

Research Article

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Research on technological process for production of muskmelon juice (*Cucumis melo* L.)

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Abstract: The effects of hydrolysis of muskmelon pomace on fruit juice recovery efficiency, transmittance, total phenolic content, total ascorbic acid content, total flavonoid content, and total carotenoid content have been studied. The aim of this study was to evaluate the potential use of pectinase enzyme in the hydrolysis process, specifically looking at the effects of pH, temperature, time, and enzyme concentration on the production of effective muskmelon juice. Additionally, the optimal mixing ratio of ingredients such as melon juice content, Brix level, citric acid, and additives (pectin, sodium carboxymethyl cellulose [CMC], xanthan gum) was investigated to create a high-quality muskmelon juice product. The results showed that using a pectinase enzyme concentration of 0.2%, a pH of 5.0, and a hydrolysis temperature of 45°C for 120 min resulted in a muskmelon juice product with a hydrolyzed juice content of 20%, a Brix level of 12%, and a citric acid addition rate of 0.04%. The addition of xanthan gum at a rate of 0.03% also contributed to the desired flavor and color of the juice. These findings provide valuable insights for the development of effective muskmelon juice processes.

Keywords: Pectinase enzyme, muskmelon juice, physico-chemical properties

1 Introduction

Muskmelon (*Cucumis melo* L.) is one of the highly important medicinal plants of Cucurbitaceae family, along with squash, cucumber, watermelon, muskmelon, gourd, and pumpkin [1,2]. Muskmelon is the fourth fruit in the world in terms of fruit production after oranges, bananas, and grapes [3]. Muskmelons are widely grown in the African region, followed by Southwest and central Asian countries such as India, Iran, Afghanistan, and Uzbekistan [4]. The muskmelon fruit is oval in shape, weighing about 1.5–3.5 kg with white veins interwoven like a net. The fruit flesh is very thick, orange in color, and has a harmonious sweet taste. Muskmelon is low in fat, has no cholesterol and provides many essential nutrients such as potassium to help excrete and reduce high blood pressure, protect the heart and prevent strokes. Muskmelon is exploited commercially for medicinal uses, as it contains a rich source of fiber (0.4 g/100 g), beta-carotenoid (169 µg/100 g), thiamin (0.11 mg/100 g), and vitamins C (26 mg/100 g) (which aids digestion, prevents constipation, and cancer) [5]. Muskmelon has been considered a miracle crop since ancient times, where its leaves and seeds were used to treat hematomas and the stems to reduce high blood pressure [6]. Thanks to the benefits of muskmelon, there have been numerous studies aiming to diversify muskmelon products in both the Vietnamese and international markets. For example, muskmelon jam [7], muskmelon juice [7], fermented muskmelon juice [8], muskmelon yogurt [5], etc., made from muskmelon has been researched and developed.

Juice drinks are products containing less than 100% pure fruit juice that are produced industrially and in ready-to-drink form without any preliminary processing. The level of fruit juice contained in these drinks can be found in the ingredients list, usually on the back of the product [9]. Ripeness of fruit used to make juice promotes the accumulation of sugars, aroma compounds, and thus flavor, as well as changes in acidity, color, and texture. The nutritional and functional properties of juice include macronutrients, many micronutrients, a variety of phytonutrients

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such as flavonoid glycosides present in the juice, and inherent related compounds in juice [10].

The aim of this study is to investigate the performance parameters for juice products made from muskmelon fruit. The following product characteristics including carotenoid content, flavonoid content, polyphenol content, vitamin C content, and sensory evaluation were analyzed. Research results are expected to develop a database of new coating materials and reduce production costs of drinking water products to improve nutritional quality.

2 Material and methods

2.1 Material preparation

Muskmelon is a fruit that usually has an oval shape and green skin. When ripe, it is usually yellow-green in color and has white veins interwoven like a net, weighing about 3–5 kg. Muskmelon is considered standard when fully ripe, the flesh of the cantaloupe is usually orange-yellow, tilted to red-yellow, and has a sweet taste. Muskmelons were harvested in Tay Ninh province, Vietnam (11.3495°N, 106.0640°E). After being transported to the laboratory, the melons were washed thoroughly with clean water to remove dirt and allowed to dry completely at a temperature of 4–6°C.

2.2 Chemicals and reagents

Folin–Ciocalteu reagent (Sigma-Aldrich Chemical, Co. Ltd (USA), 99.99 (%)), 2,6-dichlorophenolindophenol (DCPIP) (India, 99%), ethanol, Na_2CO_3 , NaHCO_3 , Acid L-ascorbic, NaHCO_3 , NaOH, acetone, and phenolphthalein (China, 99.5%) were used. Some additives such as citric acid ($\text{C}_6\text{H}_8\text{O}_6$, >99%, moisture content <0.3%), sugar ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$, >99.5%, moisture content <0.1%, reducing sugar content <0.1%), xanthan gum, pectinase enzyme which were purchased in Vietnam.

2.3 Production process of muskmelon juice

Muskmelons are preliminarily inspected before the juice is extracted. In short, the muskmelon is peeled, seeded, and cut into small pieces of 1–2 cm and then put into a fruit blender to get the juice from the muskmelon. Next the juice is hydrolyzed with the enzyme pectinase (0.2%) with pH 4.5, at a temperature of 45°C for 120 min to help recover

more juice and filtered to get clear juice. Then, hydrolyzed muskmelon juice with 20% juice content will be mixed with prepared ingredients (water, 75° Brix syrup, 0.04% citric acid, and 0.03% xanthan gum) to get the final product. The product created is a melon drink with 12% total soluble solids (TSS). Next the product is bottled in a 200 mL glass and pasteurized at 90°C for 15 min. Finally, the finished muskmelon product is stored in the refrigerator at a temperature of 4–6°C for long-term use to limit spoilage (Figure 1).

2.4 Characterization of the products

2.4.1 Measurement of color change $L^*a^*b^*$

The prepared muskmelon juice was measured using the Chroma Scanner colorimeter (model CR-400, Osaka, Japan). The CIE Lab* color space is a reference color option based on three values L^* , a^* , and b^* . The results are displayed numerically as L^* (brightness ranges from 0–100), a^* (from green to red), and b^* (from blue to yellow) values [11].

2.4.2 Determination of TSS content and pH

TSS of the muskmelon juice was determined by using Atago refractometer (Tokyo, Japan). The pH of the juice was

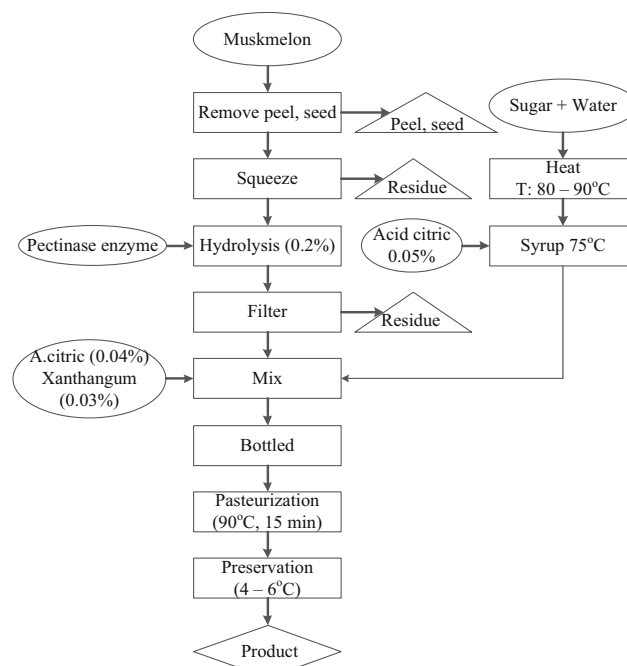


Figure 1: Diagram of muskmelon juice processing.

measured by inserting the probe of Hanna HI2210-02 pH meter into the solution and recording the results displayed on the screen [12].

2.4.3 Viscosity measurement method

The viscosity of muskmelon juice was measured using a viscosity meter (Daihan WVS-0.1M, Gangwon-do, Korea). After measurement, the sample will be displayed on the screen and the results will be recorded [12].

2.4.4 Determination of the juice recovery efficiency

The melon juice will be weighed again with mass m_0 . After being hydrolyzed with mass m , the juice recovery efficiency will be calculated according to the method reported by Orellana-Palma et al. with equation part [13]:

$$\text{TAc(\%)} = \frac{m}{m_0} \times 100,$$

where m_0 and m represent the mass of sample before and after hydrolysis, respectively.

2.4.5 Method of transmittance determination

Transmittance which indicates the juice clarity was measured according to the method of Wang et al. [14]. A volume of 40 mL of fruit juice was centrifuged at 3,600 rpm for 10 min to remove residue and coarse cloudy particles. The transmittance percent was determined at 625 nm using a spectrophotometer. (UV-Vis spectrophotometer, manufacturer: Metash, origin: China, model: UV-5100).

