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Formulation of Slice Jam from Star Gooseberry (*Phyllanthus acidus*): Effect of Sucrose and Carrageenan Concentration on Physicochemical and Sensory Characteristics

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ABSTRACT

Star gooseberry (*Phyllanthus acidus*) is a tropical fruit rich in vitamin C, phenolic compounds, and pectin, but its utilization remains limited due to high acidity and short shelf life. This study aimed to analyze the effects of sucrose and kappa-carrageenan concentrations on the physicochemical and sensory characteristics of star gooseberry slice jam and to determine the best formulation. A two-factor Completely Randomized Design was employed, comprising sucrose (55%, 60%, 65%) and kappa-carrageenan (2%, 4%, 6%) with two replications. Sensory evaluation was conducted by 30 semi-trained panelists. Results showed that the interaction between sucrose and carrageenan significantly affected ($p \leq 0.05$) antioxidant activity, texture profile (hardness, cohesiveness, gumminess), and sensory scores for taste, color, and texture. Based on the De Garmo effectiveness index, the optimal formulation was 65% sucrose and 4% carrageenan (effectiveness value 1.317). This treatment yielded a slice jam with 7.41% moisture, pH 3.55, 77.70% total soluble solids, 73.54% total sugar, 76.37% antioxidant activity, 18.83 mg/100 g vitamin C, 107.65 N hardness, 0.432 cohesiveness, -0.00111 J adhesiveness, and 46.51 N gumminess.

Contribution to Sustainable Development Goals (SDGs):

SDG 12: Responsible Consumption and Production- loss.

SDG 3: Good Health and Well-being

SDG 2 : Zero Hunger

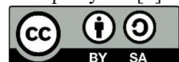
SDG 8 : Decent Work and Economic Growth-

1. INTRODUCTION

Indonesia is a tropical country with two seasons, drought and rain, which supports soil fertility in various regions. This condition gives Indonesia fertile land suitable for growing various plants, including local fruits. One fruit that grows well in Indonesia is the star gooseberry (*Phyllanthus acidus*), a yard plant known for its adaptability to various soil conditions and climates. Data from the Tropical Fruit Crops Research Institute (2022) show that cherry trees are widespread in Indonesia's tropics, especially Java and Sumatra, with an average productivity of 15–25 kg of fruit per tree per year [1]. However, like other fruits, star gooseberry is

perishable and decays rapidly, which can harm farmers and traders [2]. Processing fruit into processed food products is one solution to increase selling value, extend shelf life, and reduce post-harvest waste without reducing nutritional content.

Star gooseberries are small tropical fruits of the *Phyllanthaceae* family that originated in Madagascar and are now widely cultivated in Asia and Latin America, including India, Thailand, Myanmar, and Indonesia. The fruit is flattened, about 2 cm in diameter, with 6–8 indentations, smooth-skinned, yellowish-green when raw and pale yellow when ripe [3]. The flesh of the fruit is crispy and juicy with a very sour taste so it is generally consumed with salt or processed into syrup, pickles, or jams. In addition to its distinctive taste, star gooseberry is rich in



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bioactive compounds such as vitamin C, flavonoids, and phenolic acids, and has enough natural pectin to form a gel [4], so it can be processed into gel-based products such as jam.

The very acidic taste of star gooseberry is due to the high content of organic acids, especially citric acid which reaches 39.8% of the total acid of the fruit [5]. This dominant sour taste makes star gooseberry less desirable for direct consumption, so processing it into jam is one of the more attractive alternatives [6]. The addition of sucrose in the manufacture of jam plays an important role not only as a sweetener, but also as a balance of the sour taste of the star gooseberry to make it more acceptable to consumers [7]. Jams with added sucrose that produce balanced sweetness and a distinctive aroma are reported to have higher preference ratings [8].

