf life of a product. The acid and sugar content in mango fruit and its processed products will affect the water activity value (Aw) (Tapia et al., 2020).
Candy is a food that almost everyone likes because it is easy to eat. There are many types of candy, such as hard candy, marshmallows, and jelly candy (Lallemand & Oomen, 2022). Jelly candy is made by mixing fruit juice, gelling ingredients, or adding flavorings. Jelly candy is made from a mixture of fruit juice, gelling ingredients, or additional flavoring ingredients, resulting in candy with a clear and transparent physical form in various flavors (Cano-Lamadrid et al., 2020). The shelf life of jelly candy as a semi-wet food is 6-8 months in packaging and one year in unopened packaging. Jelly candy tends to be sticky due to the hygroscopic properties of the reducing sugar that forms the candy, so the coating material required is usually a mixture of tapioca flour and refined sugar.

Citric acid is a weak organic acid found in citrus leaves and fruit (Salihu et al., 2021). Citric acid is an excellent natural preservative and is also used as an acidity enhancer in foods and soft drinks. The amount of citric acid added to the jelly confectionery depends on the gelling agent used. Citric acid is commonly used as a food ingredient and is generally categorized as safe (Reena et al., 2022).

2. RESEARCH SCOPE

This research focuses on evaluating the feasibility and effectiveness of several factors in the production of mango jelly candy. Specifically, it investigates whether the critical water content method can be applied, examines the influence of citric acid concentration on extending shelf life, and analyzes the sensory attributes of the product through hedonic tests and quality assessments. Furthermore, the study includes proximate analysis to determine the nutritional composition of the final product, thereby providing a comprehensive evaluation of both its physical and sensory characteristics.

3. MATERIALS AND METHODS

One hundred grams of mango juice was mixed with 20% gelatin, 5% seaweed, and 15% xylose, then heated to a temperature of 73 °C. Citric acid was subsequently added at concentrations of 0.5%, 1%, and 1.5%, with an extended cooking time of 15 minutes. The cooking process continued until the mixture thickened, after which it was removed from the heat source. The thickened mango jelly mixture was poured directly into molds and cooled at room temperature (28 °C) for one hour. Afterward, the jelly candy was placed in a refrigerator for 10 minutes to achieve maximum firmness at refrigerated temperature. Once removed from the refrigerator, the mango jelly candy was allowed to rest at room temperature (28 °C) and was then subjected to further analysis (Tasiri et al., 2023).

3.1 Research Design

The research was carried out using descriptive methods to model the calculation of product shelf life using the critical water content method (Labuza & Altunakar, 2020). The research design is presented in Table 1.

Table 1. Jelly Mango Candy Formulation

Ingredients	Formulation		
	A1	A2	A3
Manggo Pure	100	100	100
Citric acid	0,5	1	1,5
Gelatin	20	20	20
Xylose	15	15	15
Seaweed	5	5	5

In this research, data analysis was conducted using Microsoft Excel for linear regression on jelly candy shelf-life data, and the SPSS One-Way ANOVA and Duncan test programs were employed to process Proximate data, Hedonic Organoleptic Tests, and Hedonic Quality and antioxidant results obtained from the research.

3.2 Shelf-life Evaluation: Critical Water Content Method

The tests were carried out by measuring the initial water content, critical water content, air humidity, determining equilibrium levels, determining the slope of the isotherm curve, calculating dry weight, calculating saturated water vapor, and finally, determining shelf life (Labuza & Altunakar, 2020).

3.4 Sensory Evaluation

The sensory evaluation of mango jelly candy was conducted through hedonic and hedonic quality tests to comprehensively assess consumer acceptance and product quality. The hedonic test was designed to measure the degree of liking based on consumer perception, while the hedonic quality test provided a more detailed evaluation regarding specific product attributes. Both assessments followed standardized scoring methods intended to capture consumer preferences in a structured and quantifiable manner. A numeric scale was employed to evaluate four primary attributes: aroma, color, taste, and texture. The aroma assessment aimed to determine the attractiveness and intensity of the product’s scent, while the color evaluation focused on the visual appeal and uniformity of the jelly. The taste test examined the balance of sweetness, sourness, and overall flavor profile, whereas the texture assessment emphasized consistency, chewiness, and mouthfeel. By utilizing this approach, the study was able to generate empirical data that not only reflects consumer preferences but also provides insights into the overall quality characteristics of the mango jelly candy (Yulianti et al., 2024).

