Versi Online: http://journal.ipb.ac.id/index.php/jtip
https://doi.org/10.6066/jtip.2022.33.2.148
Hasil Penelitian

J. Teknol. dan Industri Pangan
Vol. 33(2): 148-156 Th. 2022 ISSN: 1979-7788
Terakreditasi Ristekdikti: 164/E/KPT/2021

The Influence of Xanthan Gum and Lemon Juice on the Quality of Tomato Sorbet

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Received March 21st 2022 / Accepted August 22nd 2022

ABSTRACT

Sorbet is one of common frozen desserts. It is prepared with low concentration of fat and protein; thus, the use of stabilizer in sorbet formulation extremely dictates the final properties. This current work investigated the quality (hardness, total solids, °Brix, viscosity, overrun, melting rate, vitamin C, lycopene content, and organoleptic test) of tomato-based sorbet added with different levels of xanthan gum as the stabilizer and lemon juice as the taste improver. The results showed that increase in xanthan gum level up to 0.5% was able to improve the overrun, melting rate, and lycopene content, *i.e.* 35%, 0.84 g/min, and 1.66 mg/100 g, respectively. Meanwhile, the addition of lemon juice into sorbet formulation could increase the content of vitamin C. Furthermore, addition of lemon juice was effective in removing the unpleasant tomato taste in the sorbet, but it did not affect the hardness, total solids, °Brix, lycopene content, viscosity, overrun, and melting rate.

Keywords: lemon juice, lycopene, sorbet, tomato, xanthan gum

INTRODUCTION

In 2019, tomato production in Indonesia is estimated at 1 million tons, with annual growth of 4.5%. However, the high production has remained a problem since 14–15% of them are wasted (Susilawati and Wahyuningsih, 2020). Further efforts focusing on reduction of wasted tomato are required, including how to convert tomato into valuable products. This concern is important regarding the nutritious and active components in tomato, such as lycopene (0.72-20 mg/100 g) and vitamin C (9.19-67.6 mg/100 g). Both components were reported to exert antioxidant properties (Sánchez-Moreno *et al.,* 2006). Therefore, their presence can enhance functional benefits of food products, such as sorbet.

Sorbet, a frozen dessert, mainly comprised of water, sugar, and stabilizer (Migoya, 2008), without adding milk as found in ice cream. To improve flavor and texture, fruit extract is usually added to sorbet. In this work, tomato-based sorbet can provide freshness to frozen desserts and deliver high nutrition due to its lycopene and vitamin C content. The formulation of sorbet influences its textural, rheological, and organoleptic quality. Due to a lack of fat and protein, sorbet rheology can be improved by adding a stabilizer. Stabilizers are a group of water-soluble biopolymers with a molecular weight of 10^5–10^6 kDa, enabling to produce a viscous solution. Most stabilizers are natural polysaccharides, such as starch, guar gum, xanthan gum, and carboxymethyl cellulose (CMC). Stabilizers interact with the water phase to provide stable structure and aeration (Goff, 2019).

Xanthan gum, a polysaccharide produced by *Xanthomonas campestris* bacteria, constitutes an excellent hydrocolloid (Freitas *et al.,* 2013; Sworn, 2021). Unlike many polysaccharides, xanthan gum is soluble in cold water and exhibits pseudoplastic flow (Sworn, 2021). Due to its non-toxic and non-irritant characteristics, xanthan gum is a favorite stabilizer in food and pharmaceutical industries.

The use of tomato for sorbet can play dual functions, *i.e.* nutritional source and flavor enhancer. Unfortunately, modern commercial tomatoes are less tasteful and give an unpleasant aftertaste. The disagreeable taste of tomato might be influenced by many components, such as tannins responsible for bitterness and astringency (drying and puckering sensation in the oral cavity) and (2E)-3-(3-pentyl-2-oxiranyl)acrylaldehyde causing metallic aftertaste (Cheng *et al.,* 2020; He *et al.,* 2015). The reduction of apocarotenoids can also worsen the flavor quality of tomato, producing a tangy taste. The tomato flavor constitutes a complex interaction between components and volatile aromatic compounds that are derived from multiple precursors such as fatty acids, amino acids, and carotenoids. The flavor quality closely relates to genetic factor, handling procedures and storage condition (Kanski *et al.,* 2020).

