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Development the gummy candies made from passion fruit (*Passiflora edulis*) and moringa leaf (*Moringa oleifera*)

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ABSTRACT

This study aimed to develop gummy candies made from passion fruit (Passiflora edulis) and moringa leaf (Moringa oleifera). Three main sections were conducted, including (i) the ratio of ground fresh moringa leaves, (ii) the ratio of gelatin, (iii) the ratios of sugar and citric acid in terms of physical properties (moisture content, hardness, and color), nutrients (vitamin C, crude fiber), and sensory values of gummy candies. The results were found that the gummy candies which 1% ground fresh moringa leaves, 8% gelatin, 30% sugar, and 0.5% citric acid, showed high nutrition and sensory evaluation. The statistical results showed that the ratio of ground fresh moringa leaves had a strong negative relationship with moisture content, a, b*, and had a strong positive relationship with crude fiber, vitamin C, and hardness. Moreover, the increase in the gelatin ratio caused a decrease in moisture content and an increase in hardness of the candies. Besides, the ratio of sugar had a significant effect on moisture content and hardness while the ratio of citric acid had a great influence on hardness and vitamin C content. Therefore, the results are expected to encourage the utilization of natural materials in confectionery products.*

1. INTRODUCTION

Viet Nam, a tropical country, is ideal for diverse fruit cultivation, including passion fruit (*Passiflora edulis*), which is extensively grown in Lam Dong, Gia Lai, Kon Tum, and Dak Lak. Recently, provinces like Hau Giang and Tien Giang in the Mekong Delta have also started cultivating passion fruit to meet market demands (Song et al., 2022). This fruit is known for its distinctive aroma and sour taste, and it is rich in carbohydrates, vitamins C and A, iron, potassium, fiber, and other nutrients (Rudnicki et al., 2007; Luzia et al., 2018; Fonseca et al., 2022). These nutrients benefit overall health and support heart health (Casimir & Whitfield, 1978; Ulmer & MacDougal, 2004; Bairey Merz et al., 2015). Typically consumed fresh, passion fruit can spoil quickly, so it is essential to develop value-added products from fresh raw materials to enhance utilization and promote sustainable development.

Moringa (*Moringa oleifera*) is a type of local medicinal Indian herb that has turned out to be familiar in tropical and subtropical countries (Pareek et al., 2023). Moringa leaves contain various bioactive compounds, rich in minerals and vitamins, which lead to an increase in the application of the leaves to the food and cosmetics industry. Some notable health benefits of Moringa oleifera include anti-inflammatory, anti-spasmodic, anti-hypertensive, anti-tumor, antioxidant, antipyretic, anti-ulcer, anti-epileptic, diuretic, cholesterol-lowering, renal, anti-diabetic (Gopalakrishnan et al., 2016; Pareek et al., 2023) and hepatoprotective activities (Aly et al., 2020; Asgari-Kafrani et al., 2020).

Currently, the processing of confectionery products is more and more widely applied. However, reality shows that many types of candy in the market bring little nutrition to the user. Besides, the use of foods containing fiber is also a current concern of consumers. Diversifying products by combining passion fruit and moringa leaves will create new, natural, and healthy products.

Achieving the desired effect on the processing of passion fruit and moringa leaf gummy candies requires a specific research process under optimized conditions. The product will be affected and changed by various factors that reduce the nutritional and sensory value. Therefore, the research on "Development of the gummy candies from the passion fruit (*Passiflora edulis*) and moringa leaf (*Moringa oleifera*)" is necessary. The study examines the effect of ground fresh moringa leaves (GFML) ratios as well as gelatin, sugar, and acid citric ratios on the properties of gummy candy products.

2. MATERIALS AND METHOD

2.1. Materials

Passion fruits and moringa leaves were selected and purchased at MM mega market at Can Tho city. Sugar RE (Bien Hoa, Viet Nam), gelatin (Ewald, Germany), and citric acid (Ensign, China) were used in this study. The reagents included KI (Sigma - Aldrich, Germany), KIO_3, (Xilong, China), H_2SO_4 (Xilong, China), HCl (Xilong, China), NaOH (Xilong, China) and starch solution 1%.