2.4.6 Determination of total polyphenol content (TPC)

TPC was measured according to the method described by Pavun et al. [15] and Singh et al. [16]. A total of 0.5 g of muskmelon was weighed, pureed, put in a 50 mL volumetric flask containing ethanol, and filtered again with filter paper. 0.1 mL of the prepared sample was mixed with 0.5 mL of Folin–Ciocalteu reagent (10%) and after 5 min, 0.4 mL of Na_2CO_3 (7.5%) was added and left in the dark for 60 min at room temperature. The sample was then measured using UV-VIS spectroscopy at a wavelength of 765 nm and results were calculated based on the gallic acid concentration mol (CM) standard curve. Each experiment was repeated three times and represented as mean value $\pm$ standard deviation (SD).

2.4.7 Determination of total ascorbic acid (TAA)

The TAA of muskmelon juice was measured by DCPIP titration method, as previously described by Denre [17]. 0.1 mL of juice sample was extracted with 20 mL of 4% oxalic acid. 10 mL of sample's aliquot was mixed with 10 mL of 4% oxalic acid in a conical flask and titrated against DCPIP dye (V_2) until a faint pink color appeared and persisted for a few minutes. Another 5 mL of 100 ppm solution of ascorbic acid and 10 mL of 4% oxalic acid were taken and also titrated against DCPIP dye (V_1).

2.4.8 Determination of total carotenoids content (TCC)

TCC was measured according to the method of Singh et al. [16] and Hussain et al. [18]. First, 1 g of muskmelon liquid was weighed and mixed with 10 mL of acetone-water mixture (4:1) until the sample was homogeneous. The sample was placed in the sonicator for 3 min for 5 rounds, with 30 s of pulse and 10 s of pause). Then, the sample was centrifuged at 5,000 rpm for 10 min. The absorption spectrum of each substance was measured and recorded at the wavelengths of 663.6 nm for Chl a, 646.6 nm for Chl b and 470.0 nm for total carotenoids.

2.4.9 Determination of total flavonoid content (TFC)

TFC was measured according to the method of Pavun et al. [15] and Hussain et al. [18]. First, 1 g of muskmelon liquid was weighed and mixed with 10 mL of ethanol solution. Then, puree and filter with cloth (repeat the operation three times) put into a 50 mL volumetric flask containing ethanol and filter again with filter paper. A volume of 0.5 mL of the sample was mixed with 4.3 mL of ethanol and 0.1 mL of AlCl_3 (10%) and 0.1 mL of CH_3COOK solution (1 M) and absorbance measurement was performed at 415 nm of wavelength. TFC was determined based on the standard curve equation of quercetin. Each experiment was repeated three times.

2.4.10 Determination of total acid content (TA)

A total of 5–10 mL of the sample was mixed with 20 mL of neutral distilled water and 3 drops of 0.1% phenolphthalein solution was added to a 100 mL triangle flask, agitated well, and titrated with 0.1 N sodium hydroxide to obtain a pale pink solution that is stable for 30 s [12].

2.4.11 Data analysis methods

All experiments were conducted in triplicates. The results were represented as mean value $\pm$ SD and calculated using the Microsoft Excel program (Microsoft Inc., Redmond, WA, USA). Experimental data were analyzed using one-way analysis of variance (ANOVA) in the JMP program at a significance level of 95%.

2.4.12 Sensory evaluation

Sensory evaluation for preparations sample was implemented according to ISO 3215 - 79. Twelve male and female staffs of Nguyen Tat Thanh University, Ho Chi Minh City at the age range of 18–60 were selected to participate in the study. The participants were interviewed for their preference indicated by a degree of liking: 1 = dislike extremely, 2 = dislike greatly, 3 = neither like nor dislike, 4 = like slightly, 5 = like. In each session, five different samples were rated for color, flavor, and overall acceptability of the samples. The sensory evaluation method was implemented according to ISO 3215-79.

Table 1: Muskmelon components

No.	Parameters	Value	Unit
1	TSS	10.20 $\pm$ 0.25	
2	pH	6.43 $\pm$ 0.01	
3	TA	0.102 $\pm$ 0.006	%
4	TAA	3.08 $\pm$ 0.24	mg/g
5	TPC	92.24 $\pm$ 0.61	mg GAE/100 mL
6	TCC	0.84 $\pm$ 0.006	μ g/g
7	TFC	0.38 $\pm$ 0.01	mg QE/mL

Data are expressed as mean value $\pm$ standard deviation with $n = 3$.

3 Result and discussion

3.1 Preliminary investigation of physical properties of input materials

The initial properties of muskmelon juice are presented in Table 1. Muskmelons are a source of vitamins A, C, E, and folic acid [6]. The results showed that muskmelon contains TCC, TFC, TAA, and TPC, which are important antioxidant compounds in human nutritional metabolism such as enhancing immunity and preventing cancer [5]. Therefore, muskmelon juice plays an important role in human health in addition to its refreshing effect.

3.2 Effects of pectin hydrolysis by pectinase enzyme on product quality

3.2.1 Effects of enzyme concentration on muskmelon juice recovery efficiency

Figure 2 shows that the recovery efficiency and transmittance of the fruit juice have significant differences ($p < 0.05$) when using pectinase enzyme for hydrolysis at different enzyme concentrations. The juice recovery efficiency tends to increase from $80.60 \pm 1.00\%$ to $83.34 \pm 0.19\%$ when adding enzymes at a concentration of 0.1–0.4% to melon juice. This can be explained because in the case of excess substrate, increasing enzyme concentration would linearly increase the reaction rate [19]. The reaction rate reached equilibrium point as the enzyme concentration becomes saturated [20]. Previous studies have shown that the enzyme pectinase in the concentration range of 0.2–0.4% would actively hydrolyze a lot of pectin, resulting in the transparent fruit juice after hydrolysis. Thus, the study shows

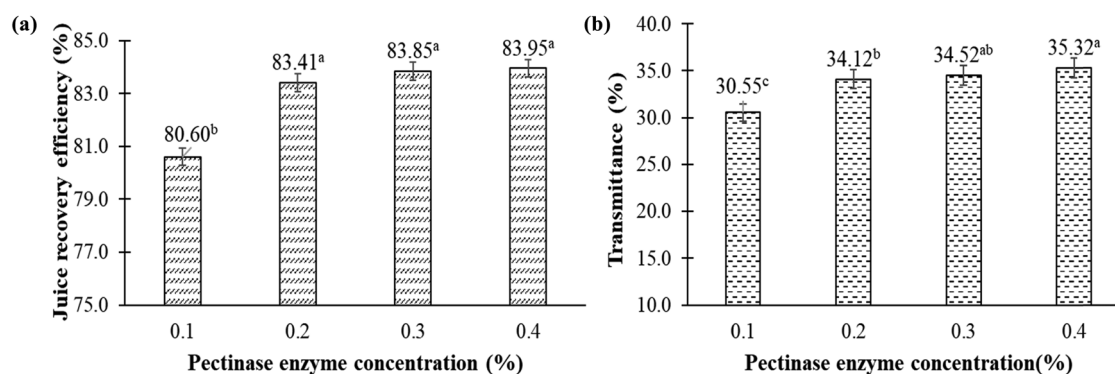


Figure 2: Pectinase enzyme concentration affects recovery efficiency and transmittance: (a) Recovery efficiency (%) and (b) transmittance (%). a, b, c, d represent the difference between treatments.

that the pectinase enzyme clearly affects the clarity of fruit juice after hydrolysis. When the concentration value is 0.1%, the amount of fruit juice reaching the lowest clarity was $30.55 \pm 0.56\%$, and as the concentration value increased from 0.2 to 0.4%, there is not much difference in the fruit clarity, which increased marginally from $34.12 \pm 0.31\%$ to $35.12 \pm 0.24\%$. Therefore, due to economic factors and material savings, 0.2% pectinase enzyme concentration is the appropriate concentration recommended for processing muskmelon raw materials.

The results presented in Figure 3 indicate a significant difference ($p < 0.05$) in TAA, TPC, and TCC levels in muskmelon juice when supplemented with different concentrations of pectinase after hydrolysis. Specifically, when a high concentration of pectinase enzyme was used, TAA increased from 3.19 ± 0.24 to 4.23 ± 0.24 mg/mL, which was higher than the other concentrations. This can be attributed to the fact that the high enzyme concentration effectively breakdown of pectin in the cell walls, resulting in a looser cell structure and allowing for better diffusion of solutes. However, there was no significant difference in TAA levels between the different enzyme concentrations [21]. Therefore, based on both the optimal TAA level of 4.03 ± 0.24 mg/mL and economic considerations, an enzyme concentration of 0.2% is recommended for treating melon ingredients and achieving effective TAA levels.

Enzymatic treatment has been shown to have several beneficial effects, including increased cell destruction, solubility, reduced solution viscosity, and release of biologically active compounds [22]. When pectinase enzyme is added to fruit juice, TPC in muskmelon fruit juice increases rapidly at a concentration of 0.1–0.2%, from 94.34 ± 0.51 mg GAE/100 mL to 97.96 ± 0.11 mg GAE/100 mL. This is due to the breakdown of the cell wall by the enzyme, which releases phenolic compounds that were previously bound and convert insoluble phenolic compounds into soluble ones. Additionally, the enzyme can also decompose lignin, leading to the release of phenolic acid derivatives or the generation of new phenolics, further increasing the TPC in the fruit juice [23]. Although the remaining concentration of TPC increases slightly at higher enzyme concentrations, there is no significant difference compared to the 0.2% concentration, which results in a TPC of 97.96 ± 0.11 mg GAE/100 mL. This is because at higher enzyme concentrations, the reaction speed is limited by the saturation of the enzyme with the substrate [19]. Therefore, based on both optimal enzyme concentration of 0.2% and economic factors, it is recommended to use a concentration of 0.2% for the hydrolysis of muskmelon raw materials.