Various researchers have evaluated the organoleptic and rheology of fruit extract sorbet and ice cream. Pavlyuk *et al.* (2018) studied sorbet prepared

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from various fruits, such as cherry, apple, blackberry, sea buckthorn, pumpkin, spinach, olive, and lemon. In their work, sorbets were produced at high freezing rate to reach -60 and -100°C, aiming to maintain the biologically active substances of the fruits. Red palm olein (RPOL) was incorporated with guar gum as a stabilizer in low-fat ice cream. It was found that 0.1% RPOL and 0.4% guar gum resembled the texture of commercial ice cream (Ismail *et al.,* 2020). Xanthan gum, palm oil, and lecithin were combined as stabilizers in tomato ice cream making. It was noted that the viscosity of ice cream increased as the amount of tomato juice enhanced. The sample containing 6.25% of tomato juice showed a satisfied level of color and organoleptic properties (Kabir *et al.*, 2020). Another work reported the various uses of sucrose and CMC as stabilizer in the production of blackberry sorbet, finding that stabilizer concentration remarkably influenced the texture, overrun, and vitamin C concentration. The best formulation was achieved at CMC 0.3% and sucrose 25%, which produced sample containing vitamin C of 22.16 mg/100 g (Cahyadi *et al.,* 2017). Starfruit extract-based sorbet was also reported (Seftiono *et al.,* 2020), resulting in the best formulation at ratio of sugar and lemon juice of 5:3. The proportion increased overrun and melting time to 23.52% and 43 min, respectively. The addition of polysaccharides (CMC, xanthan gum, pectin, and agar) improved color and texture of sorbet. Xanthan gum 1% gave the best texture, but overrun was still low at about 0.48% (Nurbaya *et al.,* 2021).

In despite of the large number of investigations on formulation of sorbet and ice cream, the study discussing formulation and quality of tomato-based sorbet is rather scarce. This present work attempted to determine the influence of xanthan gum and lemon juice on tomato sorbet quality. Xanthan gum was selected as a stabilizer due to its solubility in hot and cold water and pH resistance, while lemon juice was added to remove unpleasant aftertaste.

MATERIALS AND METHODS

Materials

Ripe and red tomatoes were obtained from local market at Gandok Ciumbuleuit, Bandung, Indonesia. Food grade xanthan gum (Fufeng, China) was applied as a stabilizer, while lemon juice concentrate (Siracuse, Italy) was obtained online. Amylum (starch indicator) and 5% iodine solution were used to determine vitamin C or ascorbic acid in tomato juice and sorbet. Both were obtained from Brataco Chemika. Hexane, acetone, and ethanol solutions (Merck, Germany) were used as a solvent to analyze lycopene concentration. Lycopene analytical standard (purity 90%, Sigma Aldrich, Germany) was employed to create a standard curve.

The preparation of tomato sorbet

Clean tomatoes were blanched at 90°C for 10 min using steam (Ramadhany *et al.*, 2021). Blanched tomatoes were peeled, while the seeds were removed. The tomatoes were blended in a food processor (Princess Pro-21700, The Netherlands) to produce juice. The °Brix value of the juice was measured using a refractometer (ATAGO, Japan).

The basic formulation of tomato sorbet was based on formulation by Migoya (2008) and could be seen in Table 1. All dry ingredients (sugar and stabilizer) were added quickly into 40°C water while stirring. The mixture was mixed and heated up to 85°C for 2 min. Subsequently, it was chilled to reach 4°C. Tomato juice and lemon juice was mixed with the mixture and incubated for 2 h to yield sorbet base. It was then agitated for 20 min to reach -6°C using an ice cream maker (Kenwood IM280, UK). The sorbet was left to solidify in a freezer (-10°C) for 4 h.

Table 1. The formulation of tomato sorbet

Ingredients	Weight Percentage
Tomato juice	35
Sugar	27
Stabilizer	0.25; 0.5; 0.75 (varied)
Water	31.25–36.75
Lemon juice	2; 4; 6 (varied)
Total	100

Determination of lycopene and vitamin C

Lycopene and vitamin C contents in tomato juice and sorbet samples were determined using spectrophotometry and iodometric titration methods (Ramadhany *et al.*, 2021). For quantification of vitamin C, distilled water was added to a 25 mL of sample to make 50 mL of total volume. A 10 mL of mixture were transferred into a 50 mL Erlenmeyer flask. A few drops of the starch indicator were added to the sample, followed by titration with iodine solution until discoloration occurred.

For quantification of lycopene, sample (±5 g) was dissolved with 50 mL of solvent (2:1:1 v/v/v of hexane, acetone, and ethanol) in 100 mL Erlenmeyer flask. The solution was stirred using a magnetic stirrer for 30 min, then filtered using a Buchner funnel. The filtrate was mixed with 10 mL of distilled water to form two layers (polar and non-polar). Polar solution at the top layer was transferred into a 100 mL Erlenmeyer flask containing the solvent. Absorbances were detected using a UV-Vis spectrophotometer (Genesys 20, USA) at 470 nm.