The selection of sheet jam products to utilize star gooseberry is based on its physicochemical characteristics that favor gel formation. The relatively high moisture content of star gooseberry fruit (91.8%) causes this fruit to spoil quickly if not processed immediately [9]. Star gooseberry also has an acidity value suitable for processing into jam because pH plays a role in gel formation; the consistent pH range for gel formation is 2.8–3.4 [10]. Research on pectin extraction from star gooseberry pomace through *Response Surface Methodology* (RSM) optimization reported that pectin yield reached 6.54% with a high methoxyl pectin category [11]. The relatively high vitamin C content of star gooseberry (around 35.62 mg/100 g), as well as the presence of dietary fiber, beta carotene, and phenolic compounds provide nutritional added value to the processed products [9], [12].

Slice jam or sheet jam is a type of jam that has a shape according to the surface of the bread, is not liquid or too soft, and is not too stiff [13]. The jam, originally semi-solid for spreading, was developed into a compact, textured sheet, similar to *sliced* cheese, non-sticky, and plastic. The characteristics of star gooseberry greatly support its processing into sheet jam. The advantage of sheet jam over spread jam is its practicality in serving because it does not require a spoon or knife, so it can be an alternative to consumption with bread [14].

The quality of sheet jam is generally determined by its chewy, elastic texture, which reflects gel stability and the ingredients' ability to form a cohesive structure. The ideal texture should be able to hold its shape when lifted from the mold without cracking or breaking, as well as being elastic enough to roll up without tearing [15]. In addition to texture, color is also an important indicator of jam quality because it is a sensory attribute that is directly assessed by consumers [16]. Some of the technical problems in making jam include crystallization due to excess dissolved solids that cause a rough texture [17], as well as too hard a texture due to excessive pectin or too low sucrose levels [18]. Additional ingredients such as hydrocolloids play an important role in determining the final texture of the jam as a thickener and structural former, but their use must be balanced so as not to cause the gel to become too stiff or not to form perfectly [19].

Carrageenan is a hydrocolloid used to improve the texture and stability of sheet jam. Its functional properties as a gelling agent, thickener, stabilizer, and its ability to react with proteins make carrageenan widely used in the food sector. Carrageenan is a linear sulfate polysaccharide that is divided into several main types, namely kappa, iota, and lambda carrageenan [21]. Kappa carrageenan is obtained from the extraction of seaweed of the *Kappaphycus alvarezii* or *Eucheuma cottonii* type using alkaline

solution or high-temperature water, with carrageenan levels in *Eucheuma cottonii* reaching 67.50% of the dry weight of seaweed [22]. Kappa carrageenan is a polysaccharide fraction with one sulfate group per disaccharide unit [23].

This study aims to (1) study the effect of the addition of sucrose and carrageenan on the physicochemical and organoleptic characteristics of star gooseberry sheet jam, and (2) determine the best treatment concentration between the combination of sucrose and carfactan that produces the best quality sheet jam and preferred by the panelists. This research is expected to increase the economic value of star gooseberry fruit and diversify local fruit-based food products, as well as provide an overview of consumer acceptance of the organoleptic properties of star gooseberry slice jam with the addition of carrageenan.

The quality standard for fruit jam in Indonesia refers to SNI 3746:2008 [25]. According to the standard, good quality jams have a solid consistency, smooth texture, bright color, natural taste, and show no signs of syneresis or crystallization of sucrose during storage [31]. Jam quality was assessed by appearance parameters, total dissolved solids of at least 65% (w/b), food additives, and limits for heavy metals and microbial contamination [25]. Jam is generally formulated from no less than 45 parts by weight of crushed fruit combined with 55 parts by weight of sucrose, then concentrated through heating until it reaches a minimum total dissolved solids level of 65% [26]. The successful processing of fruit jam is influenced by the cooking temperature as well as the addition of pectin and sucrose which play a role in the formation of texture and flavor [27], where sucrose, acid, and pectin must be in a certain balance in order to form a perfect gel [28]. The formation of a stable gel structure in the jam is also highly dependent on the acidity of the mixture, with the ideal pH range for jam production being between 3.10 and 3.46 which allows for optimal pectin–sucrose–acid interactions [26].