Figure 3 illustrates that the TCC content reaches its lowest value of 1.08 ± 0.028 µg/mL at a concentration of

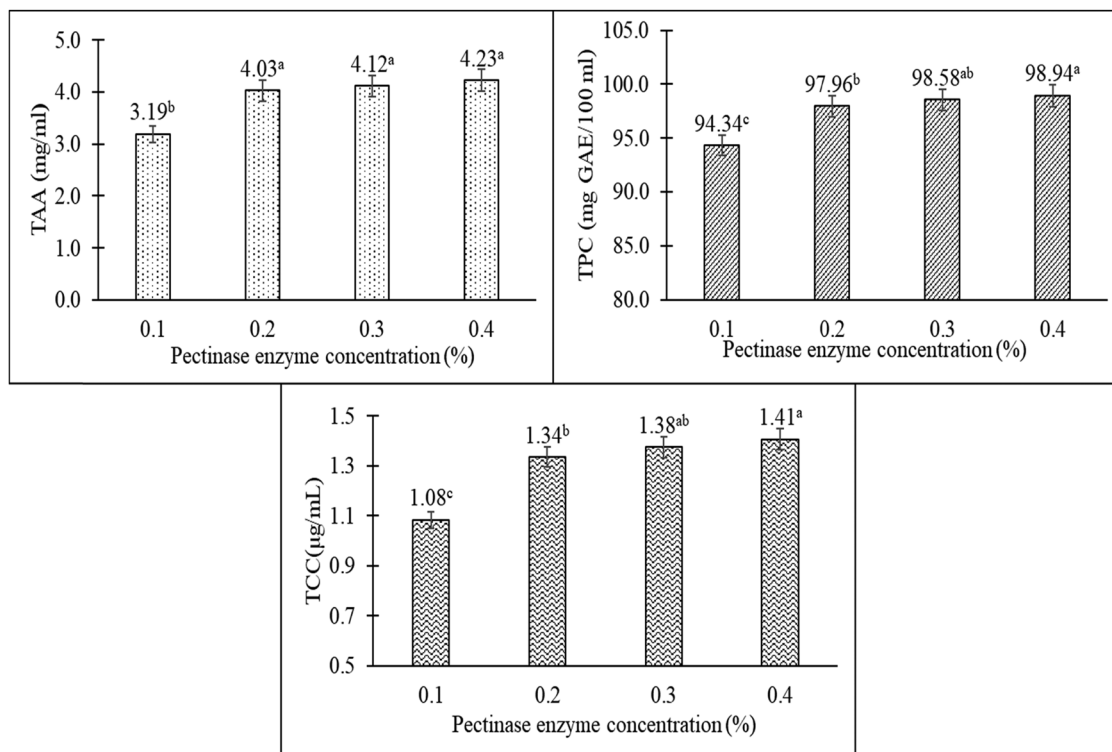


Figure 3: Pectinase enzyme concentration affects TAA, TPC, and TCC. a, b, c, d represent the difference between treatments.

0.1% and then increases to $1.34 \pm 0.017 \mu\text{g/mL}$ at a concentration of 0.2%. However, there is no significant difference in TCC content across the remaining concentrations. This can be attributed to the fact that pectinase, which is responsible for breaking down pectin, also releases carotenoids from the cell wall, thereby increasing extraction efficiency [24]. In this study, the enzyme concentration affected the amount of carotenoid pigment extracted because the higher the carotenoid amount, the higher the measured absorbance value. The amount of enzyme used in the extraction process directly affects the amount of carotenoid pigment extracted, as a higher carotenoid amount results in a higher absorbance value. While a higher enzyme concentration leads to faster hydrolysis, it also comes at a higher cost [25]. Therefore, a concentration of 0.2% is a reasonable choice for muskmelon raw materials.

3.2.2 Investigation of the influence of hydrolyzate pH on the enzymatic hydrolysis process

Besides the enzyme concentration, pH also has a significant impact on the recovery efficiency and transmittance of muskmelon juice after hydrolysis. As shown in Figure 4, there is a significant difference ($p < 0.05$) in the result when examining the influence of pH at values of 4, 4.5, 5, and 5.5. The data in Figure 4 indicate that the lowest recovery efficiency ($81.16 \pm 0.20\%$) is achieved at pH 5.5, while the highest recovery efficiency of pectin content ($83.55 \pm 0.21\%$) and transmittance ($34.36 \pm 0.57\%$) are obtained at pH 5. This can be attributed to the fact that in a low pH environment, the bonds between the polysaccharide chains in the cell wall and the middle lamella are broken, so pectin is easily released to diffuse into the solvent and dissolve. The clarity

of muskmelon juice was found to increase rapidly as the pH increased [26]. In a lower pH environment of pH 4, not only are large molecular weight substances hydrolyzed but the bonds in the polygalacturonic acid chain are also broken, resulting in lower recovery efficiency. Based on these findings, pH 5 was chosen as the optimal pH for pectin hydrolysis in subsequent experiments. This is consistent with the results of a study by Chauhan *et al.* [27], who also found pH 5 to be the most suitable for the activity of hydrolytic pectinase enzyme.

The results of the research, as shown in Figure 5, indicate that the pH of pectin hydrolyzate has a significant impact on the TAA, TPC, and TCC contents in muskmelon juice ($p < 0.05$). The TAA content increases from pH 4.0 to pH 5.0, with the highest TAA content of $4.17 \pm 0.24 \text{ mg/mL}$ achieved at the pH 5.0 of the enzyme hydrolysis solution. However, at pH 5.5, the TAA content decreased to $3.39 \pm 0.41 \text{ mg/mL}$, indicating a significant difference in the TAA content of muskmelon juice. It is important to note that extremely high or low pH levels, such as highly acidic or highly alkaline conditions, can accelerate the breakdown of vitamin C through oxidation, resulting in a loss of TAA in the hydrolyzate. Therefore, adjusting the pH of the hydrolysis solution is just one of the necessary factors to protect vitamin C during the hydrolysis process. According to the research of Mai *et al.* [28], a pH of 5 is the most suitable for achieving optimal vitamin C content in muskmelon raw materials.

TPC reached its highest level of $98.17 \pm 0.37 \text{ mg GAE/100 mL}$ at pH 5. This increase in TPC during enzyme treatment at a pH of 4–5.5 is due to the optimal pH range for the pectinase enzyme to effectively cleave pectin and release substances with high biological activity, such as TPC and TAA. The appropriate pH for polyphenols varies depending on the type of polyphenol and its intended use. For

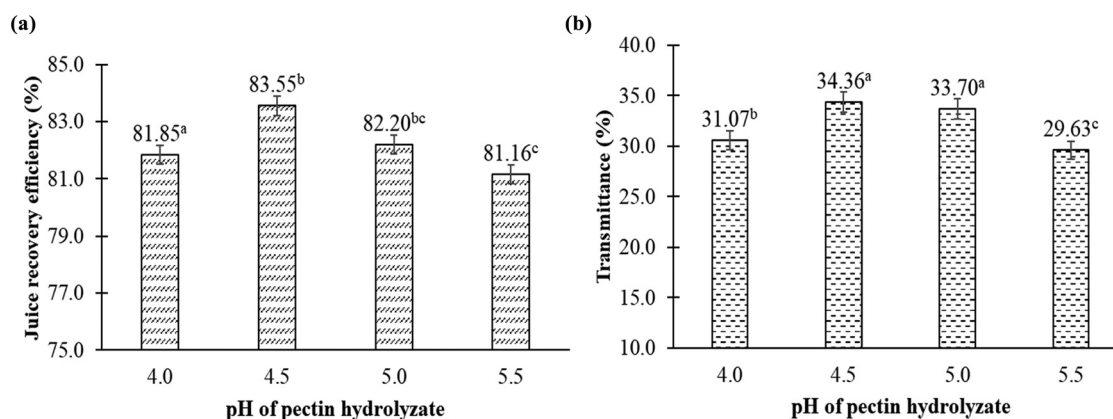


Figure 4: The pH of pectin hydrolyzate affects recovery efficiency and transmittance. (a) recovery efficiency (%) and (b) transmittance (%). a, b, c, and d represent the difference between treatments.