Physical quality analysis

Physical quality (color, °Brix, total solid, overrun, viscosity, hardness, melting time) of tomato was determined. All measurements were performed at room temperature after sample tempering to 10°C. Color measurement of the samples followed CIELAB system (L* represents sample brightness; a* represents chromaticity of red-green; b* represents chromaticity of blue-yellow). In addition, color difference (ΔE) between reference sorbet (S0) and formulated sorbet (containing lemon juice and xanthan gum) was calculated using Equation 1. The °Brix value was measured by refractometer (ATAGO, Japan) at room temperature. At the same time, the sample was tempered at 10°C. The total solid in wet weight basis (wb) was determined by drying 3 g of sample in the oven at 105°C until reaching constant weight (Singo and Beswa, 2019). The total solid percentage was calculated using equation 2.

$$\Delta E=\sqrt{(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2} \quad \ldots (1)$$

$$\text{Total Solids (\%)}=\frac{\text{weight before drying}-\text{weight after drying}}{\text{weight before drying}}\times 100\% \quad \ldots (2)$$

The mix viscosity was determined using a rheometer (Brookfield, USA). The sorbet was taken at 10°C, and the rheometer was operated at 30 rpm for 30 seconds (De la Cruz Martínez *et al.,* 2020). The results were recorded in duplicate. The hardness of tomato sorbet was estimated using a texture analyzer (CT3 Brookfield, USA), measured at room temperature. Briefly, sorbet was taken at 10°C and cut into 4x2 cm sizes (Kabir *et al.,* 2020). The trigger, initial distance between the grips, and the initial velocity of the Texture Analyzer were adjusted to 7.5 g, 30 mm, and 0.5 mm/s.

The melting rate of sorbet was determined by placing tomato sorbet (10 g) in a wire mesh screen. The time when tomato sorbet completely melted was indicated as sorbet melting time (Singo and Beswa, 2019). The sorbet overrun procedure referred to the method by Daw and Hartel (2015). A 500 mL of sorbet base was filled into a 1 L container. The weight before and after churning was measured using equation 3.

$$\text{Overrun(\%)}=\frac{\text{Weight of sorbet base after churning}-\text{Weight of sorbet base}}{\text{Weight of sorbet base}}\times 100\% \quad (3)$$

Organoleptic analysis

Organoleptic test involved 50 untrained panelists (aged 18-45 years old; from various occupational backgrounds; ±60% of them are women) in a daylight condition based on rate-all-that-apply (RATA) at Parahyangan Catholic University following Adawiyah *et al.* (2020). The panelists were carefully diagnosed to meet requirement, *i.e.* actual product users of ice cream and sorbet. Five sessions of test were given to each panelist, in which two samples were introduced in each session. Prior to test, the panelists received experimental details including sensory variables (*i.e.* aftertaste, sourness, sweetness, hardness, gummy, watery, creamy, icy mouthfeel) used in this test. The order of presentation was randomized to reduce subjectivity. During the test, panelists were asked to taste the sample and fill their preference score of 1-5 (extremely dislike to extremely like) in a questionnaire (Çam *et al.,* 2013).

Statistical analysis

ANOVA two-way test with replication (5% confidence interval) was conducted to determine which variable most affect the studied variables. Variables with *p*-value >0.05 were statistically insignificant (Hartmann *et al.,* 2018). The test was carried out in Microsoft Excel©. Organoleptic data followed Partial Least Square Regression (PLSR) in Unscrambler™.

RESULTS AND DISCUSSION

Characteristics of tomato juice

The tomato juice showed values of 5.5°Brix and pH 4.3 (Table 2). This conformed to previous results reporting the brix and pH of fresh tomato at 4-6°Brix and 3.39-4.92, respectively (Tigist *et al.,* 2013). Levels of °Brix and pH were important factors since both determined quantity of sugar and lemon juice required in sorbet base. Furthermore, combination of sugar and acidity could remove unpleasant and bitter taste (Chen and Amrein, 2014). However, Brix value and pH of fruit extract should not exceed 32°Brix and 3.5, respectively, which avoid over-sweet and astringency (Migoya, 2008; Hipólito *et al.,* 2016).

Table 2. The characteristic of tomato juice

Parameters	Value
°Brix	5.50±1.01
pH	4.50±0.20
Lycopene (mg/100 g)	4.76±0.82
Vitamin C (mg/100 g)	31.9±1.56

The tomato juice contained 4.76 mg/100 g of lycopene and 31.9 mg/100 g of vitamin C. This was in accordance with the previous study. Fresh tomato juice contained around 4.69±0.153 mg lycopene/100 g wb, depending on the tomato variety, ripeness, and growth conditions (Ramadhany *et al.*, 2021). According to Ramadhany *et al.* (2021) and Sánchez-Moreno *et al.* (2006), vitamin C in fresh tomato juice reached 9.19-67.6 mg/100 g wb. The composition of vitamin C in tomato depends on the tomato’s variety, ripeness, and growth.