2.2. Research methods

2.2.1. Process flow diagram for passion fruit and moringa leaf gummy candies

Ripe passion fruit was selected based on its deep purple color, wrinkled skin, and distinct aroma. Young moringa leaves were chosen for their light green color, soft texture, and mild flavor. Both the fruit and leaves were washed with tap water and drained before further processing.The procedure followed the flowchart in Figure 1, with the ratio of ingredients and additives adjusted for each experiment. Passion fruit juice was soaked with gelatin powder for 15 minutes. Meanwhile, moringa leaves were ground using a 0.5 mm sieve. The mixture, consisting of the ground leaves, sugar, citric acid, and water, was then heated to approximately 100°C for 5–6 minutes, along with the gelatin-infused passion fruit juice. After cooking, the gummy mixture was poured into silicone molds and placed in the refrigerator until solidified. Once set, various parameters were analyzed.

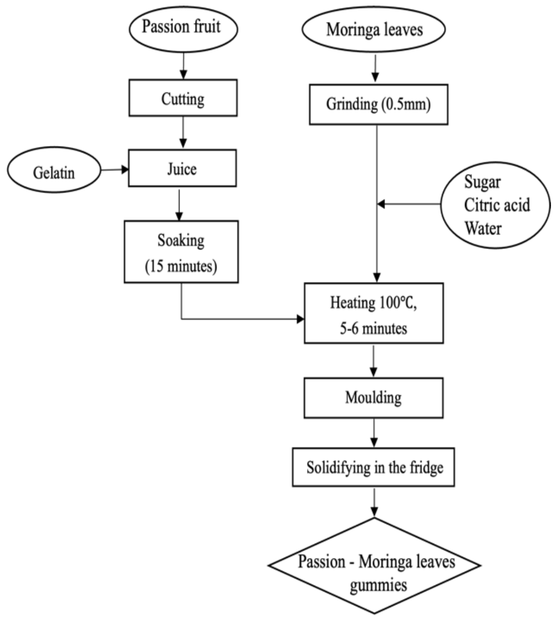

Figure 1. The flowchart processing for passion fruit – moringa leaf gummies

2.2.2. Investigating the effect of added GFML ratios

The experiment was carried out with the different ratios of GFML at 0; 1; 1.5 and 2 which was indicated as table below.

Table 1. The ingredient composition (%) in the experiment 1

Ingredients	Ratio (%)			
Passion fruit	50			
GFML	0	1	1.5	2
Gelatin	5			
Sugar	26			
Citric acid	0.3			
Water	18.7	17.7	17.2	16.7

Targets: sensory evaluation of color, odor, flavor, texture, hardness (N/cm^2), moisture content (%), color (L, a, b*), vitamin C (mg%), and crude fiber (%).*

2.2.3. Investigating the effect of added gelatin ratios

The experiment was performed with the different percentages of ingredients at 6, 8, and 10% which was indicated as table below.

Table 2. The ingredient composition (%) in the experiment 2

Ingredients	Ratio (%)		
Passion fruit	50		
GFML	1		
Gelatin	6	8	10
Sugar	26		
Citric acid	0.3		
Water	16.7	14.7	12.7

Targets: sensory evaluation of color, odor, flavor, texture, hardness (N/cm²), and moisture content (%).

2.2.4. *Investigating the effect of added sugar and citric acid ratios*

The experiment was carried out with two factors including sugar at 25, 30, and 35%; and citric acid at 0.5, 1, and 1.5% which were indicated as shown in Table 3 below.

Table 3. The ingredient composition (%) in the experiment 3

Ingredients	Ratio (%)											
Passion fruit	50											
GFML	1											
Gelatin	8											
Sugar	25				30				35			
Citric acid	0	0.5	1	1.5	0	0.5	1	1.5	0	0.5	1	1.5
Water	16	15.5	15	14.5	11	10.5	10	9.5	6	5.5	5	4.5

Targets: sensory evaluation of color, odor, flavor, texture, hardness (N/cm²), moisture content (%), and vitamin C (mg%).

2.3. Methods of analyzing

Moisture content (%): determined by oven-drying (Isotherm Convection, Esco, Singapore), the sample at 105°C to evaporate water. The sample was weighed before and after drying using an analytical balance, and the moisture percentage was calculated based on the weight loss. The reduction in weight after drying represented the moisture content, following the Association of Official Analytical Chemists – AOAC (2004) procedure.

Vitamin C (mg/100 mg): measured using redox titration with potassium iodate, following the AOAC (2016) method.