2. MATERIALS AND METHODS

The research was carried out in January–April 2026 at the Food Analysis Laboratory, Food Processing Technology Laboratory, and Sensory Test Laboratory of the Food Technology Study Program, "Veteran" National Development University of East Java. The main ingredients used are star gooseberry fruit obtained from Jombang, kappa type carrageenan obtained from *online shop*, and sand sucrose obtained from grocery stores in the Rungkut Asri area, Surabaya. The materials for analysis include aqueducts, buffer solutions, methanol, DPPH solution, 95% alcohol, 10% K₂SO₄, 0.313 N, and 0.255 N H₂SO₄ obtained from Phoenix Chemical Store, Surabaya. The tools used to make sheet jam include 20×20 cm baking sheets, plastic pans, spoons, knives, steamers, *cabinet dryers*, scales, measuring cups, blenders, and stoves, while analysis equipment includes ovens, pH meters, refractometers, *texture analyzers*, analytical scales, spatulas, weighing bottles, desiccant, filter paper, erlenmeyer, funnels, measuring cups, *beaker glass*, drip pipettes, volume pipettes, and sensory test containers.

The study used a Completely Randomised Design (CRD) factorial pattern with two treatment factors and two replications. Factor I is the sucrose concentration, with three levels: A1 = 55%, A2 = 60%, and A3 = 65%. Factor II is the concentration of carrageenan addition with three levels: B1 = 2%, B2 = 4%, and

B3 = 6%, resulting in nine treatment combinations (A1B1, A1B2, A1B3, A2B1, A2B2, A2B3, A3B1, A3B2, A3B3). Fixed variables in the study included the proportion of star gooseberry fruit porridge 100 g, the ratio of fruit to water 1:1, the thickness of the dough 2–3 mm, the cooking temperature of 90°C, the cooking time ± 10 minutes, the drying temperature of 60°C, and the drying time of 6 hours.

A complete randomized design statistical model of a two-factor factorial pattern follows the equation $Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ijk}$, with Y_{ijk} being the observation value at the i th treatment and the j repeat, α_i being the effect of the sucrose factor at the i th level, β_j being the influence of the carrageenan factor at the j th level, $(\alpha\beta)_{ij}$ being the interaction between the sucrose factor and the carrageenan, and e_{ijk} being the experimental error [33]. Data were analyzed using the ANOVA (*Analysis of Variance*) test at a 95% confidence level ($\alpha = 0.05$) to see the effect of treatment. If treatments differed significantly, a follow-up Duncan's Multiple Range Test (DMRT) was carried out at the 5% level.

The analysis of the raw materials of star gooseberry fruit included moisture content [36], total sucrose content [36], antioxidant activity by the DPPH method [37], crude fibre content [38], acidity degree (pH) [39], and pectin content by the gravimetric method [38]. Analysis of sheet jam final products included moisture content [36], antioxidant activity [37], pH [39], total sugar [36], total dissolved solids with refractometer [40], instrumental texture using *texture analyzer* including *hardness*, *cohesiveness*, *adhesiveness*, and *gumminess*, as well as hedonic organoleptic tests [41] for color, taste, and aroma parameters, and scoring for texture parameters. The best treatment was determined using the De Garmo effectiveness index method [42], followed by an analysis of vitamin C levels at the best treatment.

The process of making star gooseberry fruit pulp refers to [34] with modifications of the type of fruit. Fresh star gooseberries are sorted to obtain fresh and non-rotten fruits, then washed with clean water to remove impurities. The fruit is then mashed in a blender with a 1:1 water-to-fruit ratio for 2 minutes at medium speed, then filtered to separate the seeds and obtain star gooseberry pulp.