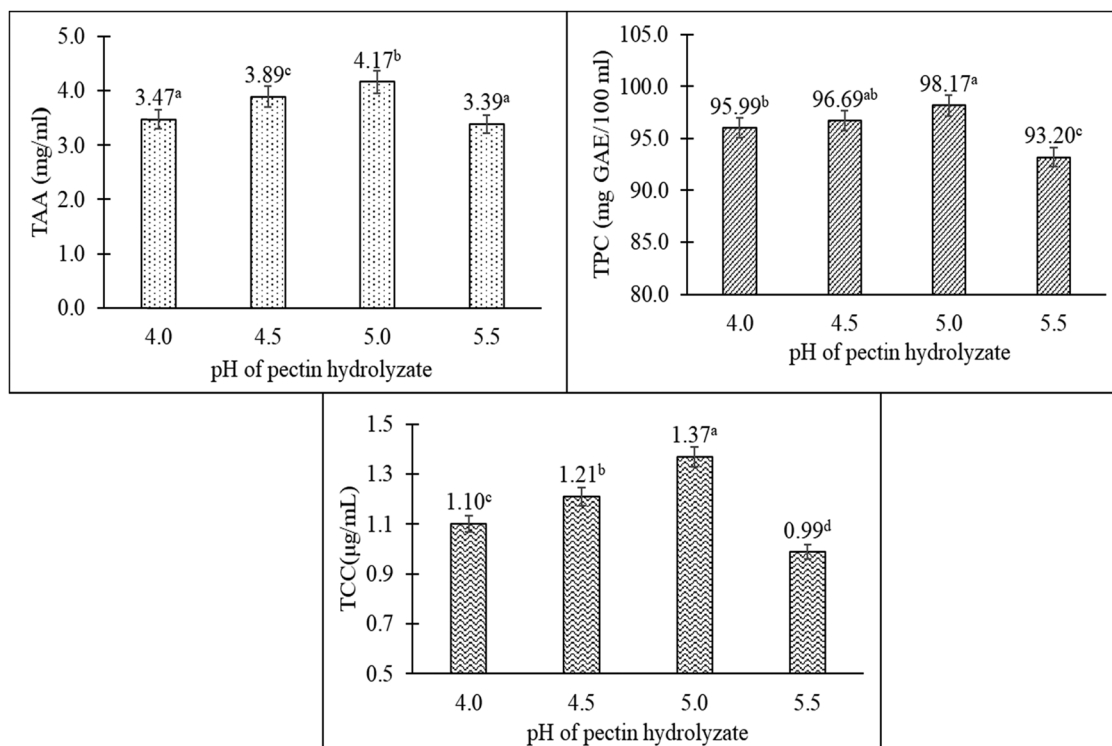


Figure 5: The pH of pectin hydrolyzate affects TAA, TPC, and TCC. a, b, c, and d represent the difference between treatments.

example, flavonoids typically have a suitable pH range of 4–6. If the pH is too low, polyphenols in tea can easily oxidize and decompose, resulting in a loss of nutritional value and an increase in bitterness. On the other hand, if the pH is too high, polyphenols can also be oxidized and destroyed over time [29,30]. This highlights the importance of adjusting the pH during the processing of foods and beverages containing polyphenols to ensure their stability and prevent decomposition or loss of nutritional value. In

this study, a pH of 5 was deemed appropriate to obtain the juice and substances with the highest biological activity.

The chart shows that the pH of the hydrolyzate initially increases, reaching a peak total carotenoid content of $1.37 \pm 0.57 \mu\text{g/mL}$. However, at pH 5.0–5.5, the carotenoid content decreases from 1.10 ± 0.62 to $0.99 \pm 0.38 \mu\text{g/mL}$. This is due to the fact that carotenoids are sensitive to changes in pH, with some being more soluble and stable at higher pH values, while others may be more stable at lower pH values

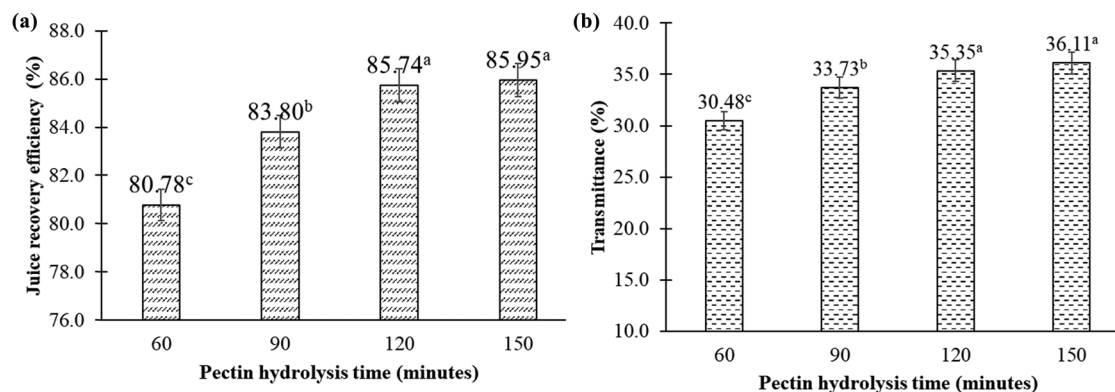


Figure 6: Pectin hydrolysis time affects recovery efficiency and transmittance. (a) Recovery efficiency (%) and (b) transmittance (%). a, b, c, and d represent the difference between treatments.

[31]. The results of this study show that a pH of 5 is optimal for the extraction of carotenoids from muskmelon raw materials, as it aids in dissolving and releasing the carotenoids from the plant matrix, resulting in a higher extraction efficiency.

3.2.3 Influence of hydrolysis time on the enzymatic hydrolysis process

Figure 6 shows the impact of enzyme time on the efficiency and transmittance of fruit juice, revealing a significant difference ($p < 0.05$). As the hydrolysis time of fruit juice increases from 60 to 150 min, both the fluid recovery efficiency and transmittance of the fruit juice tend to increase. According to Tapre *et al.* (2014), extending the hydrolytic activity time of the enzyme is necessary to produce a larger quantity of fruit juice and improve its clarity. However, excessive on hydrolysis times do not result in a proportional increase in juice production and can be time-consuming [32]. Similar to the findings of this study, incubation for 150 min leads to a slight increase in recovery efficiency compared to 120 min ($85.95 \pm 0.61\%$). Conversely, a shorter hydrolysis time is insufficient for the reaction to occur, resulting in lower juice recovery efficiency ($80.78 \pm 0.87\%$) and transmittance. These results are compatible with the study of author Rai *et al.* when analyzing fruit juices [32]. Therefore, to achieve optimal recovery efficiency and

transmittance, the pectinase enzyme time must be carefully adjusted to ensure complete hydrolysis of pectin and clarification of the melon juice, without compromising its activity. Based on the properties of the enzyme, a hydrolysis time of 120 min is suitable for muskmelon fruit juice, resulting in a recovery efficiency of $85.75 \pm 0.77\%$ and transmittance of $33.73 \pm 0.63\%$.

Figure 7 shows that the influence of enzymatic hydrolysis time on the Vitamin C content of fruit juice has a significant difference ($p < 0.05$) and indicates that enzymatic hydrolysis time is a factor that effects not only TAA, but also TPC and TCC. The highest TAA content (4.67 ± 0.04 mg/mL) was observed when the hydrolysis time was increased from 60 to 120 min. However, it should be noted that prolonged incubation times can decrease this content due to the oxidation of Vitamin C at normal atmospheric temperatures. This is because as the hydrolysis time increases, the concentration difference between the raw material and solvent decreases, the resonance of temperature and oxidation due to long exposure to light and air leads to TAA content being reduced. This finding is consistent with the research conducted by Sagu *et al.*, who used pectinase enzyme to optimize the extraction process of banana juice [33]. Therefore, a hydrolysis time of 120 min is recommended for melon juice.

The TPC levels in the hydrolyzate increased from 96.083 ± 0.49 mg GAE/100 mL to 105.447 ± 0.28 mg GAE/100 mL at 60–150 min. However, there was no significant difference in TPC levels between 120 and 150 min. This can

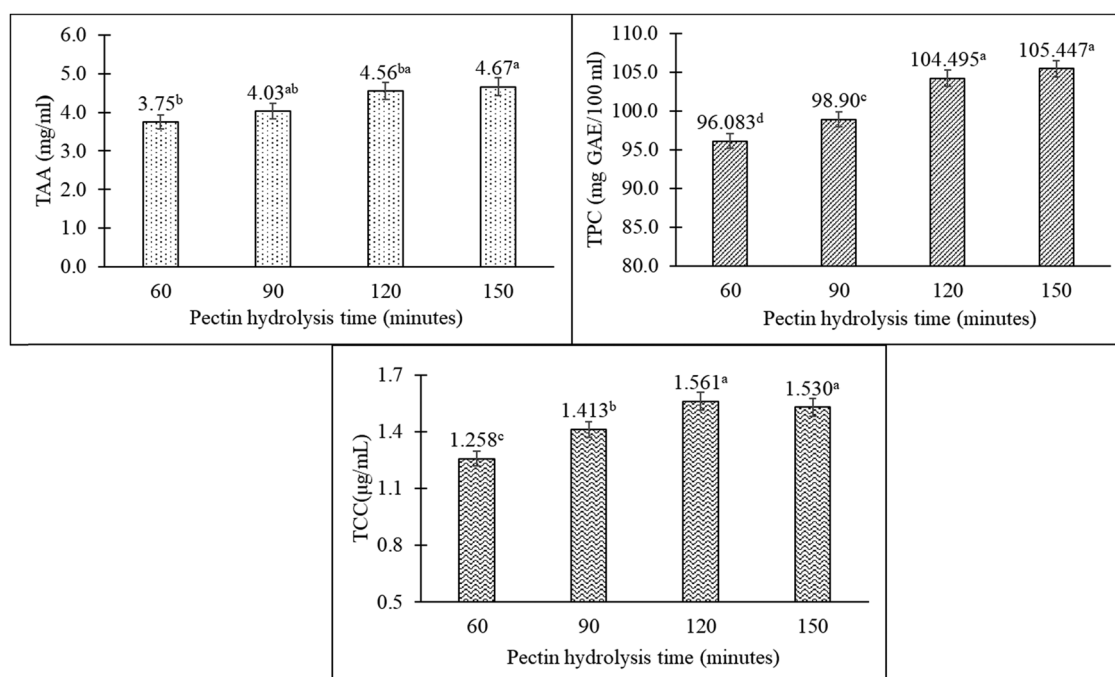


Figure 7: Hydrolysis time affects TAA, TPC, and TCC. a, b, c, and d represent the difference between treatments.