3.4 Proximate Analysis

The analysis was carried out on the selected formula that demonstrated the longest shelf life and the most stable physical characteristics during storage. A series of proximate analyses were conducted to evaluate the nutritional composition and quality parameters of the mango jelly candy. These analyses included the determination of water content, which is a critical factor influencing texture, microbial stability, and product durability; ash content analysis, which provided information regarding the total mineral composition of the product; protein analysis to assess the contribution of amino acid-based nutrients; fat analysis to determine the lipid concentration and its potential impact on flavor and mouthfeel; and carbohydrate analysis, which was calculated by difference to establish the proportion of carbohydrates as the primary source of energy in the jelly candy. Together, these analytical assessments offered comprehensive insights into the nutritional value, stability, and overall quality of the mango jelly candy, allowing for a better understanding of how citric acid concentration and production methods influenced the product’s shelf life and sensory characteristics.

3.5 Antioxidant Activity

The antioxidant activity assay was conducted to evaluate the ability of mango jelly candy extracts to inhibit free radicals at varying concentrations. The test was performed using samples prepared at concentrations of 12.5 ppm, 25 ppm, 50 ppm, and 100 ppm. Each concentration was carefully analyzed to determine its relative antioxidant potential. Vitamin C, which is a well-established standard reference compound with strong antioxidant properties, was employed as the positive control in this study, while 70% ethanol served as the blank solution to ensure accuracy and consistency in measurement. The results of the antioxidant activity evaluation, including the percentage inhibition values obtained at different sample concentrations compared to the control, are systematically summarized and presented in Table 2. This analysis provides an important indication of the functional properties of the mango jelly candy, highlighting its potential contribution not only as a food product but also as a functional food with added health benefits.

Table 1. The Chemical Characteristics of Mango Jelly Candy

Chemical Characteristics	Formulation A1	A2	A3
Water	19.91 ± 0.07^{a}	20.13 ± 0,01^{b}	20.19 ± 0,01^{c}
Ash	1.30 ± 0.01^{a}	1.34 ± 0.001^{b}	1.36 ± 0.001^{b}
Protein	0.71 ± 0.001^{a}	0.28 ± 0.001^{b}	0.54 ± 0.001^{c}
Fat	0.33 ± 0.001^{a}	0.28 ± 0.001^{b}	0.24 ± 0.001^{c}
Carbohydrate	77.77 ± 0.001^{a}	77.76 ± 0.01^{a}	77.78 ± 0.14^{a}
Antioxidant Activity	33.73 ± 0.001^{c}	27.30 ± 0.01^{b}	16.11 ± 0.001^{a}

A1 (200% ground mango, 5% seaweed, 15% xylose, 0.5% citric acid); A2 (200% ground mango, 5% seaweed, 15% xylose, 1% citric acid); A3 (200% ground mango, 5% seaweed, 15% xylose, 1.5% citric acid). The data presented are the results ± standard deviation. Letters that are not similar indicate fundamental differences. The Duncan test level is 5% (sig<0.05).

4. RESULT AND DISCUSSION

The mango jelly candy produced in this research is presented in Figure 1.

Figure 1. Mango Jelly Candy

The result from figure 1 are A1 (200% ground mango, 5% seaweed, 15% xylose, 0.5% citric acid), A2 (200% ground mango, 5% seaweed, 15% xylose, 1% citric acid), A3 (200% ground mango, 5% seaweed, 15% xylose, 1.5% citric acid). Based on Figure 1, Mango jelly candy boasts a vibrant, sunlit hue that mirrors the rich, golden-orange color of a ripe mango. The candy is molded into bite-sized pieces with a heart-shaped design and a slightly squishy texture, resulting in a soft, gummy consistency. It has the tropical essence of mango in a chewy and mouthwatering delight.

4.1 Chemical Characteristic

The chemical properties of the mango jelly candies are summarized in Table 2. Among the treatments, sample A3 exhibited the highest average water content at 20.19%, while sample A1 recorded the lowest at 19.91%. These findings indicate that the concentration of citric acid has a measurable influence on the water content of mango jelly candy. The increase in water content with higher concentrations of citric acid can be attributed to the process of syneresis, in which carbohydrate structures within the jelly matrix are partially broken down. Citric acid acts as a hydrolyzing agent that accelerates the breakdown of polysaccharides into simpler molecules, thereby releasing additional water into the system. As a result, the greater the concentration of citric acid incorporated into the formulation, the more extensive the hydrolysis of carbohydrates that occurs, leading to higher water retention in the final product. This outcome suggests that citric acid not only contributes to the flavor profile of mango jelly candy but also plays a significant role in modifying its physicochemical properties, particularly moisture content, which in turn may affect the product's texture, stability, and shelf life (Guo et al., 2022).