The process of making sheet jam refers to [35] with modifications of the type of fruit, the length of drying time, the concentration of sucrose, and the addition of carrageenan. Cherry pulp is mixed with sucrose according to the treatment, then stirred while heated to 90°C for 10 minutes. Carrageenan that has been diluted before is added when the temperature of the star gooseberry pulp reaches 70°C, then stirred again. The dough is then molded in a baking dish and flattened, then dried in a *cabinet dryer* for 6 hours at 60°C. The dried sheet jam is cut to 8.5 × 8.5 cm and 3 mm thick.

3. RESULT AND DISCUSSION

3.1 Raw Material Analysis Results

The analysis of the raw materials of star gooseberry fruit includes water content, total sugar, crude fiber, pH, pectin levels, and antioxidant activity. The results of the analysis of the moisture content of fresh star gooseberry were 93.45%, slightly higher than the literature (91.8%) [9]; These differences are influenced by where they grow, the level of ripeness of the fruit, and the difference in temperature and drying methods [43]. The total sugar content of star gooseberry fruit was 2.66%, lower than the

literature (3.45%) [44] which is thought to be due to differences in the ripeness level of the fruit at harvest and metabolic processes that affect the conversion of polysaccharides and organic acids into simple sugars. The crude fiber content of 1.27% is relatively in line with the literature (1.21%) [9]. The pH value of the star gooseberry of 2.71 indicates a highly acidic nature, not much different from the literature (2.3) [45], where the pH is influenced by the total organic acids in the fruit. The pectin level was 0.62% compared to star fruit, which had similar characteristics (pectin yield 1.2%) [46], with differences influenced by plant species, growing location, genetic factors, and harvest age [47]. The antioxidant activity of star gooseberry was 50.46%, lower than the literature (75.52%) [44], influenced by the growing location, ripeness level, weather, and maintenance methods [48], considering that phytochemical compounds increase with the ripeness rate of the fruit [49].

Table 1. Results of Analysis of Star gooseberry Fruit Raw Materials

Parameter	Test Results	Literature	Source
Moisture content (%)	93.45 ± 0.09	91.8	[9]
Total sugar (%)	2.66 ± 0.07	3.45	[44]
Crude Fiber (%)	1.27 ± 0.04	1.21	[9]
pH	2.71 ± 0.04	2.3	[45]
Pectin content (%)	0.62 ± 0.03	1.2	[46]
Antioxidant activity (%)	50.46 ± 0.36	75.52–90.54	[44]

3.2 Physicochemical characteristics of sheet jam

Moisture Content. Analysis of variance showed no real interaction ($P \geq 0.05$) between the addition of sucrose and carrageenan, but each factor had a significant effect ($P < 0.05$) on water content. Moisture content ranged from 7.41–11.06% in the sucrose treatment and 8.65–9.84% in the carrageenan treatment, with a trend of decreasing moisture content as sucrose and carrageenan concentrations increased. This decrease is due to the hygroscopic properties of sucrose that binds to free water during cooking [54], as well as the ability of carrageenan to form a tightening three-dimensional gel network so that most of the water is bound in a gel matrix [59].

Antioxidant Activity. The two factors showed a significant interaction ($P < 0.05$) on antioxidant activity, which ranged from 66.88–91.18%. The highest value was obtained in A1B3 (sucrose 55%, carrageenan 6%) at 91.18%, while the lowest was in A3B1 (sucrose 65%, carrageenan 2%) at 66.88%.

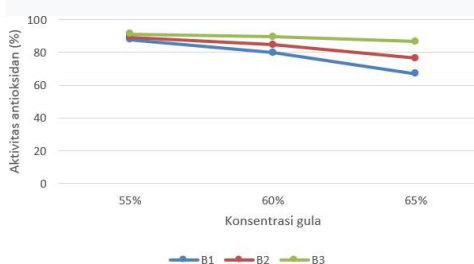


Figure 1. Graph of the relationship between the treatment of sucrose addition and carrageenan addition to the antioxidant activity of sheet jam.