Physical quality of tomato sorbet

The °Brix value represents the amount of dissolved sugar in the sorbet. It can be seen in Table 3 that the sorbet base samples show a similar °Brix value with an average of 28.6 °Brix because the sugar and tomato juice used in the formula was kept at 27% w/w and 35% w/w. The °Brix value of sorbet base should be in the range of 25-32°Brix to maintain the sweetness of the sorbet. Increased sugar content (>32°Brix) generated a sticky and soupy sorbet. Sugar helps to form tiny ice crystals and to trap small bubbles that caused the smooth texture of the sorbet. Sorbet with less sugar than 25°Brix had harder texture (Migoya, 2008).

The total solids represent the sum of all other components other than water, they consist of sugar and biopolymer. They affect tex-tural properties of the sorbet. Typical frozen desserts have 7-36% total solids (Fayed *et al.*, 2020), and the results of this study also showed that the total solids ranged between 28-34% wb. Xanthan gum is a poly-saccharide that improves sorbet consistency due to its property as a cryo-protectant. The increase of the xanthan gum concentration increased the total solids. Xanthan gum has a high water-binding capacity, thus limiting the diffusion of water from and to ice crystals (Syed and Shah, 2016). Restraining the diffusion of water decreased the size of ice crystals and hardness of sorbet, as shown in Table 3. A previous work also reported similar pattern, reporting that the increase of xanthan gum concentration from 0% to 0.4% would decline the hardness of ice cream from 13.22 kg to 0.6 kg (Ismail *et al.,* 2020).

The color difference (ΔE) between reference sorbet (S0) with formulated sorbet samples is dis-played in Table 3. It can be seen that ΔE value was more prominent as more xanthan gum added. Sorbet added with xanthan gum had a higher bright-ness than the reference sorbet. The bright color related to lycopene content in the sorbet (Sánchez-Moreno *et al.*, 2006). It was suggested that the addition of xanthan gum could preserve lycopene.

The influence of lemon juice is presented in Table 3. It is noted that the lemon juice addition declined pH value of the sorbet due to the acids content especially the high concentration of ascorbic acid in lemon juice concentrate (51 mg/100 mL). Lemon juice also slightly increased °Brix and total solid value due to the dissolved sugar in the lemon juice. However, the effect of lemon juice on total solids, °Brix, hardness, and color of the sorbet is negligible.

Table 4 indicates that xanthan gum affects total solids and hardness of sorbet. Meanwhile, lemon juice and its interaction with xanthan gum did not significantly alter °Brix, total solids, and hardness. These results agreed with previous explanation, as also presented in Table 3.

Mix viscosity and overrun

Figure 1 demonstrates mix viscosity and overrun of the sorbet prepared with different levels of xanthan gum and lemon juice. In reference product (S0), mix viscosity and overrun reached 0.29±0.05 Pa.s and 0%, respectively. Due to its high water-binding capa-city, the rise of xanthan gum level increased viscosity of sorbet (Syed and Shah, 2016). Addition of xanthan gum up to 0.75% at 4% of lemon juice increased the viscosity up to 0.74 Pa.s at a shear rate of 100 s^{-1}. This result was in line with Arellano *et al.* (2013), reporting that the fruit sorbet had a mixed viscosity of 0.058–2.01 Pa.s at a shear rate of 100 s^{-1}. In addition, Goff (2019) stated that dairy ice cream viscosity ranged 0.1–0.8 Pa.s at a shear rate of 115 s^{-1}.

Table 3. The influence of xanthan gum and lemon juice on sorbet

No	XG (%-w)	Lemon Juice (%-w)	pH	°Brix	Total Solid (%)	Hardness (Force g^{-1})	Color Difference ΔE
S0	0	0	4.7	27.90±0.71	28.2±1.41	9688±265	-
S1	0.25	2	4.4	28.30±0.14	31.0±0.42	8833±46	2.576
S2		4	4.0	28.80±0.42	31.4±0.21	8829±100	3.548
S3		6	3.8	28.85±0.35	31.7±0.14	8873±165	4.754
S4	0.5	2	4.3	29.15±0.35	32.8±0.64	6882±11	13.880
S5		4	4.1	28.55±0.64	33.1±0.99	6888±187	13.520
S6		6	3.8	28.25±0.36	33.3±0.64	6827±180	13.910
S7	0.75	2	4.2	29.00±0.42	34.3±0.64	5617±367	23.860
S8		4	4.2	28.40±0.85	34.2±1.13	5583±148	23.400
S9		6	3.9	28.15±0.78	34.8±0.28	5485±421	23.010