The addition of gelatin can affect the water content of mango jelly candies (Qiao et al., 2021). According to SNI 01-3547-1994, the maximum standard water content for jelly candy is 20%, which means that the total water content meets quality standards. Gelatin is a protein compound produced by partially hydrolyzing collagen (Alipal et al., 2021). Its role is to form a gel. It can absorb water from materials and is a colloidal dispersion system that quickly absorbs large amounts of water, forming a network that prevents water movement (Bello et al., 2020).

Ash content refers to the estimated amount of minerals present in a product. Treatment A3 had the highest average ash content at 1.36%, while treatment A1 had the lowest at 1.30%. Depending on the number of mangoes added, the ash content in mangoes is 0.40%. Determining the ash content is closely related to the mineral content of food. Mangoes contain several minerals, including iron (Fe), copper (Cu), potassium (K), phosphorus (P), zinc (Zn), calcium (Ca), manganese (Mn), and selenium (Se). The increase in ash content at citric acid concentrations of 1.0% and 1.5% is related to sodium, a citric acid component. It is thought that the sodium in citric acid dissolves as the product's water content increases (Bello et al., 2020).

Treatment A1 had the highest fat content in mango jelly candy at 0.33%, while treatment A3 had the lowest at 0.24%. The reduction in fat content between treatments A1 and A3 was significant. The decrease in fat content in treatment A3 was due to an increase in the product's water content. An increase in water content can cause fat to hydrolyze into glycerol and fatty acids (Feng et al., 2020). This reaction occurs more rapidly in an acidic environment. Increasing the amounts of citric acid and water in the A3 formulation decreases the fat content. Treatment A1 had the highest protein value at 0.71%, followed by treatments A3 and A2. Weak acid treatment affects the protein in particles, causing them to clump together. Administering acid increases H+ ions, which allows the protein to become neutral. An isoelectric pH is formed when the positive and negative charges combine, resulting in neutralization. Proteins that are hydrolyzed after reacting with acid can cause denaturation phenomena (Wu et al., 2020). Citric acid can coagulate minimal protein, thus affecting only protein denaturation. Matter. This can prevent the pH of the product from changing because citric acid is partially ionized due to its less electronegative characteristic. Due to denaturation, protein peptide bonds are partially broken, affecting the primary structure. The protein is unaffected after processing.

Denaturation the third protein structure has four types of bonds in its side chains: hydrogen bonds, sodium bonds, disulfide bonds, and nonpolar hydrophobic interactions, all of which are expected to be affected (Zhao et al., 2020). In general, denaturation is the process by which proteins precipitate and coagulate. This explains the decrease in protein levels in treatment A2. However, as the concentration of citric acid increases in treatment A3, the protein levels also increaseThe carbohydrate content in treatments A1, A2, and A3 was not significantly different, with values ranging from 77.76% to 77.78%. The carbohydrates calculated in the study were the total carbohydrates, so they remained relatively unchanged. The highest antioxidant activity value was in treatment A1 at 33.73%, while the lowest was in treatment A3 at 16.11%.

Citric acid is a metal chelator and an antioxidant. In this study, increasing the concentration of citric acid reduced the product's antioxidant activity value. An excess of citric acid has this added effect, rendering it a prooxidant or excess oxidant and resulting in an excess of O radicals (Saffari & Saffari, 2020). This increase in peroxide levels can be caused by hydroperoxides formed from an increase in fatty acids resulting from the hydrolysis of product fats.

4.2 Sensory Characteristic

The sensory evaluation test results of mango jelly candy are presented in Table 3.

Table 3. Sensory Evaluation of Mango Jelly Candy

Sample	Aroma	Color	Taste	Texture
Hedonic				
A1	3.56 ± 1.04^{a}	4.04 ± 0.20^{a}	4.00 ± 0.95^{b}	3.56 ± 1.04^{a}
	b			
A2	3.24 ± 0.87^{a}	4.00 ± 0.001^{a}	3.00 ± 1.08^{a}	3.24 ± 0.87^{a}
A3	3.84 ± 0.89^{b}	4.04 ± 0.20^{a}	2,88 ± 1.11^{a}	3.24 ± 0.87^{a}
Hedonic Quality				
A1	4.08 ± 0.40^{b}	4.00 ± 0.57^{a}	2.40 ± 0.70^{b}	3.56 ± 1.04^{a}
A2	3.24 ± 0.87^{a}	4.04 ± 0.45^{a}	1.44 ± 0.86^{a}	4.00 ± 0.28^{b}
A3	3.84 ± 0.89^{b}	4.00 ± 0.40^{a}	1.44 ± 0.86^{a}	4.04 ± 0.45^{b}

A1 (200% ground mango, 5% seaweed, 15% xylose, 0.5% citric acid), A2 (200% ground mango, 5% seaweed, 15% xylose, 1% citric acid), A3 (200% ground mango, 5% seaweed, 15% xylose, 1.5% citric acid). The data presented are the results ± standard deviation. Letters that are not similar indicate fundamental differences. The Duncan test level is 5% ($sig<0.05$).