Increased sucrose decreased antioxidant activity is thought to result from the degradation of antioxidant compounds during heating; the higher the concentration of sucrose, the greater the total solidity and viscosity of the dough, so that the heating becomes more intense, triggering the degradation of vitamin C and phenolic compounds. During heating, sucrose can invert into more reactive glucose and fructose in non-enzymatic browning reactions, consistent with findings that adding sucrose and heating decrease phenolic content and antioxidant activity in jam [50], [51]. In contrast, the increase in carrageenan is related to its ability to form a gel network that binds water and reduces contact between antioxidant compounds and oxygen, helping maintain the stability of vitamin C and phenolic compounds during processing [52].

Degree of Acidity (pH). There was no real interaction ($P \geq 0.05$), but each factor had a real effect ($P < 0.05$). The pH ranged from 3.37–3.55 in the sucrose treatment and 3.39–3.52 in the carrageenan treatment, both increasing with higher concentration. The increase in pH due to sucrose is thought to be due to the increased proportion of dissolved solids decreasing the relative proportion of citrus fruit's organic acids, as well as the ability of sucrose to bind to free water, which affects the balance of hydrogen ions [53], [54]. The increase in pH due to carrageenan is related to its relatively neutral to slightly alkaline properties, as it is processed using an alkaline solution, with a carrageenan pH range of about 6–9 [54], [55]. All treatments remain in the acidic pH range (3.29–3.62), so the product is classified as an acidic food.

Total Sugar. There was no apparent interaction; carracene had no real effect ($P \geq 0.05$) while sucrose had a noticeable effect ($P < 0.05$) on total sugar, which increased from 67.84% in 55% sucrose to 73.48% in 65% sucrose. This is in line with the nature of sucrose as a simple carbohydrate of the disaccharide group that contributes directly to the sugar content of the final product [56]. Carrageenan does not exert any noticeable effect as it functions as a gelling and stabilizing hydrocolloid rather than a sugar contributor [57].

Total Dissolved Solids (TSS). No real interaction was observed, but each factor had a real effect ($P < 0.05$). TSS ranged from 73.67–77.75% in the sucrose treatment and 74.95–76.48% in the carrageenan treatment, both increasing with concentration. The increase due to sucrose is due to its nature as a water-soluble component of solids [54], while the increase due to carrageenan is related to its ability to bind to free water so that the proportion of solids in the liquid phase increases [58]. All treatments have met the quality requirements of SNI 01-3746-2008 for TSS at least 65% [25].

Table 2. Summary of Average Values of Physicochemical Characteristics of Star gooseberry Fruit Sheet Jam in the Treatment of Adding Sucrose and Carrageenan

Parameter	Value Range (Sucrose Treatment)	Range of Values (Carrageenan Treatment)	Influence of Interaction
Moisture content (%)	7.41–11.06	8.65–9.84	Not real
pH	3.37–3.55	3.39–3.52	Not real
Total sugar (%)	67.84–73.48	No real difference	Not real

Parameter	Value Range (Sucrose Treatment)	Range of Values (Carrageenan Treatment)	Influence of Interaction
TSS (%)	73.67–77.75	74.95–76.48	Not real
Antioxidant activity (%)	66.88–91.18 (combination)	—	Real ($P < 0.05$)

3.3 Characteristics of instrumental textures

Hardness. A real interaction ($P < 0.05$) existed between the two factors. The lowest hardness value was 42.48 N and the highest was 123.28 N, increasing with increasing sucrose and carrageenan.



Figure 2. Graph of the relationship between the treatment of adding sucrose and the addition of carrageenan to the hardness value of sheet jam

The increase in hardness occurs because sucrose, which is hydrophilic, binds to water molecules in the jam matrix so that the free water decreases and the total solids increase [60], while the three-dimensional network of carrageenan strengthens the bonds between particles so that the gel structure becomes more rigid and dense [59], [61]. Carrageenan has strong gel characteristics that increase the product's resistance to pressure [34]. These instrumental results align with the texture-scoring organoleptic test results, where the treatment with 55% sucrose and 2% carrageenan obtained the lowest score (1.52), while the treatment with 65% sucrose and 6% carrageenan obtained the highest score (4.68).