be attributed to the initial stage of hydrolysis, where the concentration difference between the solvent and the substrate promotes intense diffusion, resulting in an increase in the extractant content leaving the cell. However, the longer the hydrolysis time, the difference in concentration of substances in the raw materials in the solvent gradually decreases, a resonance of temperature and oxidation appears due to long exposure under the influence of light and air, causing the reduction in TPC [34]. Based on these findings, it can be concluded that the optimal hydrolysis time for treating muskmelons with pectinase preparation is 120 min.

In addition to concentration, pH, temperature, and hydrolysis time is also an important factor affecting the TCC. Figure 7 shows that different time levels of the hydrolysis process affect TCC with a significant difference ($p < 0.05$). As shown in the chart, TCC tends to increase at 60–120 min from 1.258 ± 0.013 to 1.561 ± 0.005 $\mu\text{g/mL}$. However, at 150 min, there is a slight decrease, and the value is not significantly different from the 120 min mark of 1.530 ± 0.005 $\mu\text{g/mL}$. This can be attributed to the interaction between carotenoids and pectin in the cell wall during hydrolysis. As the decomposition and migration of TCC occurs, the concentration of TCC increases [31,35]. Therefore, the optimal hydrolysis time for evaluating the TCC in muskmelon was 120 min.

3.2.4 Influence of temperature on hydrolysis process

The results presented in Figure 8 demonstrate that the temperature of pectin hydrolyzate has a significant impact on both the efficiency of liquid recovery and the transmittance of muskmelon juice. This difference is statistically significant ($p < 0.05$) when compared to other temperatures. As the enzyme incubation temperature increases to 40°C, the recovery efficiency initially decreased and then

increased. The maximum efficiency is observed at higher temperatures around 45°C, while at remaining temperatures of 40°C and 50–55°C, a decrease in recovery efficiency is observed. This is due to the fact that higher temperatures reduced enzyme activity leading to reduced recovery efficiency. On the other hand, lower temperature can slow down the reaction rate and decrease the solubility of pectin in water, ultimately leading to a decrease in solution recovery. These findings demonstrate that temperature plays a crucial role in the optimal activity of the pectinase enzyme, resulting in a higher cleavage ability and a larger amount of fluid released [36]. This result is consistent with the previous research on fruit juice by Sagu et al. [33] and Sandri et al. [32,37]. Therefore, in order to achieve optimal recovery efficiency, the hydrolysis temperature of pectinase enzyme needs to be carefully adjusted. It should be high enough to completely hydrolyze pectin, but not too high so as not to reduce the enzyme's activity. It can be concluded that a hydrolysis temperature of 45°C is ideal for muskmelon juice, as it showed a good recovery efficiency of $86.17 \pm 0.63\%$ and a high transmittance of $35.59 \pm 0.25\%$.

Figure 9 illustrates the impact of temperature on pectin hydrolysis and the levels of TAA, TPC, and TCC in muskmelon juice. The results indicate that TAA increases between 40 and 45°C, reaching its peak at 45°C with a value of 4.58 ± 0.41 mg/mL. However, TAA gradually decreases between 50 and 55°C. This difference is statistically significant ($p < 0.05$) compared to other hydrolysis temperatures. The chart clearly shows a significant drop in TAA at temperatures of 50–55°C. This can be attributed to the denaturation of the pectinase enzyme at high temperatures, leading to a decrease in vitamin C content and the destruction of unstable antioxidant groups. Vitamin C is known to be sensitive to heat treatment [38]. These findings are consistent with previous research by Chauhan et al. [27].

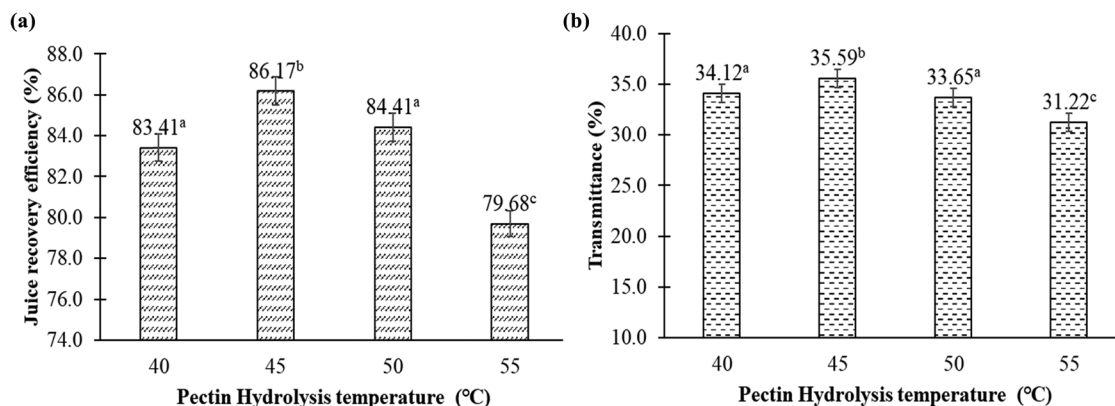


Figure 8: Hydrolysis temperature affects recovery efficiency and transmittance. (a) Recovery efficiency (%) and (b) transmittance (%). a, b, c, and d represent the difference between treatments.

Therefore, the appropriate temperature for processing muskmelons with pectinase enzyme is 45°C.

Figure 9 shows that TPC increased initially slightly and reached its peak at 45°C, with a value of 104.13 ± 0.23 mg GAE/100 mL. However, at higher temperatures of 50 and 55°C, the polyphenol content decreased from 99.198 ± 0.96 mg GAE/100 mL to 93.926 ± 0.56 mg GAE/100 mL. This decrease in polyphenolic compounds can be attributed to thermal decomposition and diffusion of compounds present in the fruit juice during hydrolysis [39]. It is worth noting that temperatures $\geq 50^\circ\text{C}$ resulted in significantly lower TPC compared to temperatures at 40 and 45°C. This can be explained by the fact that higher temperatures cause decomposition of active polyphenols, leading to a loss of their antioxidant properties in the fruit juice. Therefore, conducting pectin hydrolysis at lower temperatures may have a minimal impact on the TPC [40]. Based on these findings, a temperature of 45°C seems to be the most suitable for pectin hydrolysis, which is consistent with the results of a study by Kaur *et al.* on the effectiveness of pectinase enzyme on guava juice in terms of hydrolyzed pectin, to obtain high TPC in muskmelon juice [41].

Figure 9 illustrates the impact of pectinase enzyme on the total carotenoid content of muskmelon juice, with the temperature of pectin hydrolyzate being a key factor. The optimal temperature for maintaining the highest carotenoid content is 45°C, with a value of 1.519 ± 0.01 µg/mL.

This result is statistically significant ($p < 0.05$) when compared to temperatures ranging from 40 to 55°C. The fluctuation in carotenoid content can be attributed to the breakdown of pectin, which releases carotenoids from the chloroplasts and liquid cells present in the fruit juice [42]. As shown in Figure 9, the total carotenoid content tends to increase at temperatures between 40 and 45°C, as the pectinase enzyme facilitates the release of pigments from plant cells, resulting in a higher carotenoid content [43]. However, at temperatures of 50–55°C, the total carotenoid content decreases from 1.376 ± 0.43 to 1.233 ± 0.85 µg/mL, as the higher temperature limits this process. The oxidation of carotenoid pigments also contributes to the decrease in total carotenoid content. These findings suggest that the most suitable temperature for pectin hydrolysis to retain carotenoid content and color is 45°C. This is consistent with the results of a study on mixed juices conducted by Wellala *et al.* [44].