Hardness (N/cm^2): evaluated using the TA. XT plus Texture Analyzer (Stable Micro Systeams, Godalming, England). The sample was placed on the analyzer's base plate with a cylindrical probe (2 mm diameter), set to travel at a speed of 1 mm/s over a distance of 4 mm. The probe penetrated the center of the sample, and the maximum compression force recorded during deformation indicated the sample's hardness.

Crude fiber (%): determined gravimetrically after chemically digesting the sample and removing non-fiber components, following the AOAC (2016) procedure.

Color: measured using the CIELAB system (FRU, Color Reader, Guangdong,China) and expressed through three indices: L*, a*, and b*. The L* value represents lightness, ranging from 0 (black) to 100 (white). The a* value indicates color variation from green (negative values) to red (positive values), while the b* value represents the spectrum from blue (negative values) to yellow (positive values).

Sensory evaluation: conducted using the qualitative descriptive analysis method (Lawless & Heymann, 2018). A trained sensory evaluation panel of 20 members assessed the sensory attributes of the gummies, including color, odor, flavor, and texture. Each attribute was rated on a descriptive scale from 1 to 5, which 1, 2, 3, 4, and 5 was equal to very bad, bad, moderate, good and very good, respectively.

2.4. Data analysis methods

Data were obtained from experiments with 3 replicates and statistical analysis using the program Statgraphics Centurion (Version 19). Data were analyzed by ANOVA, Duncan's test was used for the calculation of significant difference (LSD), the relationship between values was analyzed by

Pearson correlation coefficient. Analysis of the influence of the factors on the parameter based on mean value, standard deviation, and the figure was processed by Microsoft Excel 2021.

3. RESULTS AND DISCUSSION

The analysis of the chemical composition contained in raw materials was to ensure the uniformity of the quality of raw materials.

Table 4. The chemical composition of passion fruit and moringa leaf

	Passion fruit	Moringa leaf
Moisture content (% wet basis)	83.77±0.24	70.54±0.39
Vitamin C (mg/100 g)	20.84±0.14	31.74±0.23

The results in Table 4 show that the moisture content of passion fruit (83.77±0.24% wet basis) is lower than the United States Department of Agriculture - USDA data of 85.6% wet basis (USDA, 2015). The vitamin C content of passion fruit (20.84±0.14 mg/100 g) was lower than USDA data (29.8 mg/100 g) (USDA, 2015). That result agreed with data reported by Charan et al. (2018), who noticed that the vitamin C content was between 18.62 and 30.50 mg/100 g. The moisture content of moringa leaves was 70.54%. It was lower than USDA data, and Joshi & Mehta (2010) that was 78.7% and 75.9%, respectively. The study's vitamin C content of moringa leaf (31.74±0.23 mg/100 g) was lower than USDA data (51.7 mg/100 g). The difference in geography areas, plant varieties, climate, and nutrition may contribute to these differences. These variables may include light, temperature, salts, and the presence of atmospheric pollutants, metals, and herbicides (Pertuzatti et al., 2015). Moreover, many pre-and postharvest factors influence the vitamin C content of horticultural crops involve climatic conditions temperature, length, and packaging material of storage (Feszterova et al., 2023). In many developing countries, including Viet Nam, poor post-harvest practices like improper storage, handling, and transportation can lead to the loss of vitamins and water (Lencho, 2023).

3.1. Effect of GFML ratios on the quality of gummy candies

3.1.1. Effect of GFML ratio on physical properties of gummy candies

The physical properties of gummies such as moisture content, hardness, and color were investigated in passion fruit – moringa leaf gummies with different GFML ratios at 0, 1, 1.5 and 2%.

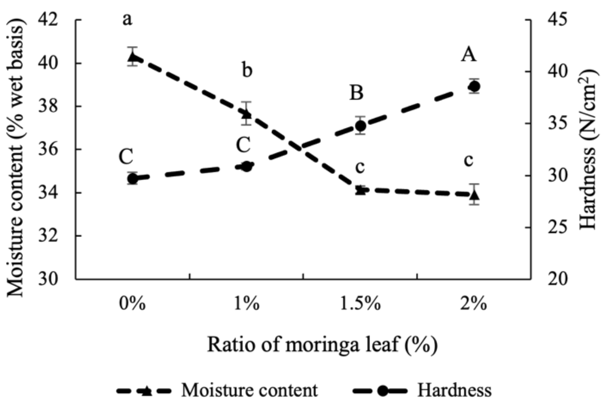

Figure 2. The change of moisture content and hardness of candies using different GFML ratios

Different letters (a-c) and (A-C) indicate significant differences ($p < 0.05$) in the moisture content and hardness of the gummies, respectively.