A hedonic test analysis is conducted to determine consumer preferences for the product. In contrast, a hedonic quality test is used to evaluate the quality standards of the tested product and determine the selected formulation (Ray, 2021). Based on the hedonic analysis test results and hedonic quality presented in Table 2, the difference in citric acid concentration does not significantly affect the product's color and texture. However, the differences in aroma and taste are significant. Increasing the concentration of citric acid decreases panelists' preference for smell and taste. This finding aligns with the proximate analysis results presented in the previous section, which indicate that increasing citric acid concentration can reduce fat and protein levels. Fat is hydrolyzed into fatty acids, and denatured protein and peroxide compounds are formed. This combination can reduce panelists' preferences and acceptance standards for aroma, as for product taste.

4.3 Shelf-life Evaluation

This research also involved a series of visual observations to evaluate the stability and shelf life of the Arum Manis mango jelly candy product. The candy samples were stored in an open room environment without any packaging in order to simulate common storage conditions and to accelerate visible deterioration. Observations were conducted over a four-day period, beginning on day zero (the production day) and continuing until the product showed clear signs of spoilage. The progressive changes in the physical appearance and quality of the mango jelly candy were systematically recorded and are summarized in the General tab (Yan, 2022).

In general, the deterioration of food products is influenced by a combination of microbiological, chemical, and enzymatic processes, which gradually reduce product quality and consumer acceptability. These degradative processes are strongly correlated with the presence of free water and bound water within the product (Du et al., 2022). Bound water refers to the initial water content retained in the candy immediately after production, which plays a significant role in determining product texture, microbial growth potential, and overall stability. Therefore, evaluating the initial water content is considered a fundamental step in predicting and extending shelf life. In this study, the critical water content method was applied as an analytical approach to estimate the shelf life of the mango jelly candy. The outcomes of this shelf-life evaluation are presented comprehensively in Table 4, providing insight into how moisture dynamics contribute to the product's preservation and deterioration over time.

Table 4. Appearance Observation of Mango Jelly Candy

Days	Physical Appearance
0	The texture is lumpy; the product does not melt, the appearance is still intact and sound,
1	The texture is lumpy; the appearance is still intact and sound.
2	The candy texture in the A1 treatment did not melt; it was still lumpy, and the appearance was still intact. Meanwhile, the texture of the candy in treatments A2 and A3 was slightly melted and not lumpy.
3	The candy texture in action A1 is slightly melted and somewhat non-clumping. Meanwhile, the texture of the candy in treatments A2 and A3 was not lumpy
4	The candy texture in all treatments (A1, A2, A3) was damaged, did not clump, mold grew and appearance damaged by fungus.

A1 (200% ground mango, 5% seaweed, 15% xylose, 0.5% citric acid); A2 (200% ground mango, 5% seaweed, 15% xylose, 1% citric acid); A3 (200% ground mango, 5% seaweed, 15% xylose, 1.5% citric acid).

The determination of the shelf life of mango jelly candy in this study was carried out using the critical water content approach, which is estimated through the application of the Labuza equation (Labuza & Altunakar, 2020). This method is widely recognized in food science research as a reliable framework for predicting product stability, particularly in relation to moisture absorption and storage conditions (Bhikadiya & Bhikadiya, 2025). The principle of this approach lies in identifying the point at which the water content of a product reaches a critical threshold (Mc), beyond which physical, chemical, or microbiological deterioration becomes significant, thereby limiting the product's shelf life.

Several key variables were taken into consideration in these calculations. These include the initial moisture content (Mi) of the mango jelly candy, the equilibrium moisture content (Me), the critical water content (Mc), the pure water vapor pressure (Po), and the packaging permeability (k/x), which reflects the ability of water vapor to pass through the packaging material. Additional parameters considered in this study were the weight of solids (Ws), the surface area of the packaging (A), and the slope (b) of the sorption isotherm curve, which describes the relationship between water activity and equilibrium moisture content. Together, these variables provide a comprehensive estimation of the rate at which moisture interacts with the product under given storage conditions.