Table 4. Two-way ANOVA statistical analysis results (α= 0.05)

Parameter	*p*-value							
	°Brix	Total Solid	Hardness	Mix Viscosity	Overrun	Melting Rate	Lycopene	Vitamin C
XG (A)	0.881	$6.75x10^{-5}$	$3.56x10^{-9}$	$1.86x10^{-5}$	$2.42x10^{-9}$	$4.27x10^{-8}$	$7.18x10^{-4}$	$2.61x10^{-3}$
Lemon juice (B)	0.449	$3.36x10^{-1}$	$9.23x10^{-1}$	$1.25x10^{-1}$	$5.07x10^{-1}$	$3.39x10^{-1}$	$3.76x10^{-1}$	$6.80x10^{-3}$
Interaction (AB)	0.325	$9.83x10^{-1}$	$9.83x10^{-1}$	$9.77x10^{-1}$	$9.90x10^{-1}$	$9.11x10^{-1}$	$9.99x10^{-1}$	$8.28x10^{-1}$

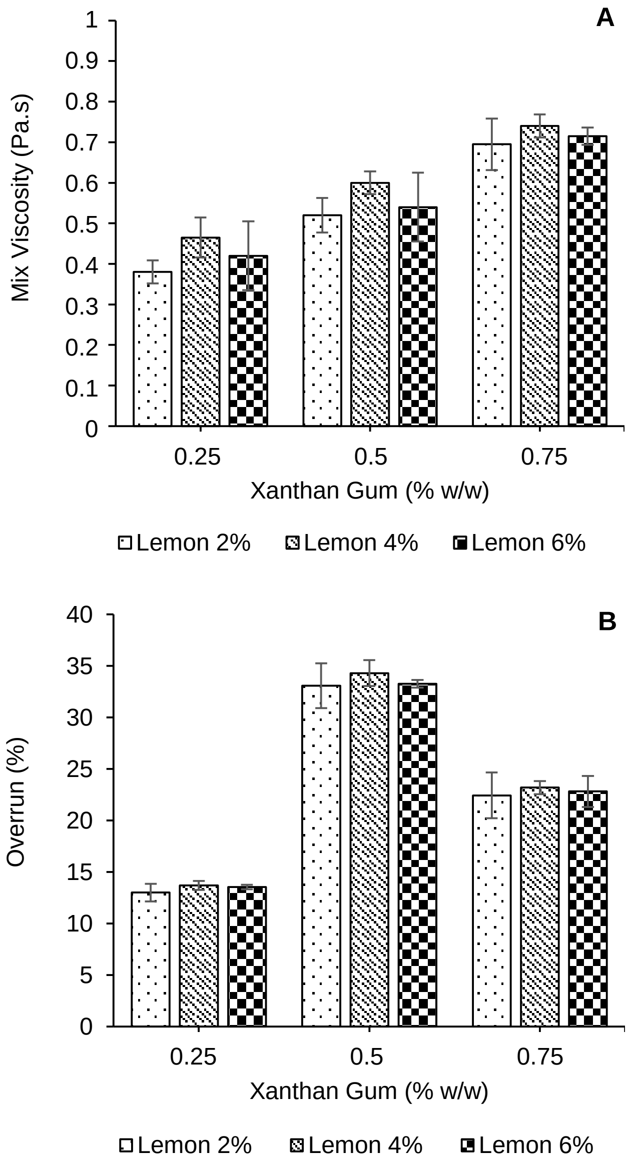

Figure 1. The viscosity (A) and overrun of tomato sorbet (B) by the addition of xanthan gum in the sorbet formula

Overrun relates to the amount of air incorporated into the sorbet base causing increment of sorbet volume (Liu *et al.*, 2018). Sorbet viscosity is pivotal to the air assimilation, in which high viscosity has a more significant obstacle to the aeration process. It is noteworthy that, when it is too low, air bubbles would break and coalesce (Goff, 2019). As displayed in Figure 1, The rising viscosity of 0.74 Pa.s achieved at 0.75% of xanthan gum did not necessarily improve the sorbet overrun. The highest overrun was achieved at xanthan gum of 0.5%. We could explain that the high level of xanthan gum (0.75%) would hamper aeration in sorbet, resulting in lower overrun. According to Cahyadi *et al.* (2017), sorbet overrun was 24–25%; in this research, the overrun reached 13–34%. The discrepancy may result from difference in formulations, churning process, and fruit extracts.

In presence of acid, high temperature process may disrupt the function of stabilizers, depending on the stabilizers used (Goff, 2019). However, xanthan gum can be stable at acidic and alkaline conditions due to its rigid structure (Vega *et al.,* 2015). In this work, levels of lemon juice did not affect the stabilizer performance, meaning that they showed no effects on the mix viscosity and overrun of the sorbet.