Figure 2 suggests that the changes in the GFML ratio contribute to the moisture content and hardness of the gummy candies. With an increasing GFML ratio, the moisture content of candies gradually diminished. This trend could be explained due to the reduction in water content in the candy formulation, hence, the overall moisture content of the gummy candies declined. As the moisture content reduced from 40.31±0.43% to 33.93±0.48%, the hardness improved significantly from 29.74±0.58 to 38.63±0.67 N/cm^2 (Figure 1). This result agreed with the report by Hartel et al. (2018) that the texture of candies was significantly affected by water content, with confections generally becoming harder as the moisture content decreased. Water acts as a plasticizer in candy formulations. Increased water content reduces the glass transition temperature (Tg) of the candy matrix, making it more flexible and softer. Conversely, reducing water content raises the Tg, resulting in a harder texture (Harte et al., 2018). For gummies, the hardening effect is due to moisture loss since water acting as a plasticizer and the tightening of the gel matrix as water content decreases. (Pirsa & Hafezi, 2023).

Table 5. Effect of GFML ratios on the color of gummy candies

GFML (%)	Color		
	L*	a*	b*
0	70.97±0.43^{b}	0.12±0.04^{c}	5.17±0.09^{d}
1	70.27±0.64^{ab}	-0.46±0.02^{b}	5.03±0.04^{c}
1.5	70.08±0.74^{ab}	-0.72±0.02^{a}	4.90±0.04^{b}
2	69.50±0.26^{a}	-0.72±0.03^{a}	4.77±0.08^{a}

Note: Means followed by different letters in the same column reveal significant differences (p<0.05)

As the results presented in Table 5, the a* value declined significantly as the ratio of GFML rose from 0-1.5% while there was no significant difference between the 1.5% and 2% GFML ratios. Moreover, the b* value decreased significantly, from 5.17±0.09 to 4.77±0.08. The reduction in a* and b* values was due to the effect of the green color of the moringa leaf. The decrease in the value of a* represented an increase in green, while the reduction in the value of b* indicated a drop in yellow. Similar results were found in the research of Lan et al. (2015), which demonstrated that the color was pale with a small amount of hibiscus extract. Conversely, since the extract amount is too high, it darkens the color and reduces the sensory value of the product.

3.1.2. Effect of GFML ratios on vitamin C and crude fiber content of gummy candies

The statistical results in Table 6 show that the Vitamin C and crude fiber content in the gummy candies are affected by the ratio of GFML (p< 0.05). For vitamin C content, there was a significant increase since the ratio of GFML increased from 0 to 2%, with 9,65±0,12 mg/100 g to 12,45±0,14 mg/100 g, respectively. The reduction in vitamin C content of candies compared to raw material was since heating at a high temperature significantly affected the vitamin C content in the product (Nhan & Quyen, 2023). Vitamin C is highly heat sensitive and degrades at high temperatures. This process is accelerated by the presence of oxygen and metal ions. At high temperatures, ascorbic acid is oxidized to dehydroascorbic acid (DHAA), which, while initially retaining vitamin activity, is unstable and further degrades into biologically inactive compounds (Giannakourou & Taoukis, 2021).

Table 6. Effect of GFML ratios on the color of gummy candies

GFML (%)	Vitamin C (mg/100 g)	Crude fiber (%)
0	9.65±0.12^{a}	0.13±0.01^{a}
1	10.68±0.14^{b}	0.15±0.01^{b}
1.5	11.28±0.13^{bc}	0.16±0.01^{bc}
2	12.45±0.14^{d}	0.17±0.01^{c}

Note: Means followed by different letters in the same column reveal significant differences (p<0.05)

Regarding the crude fiber content, there is a variation from the 0% to 2% samples, with values of 0.13±0.01%, 0.15±0.01%, 0.16±0.01%, and 0.17±0.01%, respectively. There was no statistically significant difference between the samples with 1-1.5% and 1.5-2% GFML ratio. The rise in vitamin C and crude fiber content in the gummy candies can be linked to the naturally high levels of these nutrients in Moringa leaves, which contain approximately 16–220 mg/100g of vitamin C and 2.2–23% crude fiber (Ariani et al., 2023; Ntshambiwa, 2023).