3.3 Influence of factors in the mixing process on muskmelon juice products

3.3.1 Effect of added hydrolyzed muskmelon juice content on product quality

The bright and attractive color of muskmelon juice is due to the presence of color pigments [45]. According to the

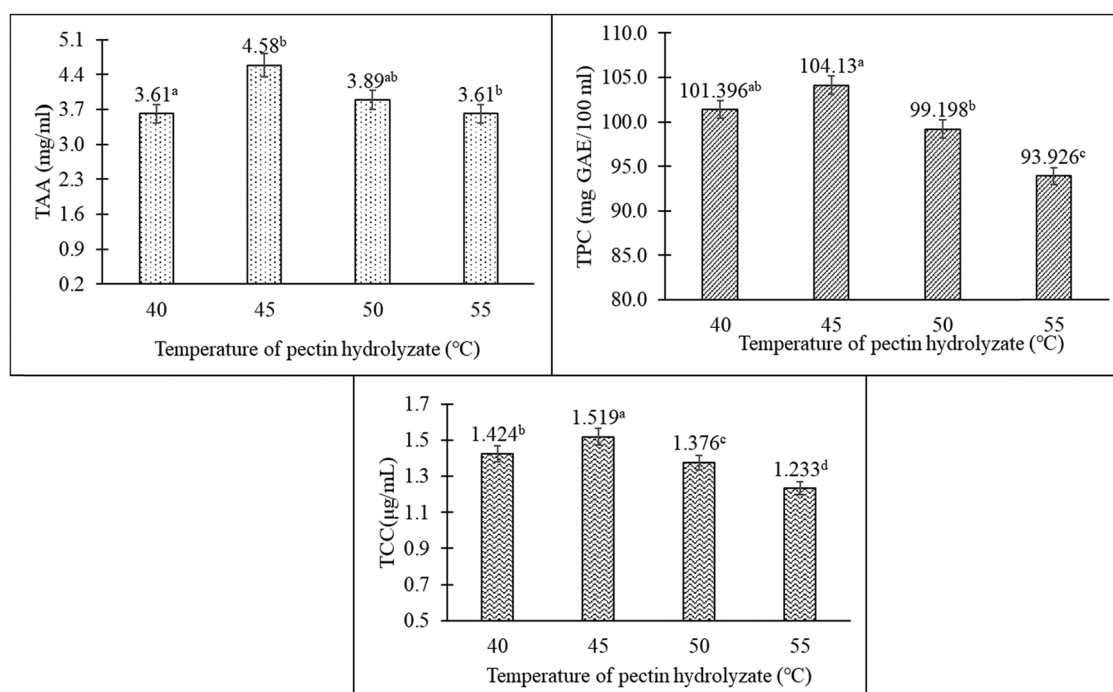


Figure 9: Hydrolysis temperature affects TAA, TPC, and TCC. a, b, c, and d represent the difference between treatments.

results in Table 2, the brightness of the juice gradually decreases as the amount of hydrolyzed muskmelon juice added increases. The highest L^* level (33.17 ± 0.05) was achieved with a 10% hydrolyzed muskmelon juice content, while the lowest level ($L^* = 29.31 \pm 0.07$) was observed with a 25% hydrolyzed muskmelon content. Initially, the drink consisted of water, syrup, and some additional ingredients mixed with melon juice. However, as the amount of hydrolyzed muskmelon juice added increases, the molecules in the water become more difficult to penetrate, resulting in turbidity and reduced brightness of the muskmelon drink.

On the contrary, the results in Table 2 for brightness (L^*), redness (a^*), and yellowness (b^*) show discrepancies with the findings of Parveen et al. regarding changes in cantaloupe properties. The L^* , a^* , and b^* values in our study were 65.25, -4.65 , and 23.47 , respectively [46]. Additionally, the ANOVA analysis showed significant differences in structure, color, smell, taste, and preference for muskmelon drink ($p < 0.05$), indicating a significant change in content. This suggests that the addition of muskmelon juice to the mixture has a clear effect on the sensory quality of the cantaloupe drink.

The results presented in Figure 10 illustrate the sensory characteristics and color of the product at varying levels of melon juice content (5, 10, 15, and 20%). As the amount of muskmelon juice increases, the sensory scores for all indicators also increase gradually. However, it was evident that a 10% melon content results in the lowest ratings for texture, color, odor, and taste, which could potentially have a negative impact on the product's popularity. This is due to the fact that the desired color, smell, and taste of the product are not achieved with this level of muskmelon juice. The use of muskmelon juice has resulted

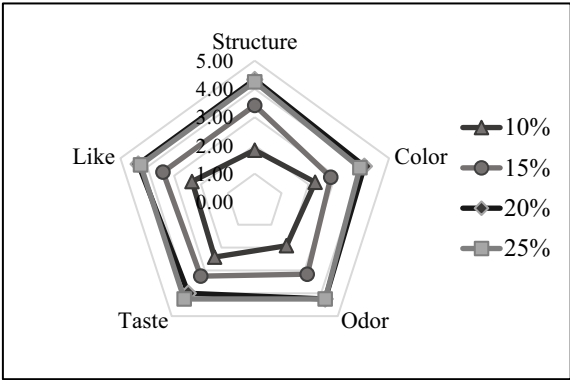


Figure 10: The content of muskmelon juice affects the sensory quality of the product.

in an unpleasant experience for consumers. As shown in the sensory score chart, consumer preference tends to increase from 3.42 ± 1.13 to 4.18 ± 0.43 as the melon juice content increases from 15 to 25%. However, the evaluation results in Figure 10 shows no significant difference in scores between 15 and 20% melon juice content. Lower juice additions were associated with lower liking, with tasters citing light color and reduced flavor as the main reasons. Therefore, to achieve economic efficiency for the product, a muskmelon juice content of 20% was suitable for both consumer tastes and product manufacturers.

Figure 11 illustrated the impact of adding muskmelon juice on the appearance of product. The viscosity of the muskmelon juice was found to be closely linked to its stability and sensory properties, with significant differences observed between the two. This can be attributed to the molecular weight of macromolecules such as pectin, proteins, and polysaccharides, as well as intermolecular forces like hydrogen bonds, which all play a role in determining

Table 2: Color value of muskmelon drink at different muskmelon juice content

Color	10%	15%	20%	25%
Figure				
L^*	$33.17^a \pm 0.05$	$31.91^b \pm 0.04$	$30.70^c \pm 0.03$	$29.31^d \pm 0.07$
a^*	$8.81^d \pm 0.04$	$9.21^c \pm 0.03$	$9.66^b \pm 0.03$	$10.44^a \pm 0.03$
b^*	$15.11^d \pm 0.04$	$16.86^c \pm 0.05$	$17.63^b \pm 0.02$	$18.43^a \pm 0.05$

Data are expressed as mean value $\pm$ standard deviation with $n = 3$. a, b, c, and d represent the difference between treatments.

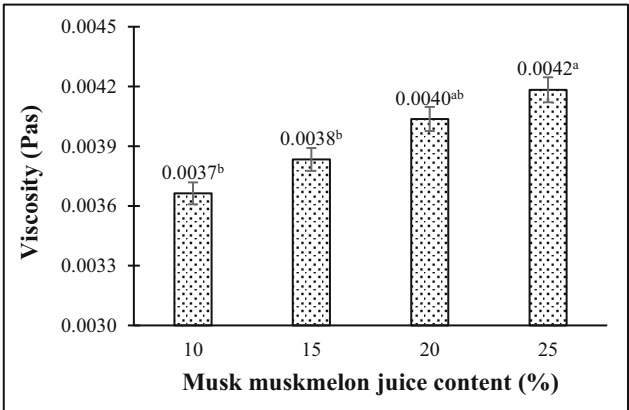


Figure 11: Muskmelon juice content affects product viscosity. a, b, c, and d represent the difference between treatments.

viscosity [47]. As shown in Figure 11, the addition of muskmelon juice resulted in an increase in viscosity, with the highest viscosity (0.0042 Pa s) observed at 25% added cantaloupe juice and the lowest (0.0037 Pa s) at 10% additional muskmelon juice. This trend is due to the fact that the juice has a lower viscosity compared to other ingredients in muskmelon juice, and adding more liquid leads to an overall increase in viscosity.

3.3.2 Effects of Brix affects product quality

Table 3 shows the color of muskmelon juice at different Brix degrees (Brix 10, Brix 11, Brix 12, and Brix 13). As the Brix level increases, the brightness of the muskmelon juice also increases. At a Brix level of 10, the juice has a bright orange color, which gradually changes to a lighter orange at a Brix level of 13. The chemical compounds present in muskmelon juice not only contribute to its characteristic aroma, but also affect its taste and overall drinking experience. Some of these compounds can even impact the taste cells in the mouth, altering the perceived sweetness of the muskmelon. Despite changes in Brix level, the smell of the product remains relatively consistent. Ultimately, taste is the most important factor in consumers' preference for muskmelon drink. The brightness of the juice was found to be lowest at a Brix level of 10 ($L^* = 30.35 \pm 0.09$) and highest at a Brix level of 13 ($L^* = 41.36 \pm 0.04$). This can be attributed to the fact that as the Brix level increases, the molecules in the drink become less dispersed in water, making them more prone to light scattering and resulting in a brighter appearance of the muskmelon juice.