Table 4 confirms that xanthan gum presents a strong correlation with viscosity and overrun of sorbet (p<0.05). On the other hand, lemon juice and the interaction between lemon juice and xanthan gum had no impact on the viscosity and overrun of sorbet.

Melting rate

Dairy-based ice cream contains a considerable amount of fat, enabling to improve the melting resistance due to fat agglomeration (Rybak, 2016). In this study, limited amount of fat in tomato sorbet may rise melting rate. To retard the process, xanthan gum was added as stabilizer since it showed high resistance to freezing and melting. A certain amount of xanthan gum enabled to form smaller ice crystals (Kamińska-Dwórznicka *et al.,* 2022). According to Muse and Hartel (2004), the large group of tiny ice crystals has a tortuous melting flow path in which the fluid has to travel through obstacles of numerous ice crystals. Hence, the melting rate can be reduced.

Figure 2 displays the effect of treatments on melting rate of sorbet. The melting rate of reference sorbet reached 1.29±0.14 g/min. Intriguingly, the addition of xanthan gum successfully decelerated the melting rate of tomato sorbet. In addition, increasing concentration of xanthan gum up to 0.75% did not only decreasing the melting rate but also increasing the gumminess of the sorbet. We also reported that lemon juice showed no effects on the melting rate. This may display the resistance of xanthan gum against pH change. Statistical analysis shown in Table 4 confirmed the results, demonstrating that xanthan gum alone affected the melting rate of sorbet.

Content of lycopene and vitamin C

Concentration of lycopene and vitamin C in samples can be seen in Figure 3. In the untreated samples, the concentration reached 2.4±0.4 mg/100 g for vitamin C and 0.91±0.18 mg/g for lycopene. It was observed that xanthan gum enhanced the lycopene content in sorbet. Lycopene is a hydrophobic component that is susceptible to oxidation and isomerization. Additionally, high moisture content accelerates the autooxidation of lycopene (Farikha *et al.*, 2013). Xanthan gum has a powerful water-binding capacity and strengthens the colloidal attraction force. It limits the availability of free oxygen, thus reduces lycopene autooxidation (Farikha *et al.,* 2013). Lycopene is relatively stable in alkaline and acidic conditions. Therefore, increasing lemon juice did not influence the lycopene composition in the sorbet (Cristea *et al.,* 2021). This finding is presented in Table 4, demonstrating that lemon juice did not significantly affect lycopene content of tomato sorbet (p>0.05).

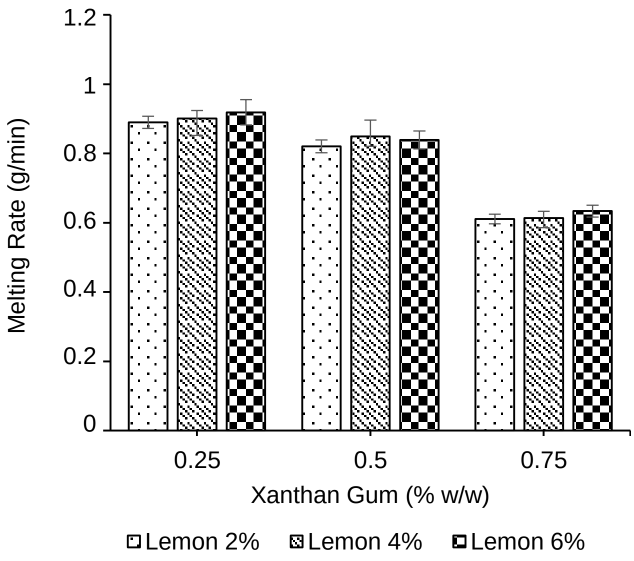

Figure 2. The melting rate of tomato sorbet

Furthermore, as depicted in Figure 3, addition of lemon juice enhanced the quantity of vitamin C in sorbet. Lemon juice extract comprised of ascorbic acid (51 mg/100 mL); therefore, the amount of lemon juice improved the content of vitamin C in sorbet. Vitamin C is an antioxidant, but it is easily degraded by light and heat. Vitamin C is readily transformed into dehydroascorbic acid with high moisture content (Jutkus *et al.,* 2015). Based on Figure 3B, xanthan gum ameliorated the content of vitamin C in sorbet. According to Salimah *et al.* (2015) and Freitas *et al.* (2013), it is known that stabilizers such as Arabic gum and xanthan gum could preserve the citric and ascorbic acid in the food. Vitamin C decomposes faster when it dissolves in water but is stable in solid conditions. Xanthan gum can bind water and thicken the sorbet's textures. Thus, it improves the vitamin C content (Dolińska *et al.,* 2012). Water-binding capacity of the xanthan gum also limits the movement of free oxygen and contributes to lowering the oxygenated atmosphere, then reducing the oxidative reaction of vitamin C (Farikha *et al.,* 2013; Golly *et al.,* 2019).