3.1.3. Evaluation of the relationship between targets and the GFML ratio factor

The relationship between targets (moisture content, L, a*, b*, hardness, vitamin C) and the factor (ratio of GFML) is shown in Table 7.

Table 7. Correlation coefficient (r) between factor GFML ratio and targets of gummies

	GFML	Moisture content	L*	a*	b*	Hardness	Vitamin C
Moisture content	-0.95***						
L*	-0.75**	0.65*					
a*	-0.96***	0.94***	0.68*				
b*	-0.93***	0.88***	0.58	0.87***			
Hardness	0.91***	-0.88***	-0.69*	-0.80**	-0.89***		
Vitamin C	0.95***	0.90***	0.69*	0.94***	0.86***	0.80**	
Crude fiber	0.90***	-0.87***	-0.81**	-0.89***	-0.72**	0.81**	0.82**

*Note: ***: p<0.001; **: 0.001<p<0.01; *: p<0.05*

Table 7 indicates that the ratio of GFML had a significant negative correlation (p<0.001) with moisture content, a*, b*, and a significant positive correlation (p<0.001) with hardness, and vitamin C and crude fiber. As the GFML ratio increased, the moisture content of gummies declined, whereas the converse was observed with hardness. Additionally, with the increase in the ratio of GFML, the values of a* and b* diminished.

3.1.4. Effect of the ratio of GFML on the sensory value of gummy candies

Table 8 presents the statistical results regarding sensory evaluation criteria, complemented by illustrated images shown in Figure 3. It is evident that the inclusion of GFML significantly impacted the color, odor, flavor, and texture of the gummy candy product. Notably, samples with a 1% addition of GFML garnered higher sensory scores and were preferred over other samples. The samples with a 1% addition of moringa leaves likely received higher sensory scores and were preferred due to several factors. It improved the color and appearance with a slight green tint from moringa might have given a natural, fresh look to the product, making it more visually appealing. Moreover, the addition of 1% GFML may provide balanced flavor with mild sweetness. Samples containing 1.5% and 2% GFML exhibited darker colors and a brownish hue, attributed to the higher GFML ratio. These samples displayed an imbalance in odor and flavor, with the strong scent and taste of moringa leaf overshadowing the passion fruit essence, leading to reduced sensory scores. Several studies have illustrated how different ingredients and formulations affect the sensory characteristics of gummy candies (Handayani et al., 2019; Tireki et., 2021; Cebin., et al 2024). The panelist seems to accept the moderate addition of herb extract since it did not change too much the flavor, color and texture of the gummies. In summary, the 1% GFML sample was highly rated for appropriate color, odor, flavor, and texture, with statistically significant differences at a 95% confidence level, thus being selected as the best parameter for the next experiment.

Table 8. Sensory value of gummy candies with different ratios of added GFML

GFML (%)	Color	Odor	Flavor	Texture
0	4.58±0.51^{b}	4.50±0.52^{c}	4.42±0.51^{b}	3.67±0.49^{bc}
1	4.42±0.51^{b}	4.58±0.51^{c}	4.67±0.49^{b}	4.00±0.60^{c}
1.5	3.83±0.58^{a}	3.75±0.45^{b}	4.25±0.62^{b}	3.58±0.51^{b}
2	3.33±0.98^{a}	2.92±0.51^{a}	3.58±0.51^{a}	2.92±0.29^{a}

Note: Means followed by different letters in the same column reveal significant differences (p<0.05)

0% 1% 1.5% 2%

Figure 3. Gummy candies with different ratios of added GFML

3.2. Effect of gelatin ratio to moisture content, hardness, and sensory value of gummy candies

3.2.1. Effect of gelatin ratio to moisture content, hardness of gummy candies

Table 9 illustrates the impact of different gelatin ratios on the moisture content and hardness of the gummy candies. The moisture content of candies gradually declined with an increasing ratio of gelatin. Because powdered gelatin has a low moisture content (10%), elevating the gelatin ratio enhances the candy's dryness and reduces the moisture content.

The hardness of gummy candies increased with a higher gelatin ratio. Similar findings were observed in the study by Kornnonntud (2018), where the hardness of Hibiscus gumdrops escalated from 24.1-31.5 kg as the gelatin ratio rose from 20% to 25%. Concurrently, as the moisture content dropped from 40.91±0.65% to 31.37±1.21%, the hardness experienced a notable increase from 25.38±1.41 to 36.52±0.79 N/cm^2. This result agreed with the report of Efe & Dawson, (2022) that the textural properties of jelly and gummy candies depended primarily on the water content and the type of gelling agent used. Regardless of the gelling agent, candies with higher water content were significantly softer than candies made with the same ingredients, but with lower water content (Cohen & Hartel, 2024).