Cohesiveness. Both factors and their interaction significantly influenced cohesiveness ($P < 0.05$). The cohesiveness value ranged from 0.278 (A1B1) to 0.519 (A3B3), increasing as sucrose and carrageenan increased.

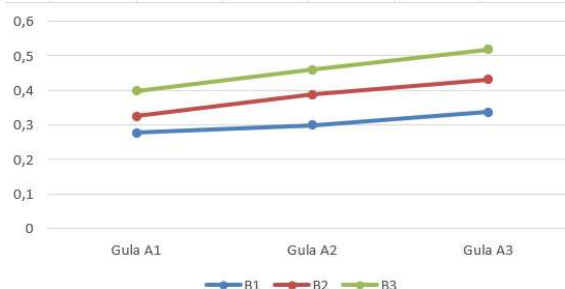


Figure 3. Graph of the relationship between the treatment of the addition of sucrose and the addition of carrageenan to the cohesiveness value of sheet jam

Sucrose reduces free water, increasing total solids and strengthening interactions between the components that make up the gel; sucrose molecules with a polyhydroxy structure hydrate, reducing the proportion of free water in the matrix [62]. Carrageenan, as a three-dimensional gel-forming hydrocolloid, increases the bond strength between components; The increased cohesiveness is related to the change of the carrageenan polymer chain into a helical structure after cooling, which forms a stable and rigid gel matrix [63].

Adhesiveness. No real interaction was observed ($P>0.05$), but each factor had a significant effect ($P<0.05$). The *adhesiveness* value decreased (became more negative) as sucrose (from -0.0009083 J at 55% to -0.0010800 J at 65%) and carrageenan (from -0.0008733 J at 2% to -0.0010917 J at 6%), indicating that the product became less sticky. This decrease is related to sucrose and carrageenan's ability to bind free water, making the gel matrix denser and tighter and reducing adhesion to contact surfaces [61], [62]. These findings are in line with research on sheet mulberry jam which reported increased carrageenan decreased *adhesiveness* markedly while *hardness* and *cohesiveness* increased [60].

Gumminess. Both factors and their interaction had a significant effect ($P<0.05$). Gumminess ranged from 11.82 N in the treatment with 55% sucrose and 2% carrageenan to 63.99 N in the treatment with 65% sucrose and 6% carrageenan, increasing as sucrose and carrageenan concentrations increased.

3.4 Characteristic Organoleptic

Taste. The Friedman test showed that adding sucrose and carrageenan significantly affected the taste preference score ($p\leq 0.05$), with total rankings ranging from 70–159. The sucrose 60% and carrageenan 4% treatment received the highest ranking (157.5), with an average value of 4.48, classified as the "like" category. The flavor of sheet jam is a combination of the acidity of the star gooseberry—which contains up to 39.8% of the total acid [5]—and the sweetness of the addition of sucrose [2]. Carrageenan does not affect taste because it has no taste [65].

Aroma. Sucrose and carrageenan treatments had no significant effect ($p\geq 0.05$) on aroma, with a total ranking ranging from 110.5–152. The 60% sucrose treatment and 6% carrageenan treatment received the highest ranking (152), with an average value of 3.60, in the "somewhat liked" category. The aroma produced is dominated by the distinctive aroma of star gooseberry fruit. Sucrose does not affect aroma significantly because aroma is more influenced by volatile compounds [66], whereas carrageenan is *odorless* and only affects the release of volatile compounds through physical changes in the food matrix without producing new aroma compounds [67].