Adjusting the level of sweetness to match consumer preferences not only extends the shelf life of the product, but also creates a well-balanced blend of sweet and sour flavors that are characteristic of the product. In a study conducted with 12 testers, various factors such as texture, color, scent, and taste were evaluated and rated on a scale of 0–5, with six levels. The results of the ANOVA analysis showed that there was no significant difference in color and taste among the four samples with $p > 0.05$. However, there was a significant difference in the remaining two indicators, with $p < 0.05$. This suggests that altering the TSS has a noticeable impact on consumer preferences and taste.

Figure 12 illustrates that the ratings given by consumers for muskmelon drink are consistent in terms of color and scent across all four product samples. However, at a total dissolved solid concentration of Brix 12, it received an average score. The highest average score for taste was 4.01 ± 0.22 points, while the scores for structure and liking were also higher than the average for the remaining three samples at 3.92 ± 0.32 and 4.25 ± 0.22 points, respectively. As the concentration of soluble solids in the syrup solution increased, the sweetness gradually intensified and became well-balanced with the melon flavor. The interaction between sugar and additives in muskmelon juice can greatly influence the aroma and taste of the drink. At Brix 12, the muskmelon juice had a moderate level of sweetness that enhanced the natural fruit flavor. Additionally, it had moderate viscosity, which is preferred by consumers, making it the chosen sample for further research and product development.

Figure 13 illustrates the impact of TSS on the viscosity of muskmelon juice. The highest and lowest viscosities

Table 3: Color value of muskmelon drink at different brix levels

Color	Brix			
	10	11	12	13
Figure				
L^*	$30.35^d \pm 0.09$	$31.14^c \pm 0.05$	$31.79^b \pm 0.09$	$41.36^a \pm 0.04$
a^*	$9.87^a \pm 0.06$	$9.72^b \pm 0.06$	$9.66^c \pm 0.08$	$9.55^d \pm 0.07$
b^*	$16.76^a \pm 0.06$	$16.68^c \pm 0.04$	$16.72^b \pm 0.06$	$16.62^d \pm 0.04$

Data are expressed as mean value $\pm$ standard deviation with $n = 3$.

a, b, c, and d represent the difference between treatments.

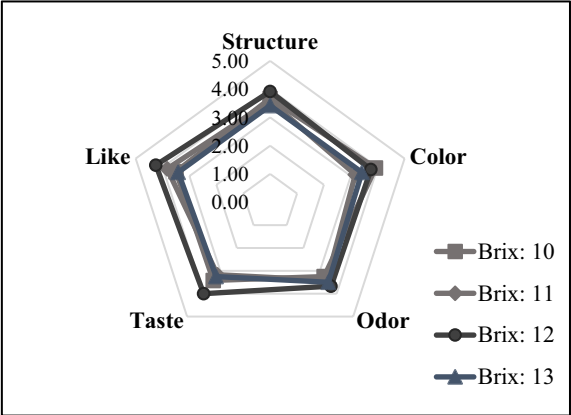


Figure 12: TSS affect the sensory quality of the product.

(0.0044 and 0.0039 Pas) were observed at Brix 13 and Brix 10, respectively. The viscosity increased proportionally with the TSS of the product [47]. TSS represents the sugar concentration in muskmelon juice, and the sugar molecules in muskmelon juice have the ability to interact with water by forming hydrogen bonds. As the sugar concentration in the melon drink increases, the interaction between sugar and water molecules becomes stronger, resulting in more hydrogen bonds and an increase in viscosity [48]. This demonstrates the direct correlation between TSS and viscosity, which is supported by previous studies on sapoche juice and watermelon juice [49–51].

3.3.3 Effects of citric acid concentration affecting product quality

Citric acid is a compound with a naturally sour taste. An increase in citric acid content in muskmelon drink can

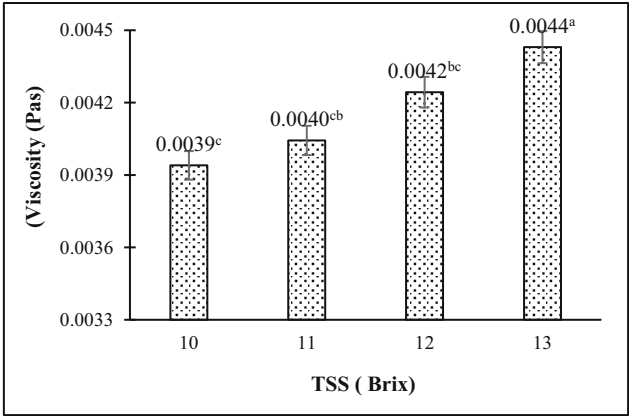


Figure 13: TSS content affects product viscosity. a, b, c, and d represent the difference between treatments.

Table 4: Color value of muskmelon drink at different citric acid contents

Color	Acid citric			
	0.02%	0.04%	0.06%	0.08%
Figure				
<i>L*</i>	31.36 ^a ± 0.11	31.18 ^c ± 0.08	31.23 ^b ± 0.11	31.03 ^d ± 0.15
<i>a*</i>	9.90 ^a ± 0.06	9.70 ^c ± 0.09	9.83 ^b ± 0.03	9.60 ^d ± 0.08
<i>b*</i>	16.66 ^b ± 0.13	16.58 ^c ± 0.09	16.40 ^d ± 0.05	16.73 ^a ± 0.05

Data are expressed as mean value ± standard deviation with *n* = 3. a, b, c, and d represent the difference between treatments.

increase the acidity of the product. Adjusting the citric acid content can satisfy consumers' sour taste preferences and stimulate their taste buds. Not only does it affect the sour taste, citric acid also provides a fresh and natural flavor for muskmelon juice.

Table 4 shows the sensory and color characteristics of muskmelon juice at varying concentrations of citric acid (0.02, 0.04, 0.06, and 0.08%). As the amount of citric acid increases, the *L** brightness of the juice also changes. This is due to certain compounds in the juice that can affect the taste cells in the mouth, altering the perception of sweet and sour flavors. The aroma of the juice, however, remained relatively consistent across all levels of citric acid. Taste is a crucial factor in determining consumer preferences for muskmelon juice. The results of ANOVA showed a significant difference in liking and taste (*p* < 0.05). However, there were no significant differences in structure, color, and odor among the four samples (*p* > 0.05). This demonstrates that varying the citric acid content in muskmelon juice can greatly impact consumer taste and preferences.

The results in Figure 14 show that the evaluated scores are quite uniform. When changing different acid concentrations, the structure, color, and scent of the product did not change significantly. When the mixing ratio was gradually increased from 0.02 to 0.08%, the evaluation score also gradually increases, the sweet and sour taste increases but decreases at 0.02%. Adding 0.04% acid to the product gave the highest average taste and liking scores of 3.83 ± 0.34 and 3.92 ± 0.22 due to balance with sour taste. The natural sweetness of the juice, compared to 0.08%, is unfavorable because the sourness overwhelms the inherent sweetness of the melon.

Figure 15 shows the effect of acid concentration on viscosity. The highest and lowest viscosities (0.0043 and

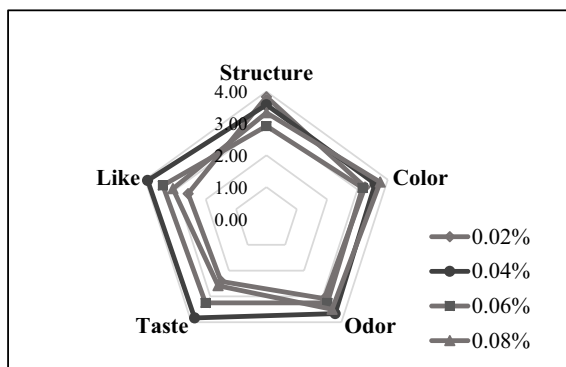


Figure 14: Citric acid concentration affects the sensory quality of the product.

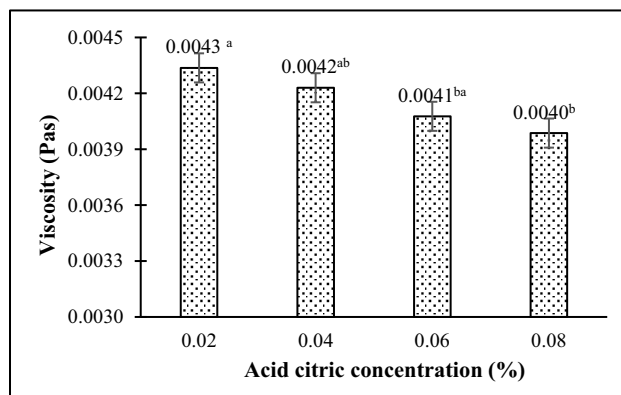


Figure 15: Citric acid concentration affects viscosity. a, b, c, and d represent the difference between treatments.

0.0040 Pas) were obtained at 0.02 and 0.08% acid concentration, respectively. This indicates that the viscosity of muskmelon juice decreases with increasing acid concentration. This can be attributed to the presence of water molecules in muskmelon juice, which form a network and interact with each other through hydrogen bonds. When acid is added, it affects these water molecules and lowers the pH of the juice [52]. Additionally, these ions also have the ability to disperse molecules in water [53]. As a result, as the acid concentration increases, the dispersion of water molecules also increases, leading to a decrease in the viscosity of muskmelon juice.