Table 9. Effect of gelatin ratio on moisture content and hardness of gummy candies

Gelatin (%)	Moisture content (% wet basis)	Hardness (N/cm^2)
6	40.91±0.65^c	25.38±1.41^a
8	38.01±0.90^b	31.08±0.68^b
10	31.37±1.21^a	36.52±0.79^c

Note: Means followed by different letters in the same column reveal significant differences (p<0.05)

3.2.2. Evaluation of the relationship between targets and gelatin factor

Table 10 demonstrates that the ratio of added gelatin exhibits a strong negative relationship (p<0.001) with moisture content and a strong positive relationship (p<0.001) with hardness. The gummy candies had a reduction in moisture content and an elevation in hardness as the ratio of gelatin increased. This finding aligns with the research conducted by Tri & Quyen (2014), which indicated a high and negative Pearson correlation coefficient (r = -0.98; p<0.001) between moisture content and the chewiness of strawberry gel candy. In other words, as the ratio of added gelatin increased, the candies showed a decrease in moisture content and became tougher.

Table 10. Correlation coefficient (r) between factor gelatin ratio and targets of gummies

	Gelatin	Moisture content
Moisture content	-0.96***	
Hardness	0.98***	-0.95***

*Note: ***: p<0,001*

3.2.3. Effect of gelatin ratio to the sensory value of gummy candies

Based on the statistical results of the sensory evaluation criteria in Table 11, it can be observed that the sensory scores regarding the flavor and texture of the gummy candies are affected by changes in the gelatin ratio. There was no statistically significant difference in the two sensory parameters, color, and odor when changing the ratio of gelatin.

Table 11. Sensory value of gummy candies with different ratios of added gelatin

Gelatin (%)	Color	Odor	Flavor	Texture
6	4.67±0.49^a	4.50±0.52^a	3.83±0.72^a	3.50±0.67^a
8	4.50±0.52^a	4.33±0.49^a	4.58±0.51^b	4.67±0.49^c
10	4.50±0.67^a	4.33±0.78^a	4.25±0.75^{ab}	4.00±0.43^b

Note: Means followed by different letters in the same column reveal significant differences (p<0.05)

Regarding to flavor and texture, the sample with a 6% ratio scored 3.83±0.72, 3.50±0.67 which indicated that it was deemed soft, friable texture and lacked the characteristic chewiness of gummy candy structure. Additionally, the sample with an 8% ratio achieved the highest scores from the sensory evaluators, with values of 4.58±0.51 for flavor and 4.67±0.49 for texture. Scores gradually decreased in the 10% sample, with values of 4.25±0.75 for flavor and 4.00±0.43 for texture. With 10% of supplemented gelatin, the candies were evaluated as having a hard texture, which was deemed unsuitable for gummy candy products. Conversely, the 8% sample was noted for its moderately chewy texture, non-sticky, and retaining the characteristic odor and flavor of passion fruit and moringa leaves. The differences in texture properties between the 10% and 8% gelatin formulations in gummy candies occur due to the functional role of gelatin in gel formation at 10% gelatin with more cross-linking, resulting in a harder, more rigid gel. This high firmness makes the gummy too tough to chew while at 8% gelatin with less cross-linking, producing a softer, moderately chewy gel, which is preferable for gummy candies (Forte et al., 2015). Therefore, it was selected as the most suitable parameter for the next experiment.

3.3. Effect of sugar and citric acid ratios to moisture content, hardness, vitamin C content, and sensory value of gummy candies

3.3.1. Effect of sugar and citric acid ratio on physical properties and vitamin C content of gummy candies

The results presented in Figure 4 demonstrate the influence of varying ratios of sugar and citric acid on the moisture content, hardness, and vitamin C content in the gummy candies ($p < 0.05$).