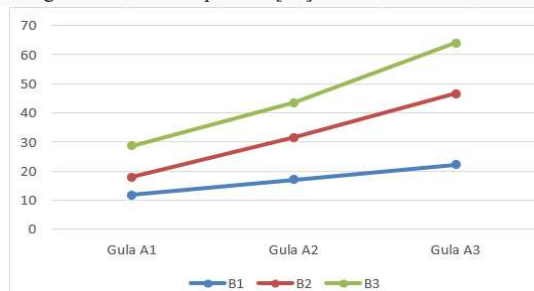


Figure 4. Graph of the relationship between the addition of sucrose and the addition of carrageenan to the gumminess value of sheet jam

The increase in *gumminess* due to sucrose relates to its ability to bind free water, increasing the density between matrix particles and raising the chewing energy required [60]. The increase due to carrageenan relates to its role as a gelling agent that strengthens cohesion; the tighter the three-dimensional tissue formed, the more strongly water molecules are trapped, making the structure stiffer and harder to break down when chewed [64].

Table 3. Instrumental Texture Value of Star gooseberry Fruit Sheet Jam at the Lowest and Highest Treatment Combinations

Parameter	A1B1 (Sucrose 55%, Carrageenan 2%)	A3B3 (Sucrose 65%, Carrageenan 6%)
Hardness (N)	42.48 ± 0.93	123.28 ± 1.90
Cohesiveness	0.278 ± 0.006	0.519 ± 0.010
Adhesiveness (J)	-0.000908 (mean sucrose 55%)	-0.001092 (mean carrageenan 6%)
Gumminess (N)	11.82 ± 0.50	63.99 ± 2.21

Color. The Friedman test showed a significant effect ($p\leq 0.05$), with total rankings ranging from 33.5–206.5. Sucrose 60% and carrageenan 2% received the highest ranking (206.5), with an average value of 4.52, in the "like" category. Higher additions of sucrose and carrageenan produced darker product colour. Increased sucrose accelerates the caramelisation reaction during cooking, resulting in a dark brown colour that is less desirable because it indicates overcooking [68], while increased carrageenan increases turbidity because the denser gel tissue structure inhibits light transmission [69].

Texture (score). Both factors and their interaction significantly influenced texture scores ($p\leq 0.05$), increasing from 1.52 for the treatment with 55% sucrose and 2% carrageenan to 4.68 for the treatment with 65% sucrose and 6% carrageenan.

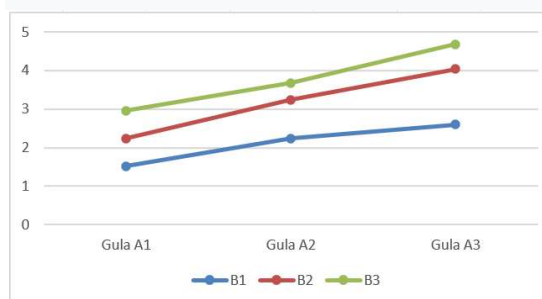


Figure 5. Graph of the relationship between the treatment of the addition of sucrose and the addition of carrageenan to the hedonic texture value of sheet jam

The 65% sucrose and 4% carrageenan treatment received a score of 4.08 in the "very chewy" category, considered the most ideal because it forms a sturdy, stable, and *well-sliceable gel matrix*. The final texture is the result of the interaction of carrageenan, sucrose, and pectin of star gooseberry in forming a gel tissue [70]. As κ -carrageenan increases, the jam becomes

denser and more stable, as it acts as a gelling and stabilising agent that increases gel consistency and strength [63]. Sucrose also supports texture formation by binding free water, increasing TSS, and supporting gelation so carrageenan molecules interact more easily to form a stable gel tissue.