3.3.4 Effects of stabilizing additives on product quality

Stabilizing additives are substances used in product that help improve the stability and enhance the quality of the

product. The aim is to create uniformity in the product, prevent segregation of the ingredients. This helps to create viscosity, evenly disperse the ingredients and maintain a stable viscosity throughout the product. This process also helps to prevent segregation or clumping of the ingredients. In addition, it also limits the phenomenon of precipitation that may occur. The aim is to ensure that the product remains uniform and stable throughout the manufacturing process, transportation and storage [54,55].

Table 5 illustrates the impact of concentration and type of additive on the L^* , a^* , and b^* indices. The L^* value of pectin increases with higher concentrations, reaching its peak at 0.04% with a value of 32.42 ± 0.79 . Conversely, the lowest L^* value is observed in the xanthan gum additive at a concentration of 0.01%, with a value of 29.02 ± 0.18 . This can be attributed to the ability of certain stabilizing additives to influence the chemical reactions of the ingredients

Table 5: Color value of muskmelon drink with different types and contents of additives

Color index	Concentration (%)	Type of additive		
		Pectin	CMC	Xanthan gum
L^*	0.01	$30.54^b \pm 0.62$	$31.54^f \pm 0.16$	$29.02^l \pm 0.18$
	0.02	$32.29^{cb} \pm 0.05$	$30.88^h \pm 1.33$	$31.10^i \pm 0.17$
	0.03	$32.39^{bc} \pm 0.57$	$31.26^g \pm 0.98$	$31.18^i \pm 0.09$
	0.04	$32.42^a \pm 0.79$	$31.95^e \pm 0.43$	$29.78^k \pm 0.07$
a^*	0.01	$9.23^b \pm 0.59$	$9.42^e \pm 0.00$	$9.90^l \pm 0.06$
	0.02	$9.15^c \pm 0.53$	$9.30^{gf} \pm 0.01$	$9.78^{lk} \pm 0.09$
	0.03	$9.27^a \pm 0.98$	$9.28^{fg} \pm 0.00$	$9.70^{kl} \pm 0.09$
	0.04	$9.26^a \pm 0.04$	$9.18^h \pm 0.00$	$9.60^m \pm 0.08$
b^*	0.01	$16.16^a \pm 0.04$	$16.62^e \pm 0.02$	$16.52^{kl} \pm 0.02$
	0.02	$15.90^{bc} \pm 0.57$	$16.43^f \pm 0.11$	$16.66^{ik} \pm 0.07$
	0.03	$15.88^{cb} \pm 0.53$	$16.38^g \pm 0.22$	$16.58^{il} \pm 0.09$
	0.04	$15.36^d \pm 0.01$	$16.22^h \pm 0.03$	$16.39^m \pm 0.01$

Data are expressed as mean value $\pm$ standard deviation with $n = 3$.

a–m represent the difference between treatments.

in muskmelon drink. Additionally, these additives can also interact with light, resulting in a change in the color of the muskmelon juice. For instance, xanthan gum, a natural polysaccharide derived from *Xanthomonas campestris* bacteria, aids in enhancing product stability, reducing separation, and reshaping particles within the product [56].

After conducting a sensory evaluation experiment with 12 participants, the results revealed that the addition of stabilizing additives, such as pectin, sodium carboxymethyl cellulose (CMC), and xanthan gum, at concentrations ranging from 0.01 to 0.04%, had a significant impact on the product's structure, color, taste, and texture. The consumers also showed a clear preference for the product ($p < 0.05$).

Figure 16 shows that the addition of 0.03% xanthan gum has resulted in high quality and uniformity in the evaluation criteria. This specific concentration achieved the highest ratings for structure (3.67 ± 0.06), scent (3.42 ± 0.02), and liking level (3.23 ± 0.09). Furthermore, the use of xanthan gum, which has stable gel-forming properties and does not have a color or scent, results in a stable structure and does not affect the natural flavor of the muskmelon drink [57]. Pectin, a polysaccharide derived from fruits such as apples and oranges, can also increase product consistency, but does not create high viscosity like xanthan gum. Another option for adjusting product consistency and viscosity during production is CMC, a type of cellulose treated with carboxylic acid [58,59].

However, in the case of xanthan gum, the addition of pectin was evaluated at a low level in all criteria. Specifically, at a concentration of 0.03%, it received the lowest preference score of 2.67 ± 0.07 and the scent only reached 3.34 ± 0.02 . This suggests that the pectin additive at a concentration of 0.01% is too low to provide product stability, resulting in sedimentation and separation in the structure. On the other hand, a

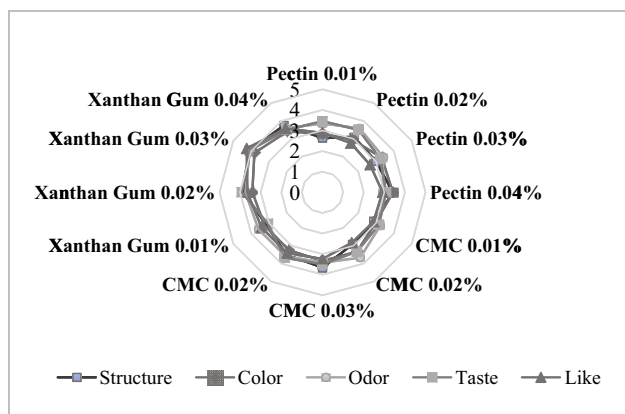


Figure 16: Concentration and type of stable additives affects the sensory quality of the product.

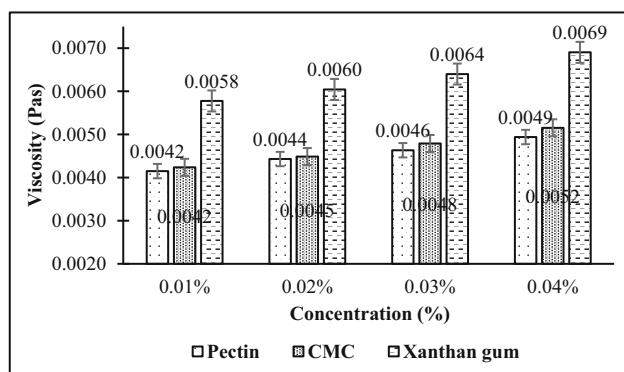


Figure 17: The concentration and type of stabilizing additives affect product viscosity.

concentration of 0.04% of pectin negatively affects the scent and taste. The lowest scores for these characteristics were 3.45 ± 0.14 and 3.08 ± 0.18 , respectively. The results indicate that consumer preference is not high when using the CMC stabilizer additive at any of the four different concentrations, with an average preference score ranging from 2.82 ± 0.07 to 3.51 ± 0.18 points. Therefore, based on the sensory evaluation and statistical data processing, it can be concluded that the optimal concentration for the xanthan gum additive is 0.03%, and this will be used for the subsequent experiments.

Figure 17 illustrates the impact of additive concentration and type on viscosity. As the concentration of the additive increases, so does the viscosity of the product. The highest viscosity (0.0069 Pas) was observed at a concentration of 0.04% xanthan gum, while the lowest (0.0058 Pas) was seen at a concentration of 0.01% pectin. This can be attributed to the ability of xanthan gum to form a network within the mixture, which interacts with water molecules to create a gel-like structure. This structure restricts the movement of water molecules, resulting in a higher viscosity. As the concentration of the additive increases, the network becomes stronger and more gel-like structures are formed, leading to a higher overall viscosity. Additionally, higher concentrations of additives can also increase viscosity by creating stronger interactions between additive molecules, making it more difficult for them to move, resulting in a highly viscous environment. However, these results are lower than those reported by Ghafoor, who obtained viscosity values of 0.0125–0.0147 [60].

4 Conclusion

This study aimed to investigate the physicochemical properties of muskmelon, including hydrolyzed muskmelon juice,

and the mixing process of muskmelon juice products. The results showed that the muskmelon had a pH of 6.43 ± 0.01 , Brix of 10.20 ± 0.25 , TA of $0.102 \pm 0.006\%$, TPC of 92.24 ± 0.61 mg GAE/100 mL, TAA of 3.08 ± 0.24 mg/g, TFC of 0.38 ± 0.01 mg QE/mL, and TCC of 0.84 ± 0.006 µg/g. The optimal conditions for hydrolysis were found to be 0.2% pectinase enzyme concentration, pH 5.0, 120 min of hydrolysis time, and a temperature of 45°C. Additionally, the effect of different mixing ratios on product quality was researched, including Brix level [10–13], citric acid concentration (0.02–0.08%), and additive type (pectin, CMC, xanthan gum) at a ratio of 0.01–0.04%. After mixing and evaluation, it was found that a Brix level of 12, citric acid concentration of 0.04%, and a ratio of 0.03% xanthan gum additive produced a product with a harmonious flavor and characteristic color that was suitable for consumer tastes. The results of this research are the basis for the production of products on an industrial scale to diversify and enhance the value of muskmelon as well as increase the choice of nutritional supplements from muskmelon.

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Conflict of interest: Authors state no conflict of interest.

Ethical approval: The conducted research is not related to either human or animal use.

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