Across different sugar ratios, statistically significant differences were observed in moisture content and hardness. With sugar ratios ranging from 25 to 35%, the moisture content experienced a notable decrease from 36.77±2.32%–29.68±2.25%, while the hardness increased significantly from 29.60±5.31 to 40.33±6.10 N/cm^2. This result is consistent with the research findings of Anjliany et al. (2022), where an elevation in sugar concentration led to an increase in total dissolved solids, consequently resulting in a reduction in water content in gummy candies. Furthermore, an increase in sugar content tends to make the product's texture harder because the resulting gel becomes more sustainable and firmer. This phenomenon occurs because the sugar molecules retained in the three-dimensional network of the gel block become more stable and denser.

Conversely, regarding citric acid ratios, the sample with 0% to 1.5% citric acid showed a significant decrease ($p<0.05$) in moisture content, from 35.71±3.35% to 30.85±3.34%. On the other hand, it was observed that the hardness significantly increased ($p<0.05$) from 27.82±4.63 to 42.88±5.73 N/cm^2. According to research by Duyen (2015) the higher the concentration of acid added, the lower the elasticity of the product because the higher the amount of acid, farther the product pH is from the isoelectric point of gelatin, causing electrostatic repulsion. This weakens the bond between the molecules, and the loosely bound gel block becomes less stable.

In terms of vitamin C content, the results indicated that vitamin C content remained unchanged with increasing sugar content from 25–35% and tended to rise with increasing citric acid ratio from 0 – 1.5%. A noticeable difference existed among the various citric acid ratios, with the highest value at 1.5% and the lowest at 0%. According to Wang et al. (2017), the loss of vitamin C was heightened by the activity of the enzyme ascorbic acid oxidase, which was less active at low pH. The presence of citric acid lowered the pH of the product and inhibited the activity of the enzyme ascorbic acid oxidase.

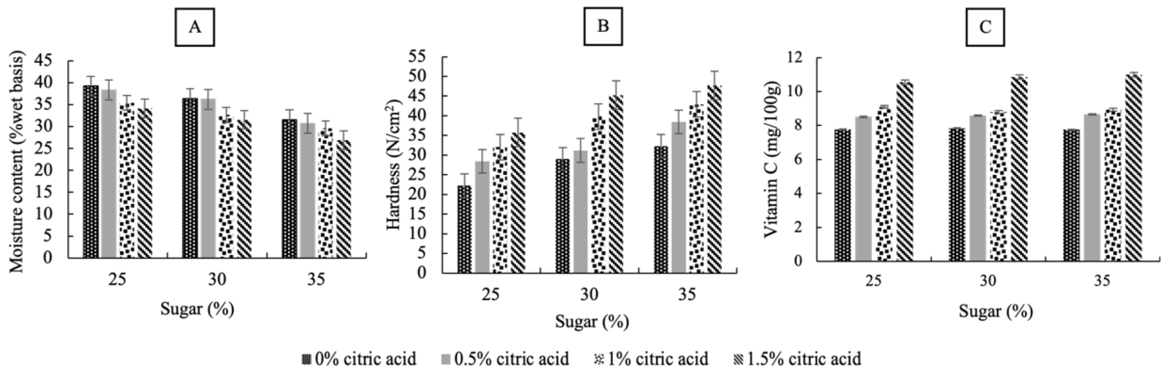

Figure 4. Effect of sugar and citric acid ratios on the moisture content (A), hardness (B) and vitamin C (C) content of the gummies

Means followed by different letters in the same column reveal significant differences ($p<0.05$)

3.3.2. Evaluation of the relationship between targets and sugar and citric acid factors

The relationship between the targets (moisture content, hardness, and vitamin C) and factors (sugar and citric acid) is presented in Table 12.

The relationship between the targets (moisture content, harness, and Vitamin C) and factors (sugar and acid citric concentration) indicated that the sugar ratio has a strong negative relationship ($p<0.001$) with moisture content and a strong positive relationship ($p<0.001$) with hardness. Generally, as sugar content increased, moisture content tended to decline while hardness tended to rise. Conversely, the ratio of citric acid demonstrated a strong positive relationship ($p<0.001$) with hardness and vitamin C. Citric acid plays a crucial role in confectionery particularly in its effects on hardness and vitamin C stability**.** Citric acid protects vitamin C by reducing enzymatic and non-enzymatic oxidation**,** ensuring better stability in food products (Shelke et al., 2024). Besides, gelatin gelation involves the formation of a network stabilized by hydrogen bonds. The presence of citric acid can influence these non-covalent interactions, affecting the gel's mechanical properties or the desired gel firmness (Musabekov et al., 2015).