Table 4. Summary of Organoleptic Test Results of Star gooseberry Fruit Sheet Jam

Parameter	Test Method	Total Ranking/Score Range	Best Treatment	Category
Taste	Hedonic (Friedman)	70–159	Sucrose 60%, Carrageenan 4%	Likes
Aroma	Hedonic (Friedman)	110,5–152	Sucrose 60%, Carrageenan 6%	Quite like it
Color	Hedonic (Friedman)	33,5–206,5	Sucrose 60%, Carrageenan 2%	Likes
Texture	Scoring	38–118 (total scores)	Sucrose 65%, Carrageenan 4%	Very chewy

3.5 Analysis of Best Behavior and Vitamin C Levels

The best treatment was determined using the De Garmo effectiveness index method based on quantity data (physicochemistry) and quality data (organoleptic) [42]. Each criterion was assigned a valence weight according to its relative importance, converted into a relative weight and combined with the effectiveness value of each treatment. The resulting values were summed to obtain the effectiveness index, with the highest index indicating the best overall treatment. The decision analysis showed that the best treatment was obtained with 65% sucrose and 4% carrageenan, with an effectiveness value of 1.317, resulting in a moisture content of 7.41%, pH 3.55, TSS 77.70%, total sugar 73.54%, antioxidant activity 76.37%, color score 1.88, aroma score 3.52, taste score 4.48, texture score 4.08, hardness 107.65 N, cohesiveness 0.432, adhesiveness -0.00111 J, and gumminess 46.51 N.

Although the selected best treatment (65% sucrose and 4% carrageenan) had a low color preference score of 1.88 on a 5-point scale, the treatment was not selected based on color alone. The De Garmo effectiveness index combines the normalized values of all selected physicochemical and sensory criteria according to their assigned weights, so a lower score for one criterion can be compensated by stronger performance in other criteria. In this treatment, the relatively favorable moisture content, total soluble solids, total sugar, antioxidant activity, taste, aroma, texture score, and instrumental texture characteristics contributed to its overall effectiveness value. The low color preference was likely associated with the darker brown appearance produced during heating, particularly at the higher sucrose concentration, where sugar concentration and thermal exposure can promote non-enzymatic browning. Further processing optimization could reduce browning by controlling cooking temperature and time while maintaining the target total soluble solids, and by evaluating suitable natural anti-browning agents that do not adversely affect the product's acidity, flavor, or texture.

This best treatment was further analyzed for vitamin C levels and yielded a value of 18.83 mg/100 g.

Table 5. Vitamin C Analysis Results Best Treatment

Treatment (sucrose)	Treatment (Carrageenan)	Up to Vitamin C
65%	4%	18.83 mg/100 g

This value shows that vitamin C can still be maintained in the final product even after heating during jam making. The vitamin C content of fresh star gooseberry is generally reported to be around 25–45 mg/100 g, so a decrease in vitamin C levels during processing is a common phenomenon because ascorbic acid is thermolabile and easily oxidized when exposed to high temperatures, oxygen, and a relatively long heating time; the higher the temperature and the longer the warming, the greater the degradation of vitamin C [71].



Figure 6. The photo of the final product of the best treatment of slice jam (sucrose 65%, carrageenan 4%) shows the texture of the sliceable sheet.

CONCLUSION

There was a significant interaction ($p \leq 0.05$) between the addition of sucrose and carrageenan and antioxidant activity, *hardness*, *cohesiveness*, *gumminess*, taste, colour, and hedonic texture of star gooseberry leaf jam, but no significant interaction with moisture content, pH, total dissolved solids, total sugar, *adhesiveness*, and hedonic scents. Based on the decision analysis using the De Garmo method, the best treatment was obtained with the addition of sucrose 65% and carrageenan 4%, with the best physicochemical and sensory characteristics: moisture content 7.41%, pH 3.55, total dissolved solids 77.7%, total sugar 73.54%, antioxidant activity 76.37%, hedonic color 1.88, hedonic aroma 3.52, hedonic taste 4.48, hedonic texture 4.08, *hardness* 107.65 N, *cohesiveness* 0.432, *adhesiveness* -0.00111 J, *gumminess* 46.51 N, and vitamin C content of 18.83 mg/100 g. Further research is needed on the shelf life of star gooseberry fruit sheet jam in various types of packaging and storage conditions to determine the stability of physicochemical, sensory, and vitamin C content during storage.

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