Organoleptic properties

The organoleptic test for samples was conducted and analyzed using PLSR model (Figure 4). Factor 1 represented 69% of data input (X) and 53% of data output (Y), while factor 2 represented 31% of data input (X) and 10% of data output (Y). The input data or predictors were xanthan gum and lemon juice variations. At the same time, the output or responses were unpleasant aftertastes, sourness, sweetness, hardness, gumminess, watery, and icy mouthfeel. The variables between inner and outer circles contributed significantly to factors 1 and 2. Relationships between X and Y-variables can be interpreted through the response (Y) variables. Predictors (X) projected in roughly the same direction from the center as a response revealed that predictors positively correlated to the response. When predictors were projected in the opposite direction, predictors showed a negative correlation. Predictors projected close to the center were not well presented in the model and could not be interpreted.

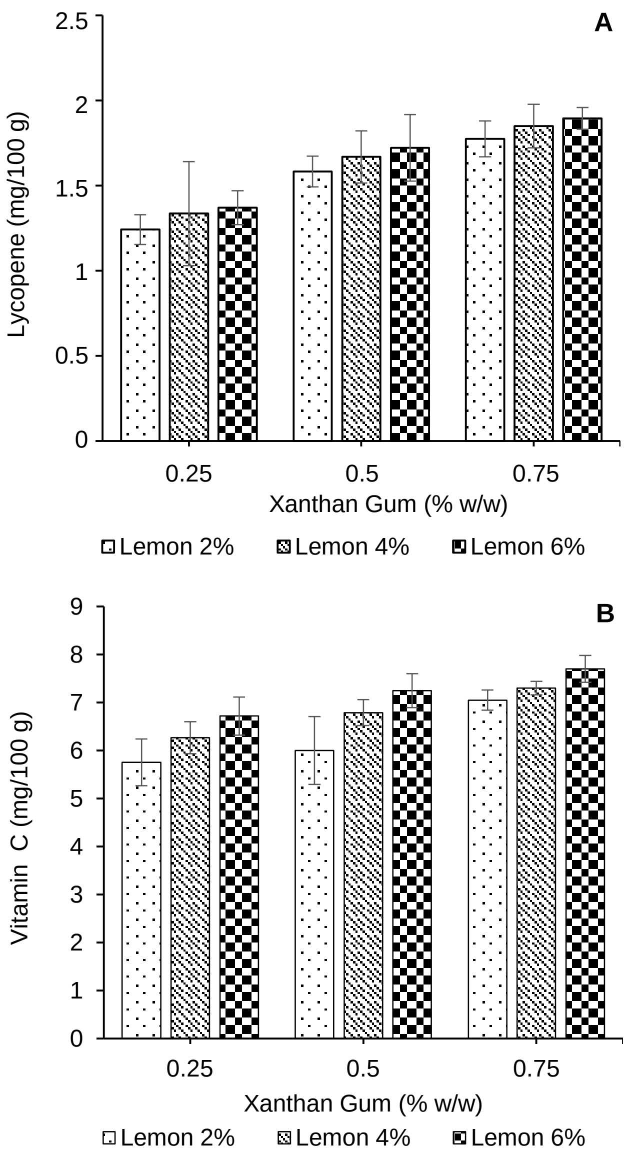

Figure 3. The lycopene (A) and vitamin C of tomato sorbet (B)