Table 12. Correlation coefficients (r) between factors (sugar, citric acid) and targets of gummy candies

	Sugar	Citric acid	Moisture content	Hardness
Citric acid	0,00			
Moisture content	-0.79***	-0.52**		
Hardness	0.60***	0.75***	-0.85***	
Vitamin C	0.04	0.94***	-0.50**	0.72***

*Note: ***: p<0.001; **: 0.001<p<0.01*

3.3.3. Effect of sugar and citric acid on the sensory value of gummy candies

Figure 5 illustrates that the variation in the ratio of sugar and citric acid significantly impacts the sensory scores of colors, odor, flavor, and texture of the gummy candies.

With respect to color, the highest sensory scores were observed for candies supplemented with 25% sugar and 1.5% citric acid, while the lowest scores were for candies supplemented with 35% sugar, and 0.5% citric acid, scoring 4.58±0.79 and 4.17±0.72, respectively. When a large amount of sugar was added to the candies, they received poor color-sensitivity scores, likely due to Maillard's reaction. Gummies with a high citric acid ratio exhibited the vibrant yellow color of passion fruit, which was preferred to candies with little or no added citric acid.

The highest sensory score for odor in gummy candies was achieved with 30% sugar and 0% citric acid (4.33 ± 0.49), while the lowest score was obtained using 35% sugar and 1.5% citric acid (3.67 ± 0.65). Candies with a lot of added sugar had a poor odor score due to the smell produced by the Maillard reaction reduced the characteristic scent of passion fruit.

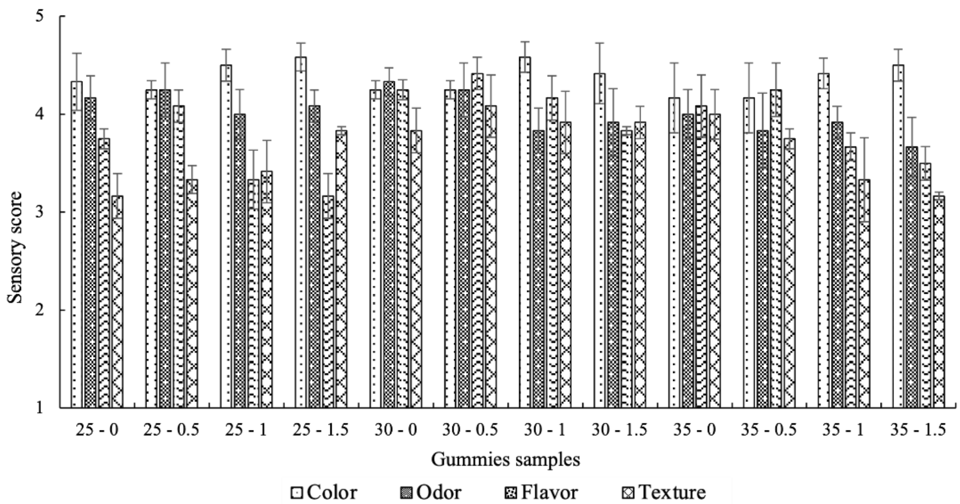

Figure 5. The sensory score of gummy candies with different ratios of sugar at 25, 30 and 35% and citric acid at 0, 0.5, 1%, respectively

Regarding flavor, the sample with 30% sugar and 0.5% citric acid ratios yielded highly preferred candies, significantly different from those with lower or higher ratios of sugar and citric acid. Adding more than 35% of sugar made the candies much too sweet, while 25% was less sweet. Similarly, adding too much acid made the candies too sour, and without citric acid, the candies were less sour.

In regard to texture, the candies were preferred when adding 30% sugar and 0.5% citric acid. With the addition of 35% sugar and a lot of citric acid (1.5%), the candies had a hard texture and were a bit too chewy due to the gelation of pectin with sugar and citric acid. In contrast, with a sugar ratio of 25% and no acid added, the candies had a slightly soft texture and did not receive a high textural sensory score.

4. CONCLUSION

From the results of the research, it was found that the factors (GFML, gelatin, sugar, and citric acid) affected the quality (moisture content, hardness, color, sensory value, vitamin C, and crude fiber concentration) of passion fruit – moringa leaf gummies. The gummy candies were supplemented with 1% ground fresh moringa leaf, 8% gelatin, 30% sugar, and 0.5% citric acid, the candies had good texture, high nutrition, and good sensory values.

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