The shelf-life estimation was conducted under controlled room temperature conditions of 29 °C, with a relative humidity (RH) of approximately 78%, which closely represents typical ambient storage environments in tropical regions. Such conditions are crucial to simulate real-world storage scenarios where high humidity often accelerates moisture transfer and potentially shortens the product's shelf life. By incorporating these environmental factors into the model, the study aims to present a realistic prediction of mango jelly candy stability during storage, thereby offering valuable insights into packaging selection, storage guidelines, and product quality maintenance.The permeability of 0.03 mm polypropylene packaging is 0.0865 g/m²·day·mmHg with an RH range of 51%-90%. This value indicates the packaging material's resistance to holding free water, which can affect the product's water absorption. Shelf-life estimation data are then calculated using the Labuza equation based on the shelf-life estimation variables obtained. The results of the shelf-life calculation for mango jelly candy are shown in Table 5.

Table 5. The Parameters for determining product shelf life

Shelf-life parameter	Relative Humidity of 75%
Initial water content (Mi) %DB (gH_2O/g solid	(A1) 0.5% = 0.23 (A2) 1.0% = 0.25 (A3) 1.5% = 0.26
Critical water content (Mc) %DB (gH_2O/g solid	(A1) 0.5% = 0.3349 (A2) 1.0% = 0.3442 (A3) 1.5% = 0.2737
equilibrium water content (Me) %DB (gH_2O/g solid – Clayton Chen	(A1) 0.5% = 3.03 (A2) 1.0% = 2.29 (A3) 1.5% = 2.93
packaging permeability (k/x) (gH_2O/g solid. Days. mmHg)	0.014
Packaging surface area (A) (m^2)	0.0049
Packaging solids weight (Ws) (g)	5
Pure vapor pressure (Po) at 29^0C.mmHg	30

Slope (b) sorption isotherm curve	(A1) 0.5% = 1.3 (A2) 1.0% = 0.9 (A3) 1.5% = 2.0
Clayton Chen Equation Model	(A1) 0.5%: ln (ln 1/Aw) = 0.5 +1.3 Me (A2) 1.0%: In (In 1/Aw) = 1.4 – 0.9Me (A3) 1.5%: In (In 1/Qw) = 0.2 + 2.0 Me
Calculation of shelf life using the Labuza equation	
(A1) 0.5%	12
(A2) 1.0%	8
(A3) 1.5%	3

The research results indicate the following shelf lives for mango jelly candies: 12 days for the 0.5% concentration, 8 days for the 1% concentration, and 3 days for the 1.5% concentration. These differences in shelf life result from the varying concentrations of citric acid. Increasing the concentration of citric acid reduces the shelf life of mango jelly candies.

The concentration of citric acid plays a critical role in determining the physicochemical stability and overall quality of food products. According to (Salihu et al., 2021), increasing the concentration of citric acid directly contributes to a higher water content within the product. Elevated water content creates favorable conditions for microbial growth, which accelerates spoilage and consequently alters the sensory and nutritional characteristics of the product. In addition, excessive citric acid concentrations negatively affect the structural integrity of food products, making their texture more fragile and less stable.

This phenomenon occurs because an abundance of citric acid can induce oxidative reactions that break down macromolecular chains, such as proteins and polysaccharides, that are responsible for maintaining the strength and resilience of the food matrix. The weakening of these macromolecules results in structural deterioration, reduced shelf stability, and compromised product quality. Therefore, determining an optimal balance of citric acid concentration is essential, not only for achieving the desired sensory attributes but also for ensuring product safety, stability, and an extended shelf life.

5. CONCLUSION

The maximum concentration of citric acid that can be optimally utilized in the formulation of mango jelly candy is 0.5%. At this concentration, the product demonstrated the most stable physical and sensory characteristics, maintaining its texture, flavor, and appearance without significant deterioration. Furthermore, stability testing revealed that mango jelly candy produced with 0.5% citric acid achieved a shelf life of up to twelve days under controlled storage conditions at room temperature. This finding indicates that a 0.5% concentration of citric acid provides the most effective balance between product preservation and consumer acceptability, while also extending the durability of the jelly candy compared to higher concentrations that may negatively affect sensory attributes.

6. SUGGESTION

Further research is required to provide a deeper understanding of the relationship between citric acid concentration and the role of gelatin in the production of mango jelly candy. Such studies should not only focus on the structural and textural properties influenced by these variables but also evaluate the impact on product stability and shelf life. In addition, it is essential to assess the nutritional profile of the product more comprehensively by testing for vitamin C content, antioxidant activity, and calorific value. These analyses would contribute significantly to determining the functional benefits of mango jelly candy, ensuring that it is not only appealing in terms of taste and texture but also delivers added nutritional value. Moreover, investigating these parameters can guide the formulation of healthier confectionery products and provide valuable insights for both industrial applications and academic contributions in the field of food science and technology.

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