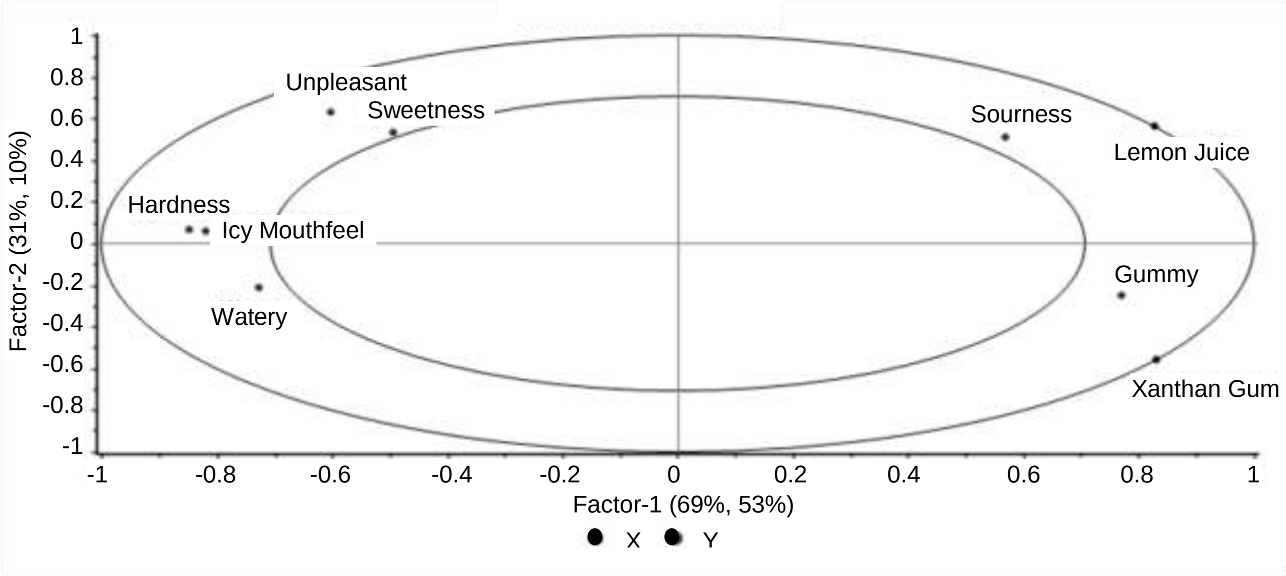

Figure 4. The partial least square regression (PLSR) of organoleptic test

Figure 4 showed that the increase of xanthan gum positively correlated to gumminess and negatively correlated to hardness, watery, and icy mouthfeel. Hardness, watery, and icy mouthfeel could reflect the ease of spooning, melting time, and size of ice crystals, respectively. Panelists agreed that the rise of xanthan gum improved the texture as observed in hardness and gumminess of the sorbet. However, xanthan gum addition up to 0.75% resulted in the excessive gumminess. Xanthan gum affected water-binding ability of sorbet, which could decelerate melting time. Additionally, xanthan gum also improved overrun. Low overrun in sorbet indicates the larger ice crystals, which are responsible for coarse icy mouthfeel. Conversely, high overrun indicates smaller ice crystals causing a smooth texture (Góral *et al.*, 2018; Liu *et al.,* 2018).

The lemon juice showed a strong positive correlation to sourness and a negative correlation to sweetness. According to the panelists, increasing lemon juice reduced sweetness and gave a sour effect. The lemon juice was added to remove the unpleasant aftertaste and improve flavor of the sorbet. As depicted in Figure 4, the predictor lemon juice and the response unpleasant aftertaste occurs in an opposite position. This shows that the rise of lemon juice up to 6% enables to eliminate unpleasant aftertaste. However, it is common that acid can be added to sorbet at 0.36% in 25-30% of sugar. The acid addition should be approximately 0.01% for each 0.1% sugar increment (Marshall *et al.,* 2003). The percentage of lemon juice in this research was higher than in the previous study. Thus, despite able to remove unpleasant after taste, it formed undesirable sourness due to high acidity.

The performance of the models was assessed by intercept, bias, root mean square error (RMSE), standard error (SE). The values of $RMSE_P$, R^2, and SE_P of validation model should be close to calibration model for a good model. The $RMSE_C$, R^2, and SE_C for calibration model were 0.50477, 0.66043, and 0.50603. On the other hand, the $RMSE_P$, R^2, and SE_P for validation model were 0.51124, 0.65537, and 0.51252. Generally, $RMSE_P$ and SE_P lower than calibrated $RMSE_C$ and SE_C indicate an overfitted reproducibility model (Rahman *et al.,* 2015). However, R^2 values for both calibrated and predictive validated model was at relatively low values, suggesting that correlation of the data could not be explained well by the model.

CONCLUSIONS

The addition of xanthan gum in formulation improved sorbet properties such as content of lycopene and vitamin C, melting rate, mix viscosity, and overrun. The best formulation was achieved at 0.5% w/w of xanthan gum, since the addition of xanthan gum more than 0.5% w/w reduced the sorbet overrun due to aeration difficulties, while also altering the gumminess of the sorbet. Besides, xanthan gum diminished size of ice crystals, resulting in the decrease of watery and icy mouthfeels. We also reported that lemon juice did not impact to hardness, lycopene content, melting rate, mix viscosity, or overrun of sorbet. In contrast, lemon juice improved vitamin C content and reduced the unpleasant taste from tomato. Based on this study, reduction of unfavorable tomato taste was best obtained at 6% of lemon juice, but it simultaneously resulted in astringency or sour taste. Future researches are expected, especially on how to reduce unpleasant tomato taste in the sorbet without decreasing its sweetness and proper rheological properties.

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