



The Effect of Rice Grain Malt Concentration during Hydrolysis of Rice on the Characteristics of Rice Sugar Syrup

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Abstract:

Malt is the germination product of cereals that contain hydrolytic enzymes capable of breaking down starch. The concentration of rice grain malt is a factor that affects the hydrolysis process of rice (*Oryza sativa* L.) and the characteristics of the resulting rice sugar syrup. The malt concentrations used in this study were 25%, 35%, 45%, 55%, and 65%. The rice sugar syrup showed positive (+) results for residual starch. The concentration of rice grain malt had a significant effect on total soluble solids, color, organoleptic ranking, and viscosity. The total soluble solids of the rice sugar syrup ranged from 41.95 to 64.95 °Brix. The color difference (ΔE) ranged from 33.410 to 12.648. The viscosity of the rice sugar syrup ranged from 244.8 to 1448.1 cPs. The organoleptic ranking showed that the syrup produced with 65% malt concentration had the highest sweetness level. Hedonic organoleptic scores for color ranged from 3.6 to 3.36, aroma from 3.48 to 3.92, taste from 3.48 to 4.00, viscosity from 3.32 to 4.00, and overall acceptance from 3.56 to 4.16. The rice grain malt concentration of 65%, which was the highest concentration used for rice hydrolysis, produced rice sugar syrup with total soluble solids of 64.95 °Brix, color difference (ΔE) of 12.648, viscosity of 1448.1 cPs, the highest sweetness ranking, and the best favorability.

Keywords: Hydrolysis, Malt, Rice, Sugar Syrup

1. Introduction

Rice sugar syrup is a traditional food product originating from Korea and Japan, known as Jochoeng ssal yeot or mizuame. Rice sugar syrup, also referred to as Rice Malt Syrup, is obtained through the breakdown of rice starch using enzymes derived from cereal sprouts, bacteria, and fungi. Rice sugar syrup has potential as an alternative sweetener for various Indonesian food products. In its application, rice sugar syrup is widely used in processed foods such as baked goods, confectionery, and soft drinks. It imparts a mild sweetness with a unique flavor. In Korea, rice sugar syrup began to replace honey as a sweetener around 1998 (Wee et al., 2016).

In the production of rice sugar syrup, besides rice as the main ingredient, malt is also used. Malt is a sprouted cereal grain that contains starch-degrading enzymes such as α -amylase and β -amylase. Common cereal malts include those from wheat, barley, sorghum, corn, and mung beans (Phieter et al., 2020). An indigenous cereal widely cultivated in Indonesia is rice grain, offering the potential for agricultural products, particularly rice, to be utilized as malt. Rice (*Oryza sativa* L.) serves as the staple food for more than half the world's population, especially in Asian countries (Lin et al., 2013).

Similar to other malt types, rice grain undergoes a malting process consisting of germination stages, activating its hydrolytic enzymes. According to Ojewumi et al. (2018), malting is conducted to stimulate the synthesis of hydrolytic enzymes capable of breaking down macromolecules into lower molecular weight components. The difference among malts lies in the enzymatic activities across various cereals. Phieter et al.

(2020) reported that the enzymatic activity of sorghum, corn, and mung bean malts in breaking down starch varies, depending on starch degradation and the formation of reducing sugars.

According to Sutamihardja et al. (2018), the production of sugar syrup or liquid sugar involves two stages: starch gelatinization and starch hydrolysis. Hydrolysis is a reaction between a reactant and water, resulting in the decomposition of compounds (Fibarzi et al., 2023). Factors influencing starch hydrolysis include enzyme concentration, temperature, and hydrolysis time (Pane et al., 2023).

Starch hydrolysis is the process of breaking down amylose molecules, either enzymatically or using acid, into simpler sugar components like dextrin, isomaltose, maltose, and glucose, ultimately producing sugar syrup (Romero-Vargas et al., 2023; Teshome et al., 2025). According to Teshome et al. (2025), enzymatic hydrolysis of starch can be applied to the production of sugar syrup, involving liquefaction and saccharification stages.

Previous studies using malt from rice in syrup production (Ojewumi et al., 2018) found that glucose syrup produced from cassava using rice malt had favorable physicochemical properties and the highest reducing sugar content compared to sorghum and corn malt.

Regarding enzyme concentration in hydrolysis, Teshome et al. (2025) found that varying amylase concentrations in the hydrolysis of *Colocasia esculenta* starch affected the total sugar yield. Similarly, Permanasari and Yulistiani (2017) noted that enzyme concentration affected the hydrolysis rate and total soluble solids in tapioca syrup production.

In enzymatic hydrolysis studies using rice as raw material, Ofoedu et al. (2019) reported the production of sugar syrup using various African rice varieties with additional enzymes like fungal α -amylase, bacterial α -amylase, and amyloglucosidase, which are relatively expensive and thus less economical. Rice malt itself naturally contains hydrolytic enzymes.

Previous research (Ojewumi et al., 2018) used relatively low rice malt concentrations (0.8% and 1.6%), with NaOH added to assist hydrolysis. Felix (2010) used malt from sorghum and millet at 25%, 35%, and 45% concentrations, but hydrolysis was carried out at high temperatures (70–80°C).

Thus, this study investigates the use of various rice grain malt concentrations to hydrolyze rice starch into rice sugar syrup. The aim is to determine the effect of rice grain malt concentration on the hydrolysis of rice (*Oryza sativa* L.) and the resulting characteristics of the rice sugar syrup, ultimately identifying the concentration that yields the best syrup characteristics.

2. Research Method

Material

The materials used in this study included: local rice grains of the Junjuang variety from West Sumatra, commercial rice (brand: Sokan), water, distilled water, iodine reagent, and Benedict's reagent. The equipment used included: germination trays, 500-watt blender, refractometer, color box, and Brookfield viscometer.

Methods

The study employed a Completely Randomized Design (CRD) with the treatment variable being the concentration of rice grain malt used during hydrolysis, consisting of 5 levels. Each treatment was repeated 4 times, resulting in 20 experimental units. The 5 treatment levels were:

B1 = 25% malt-to-rice weight ratio

B2 = 35% malt-to-rice weight ratio

B3 = 45% malt-to-rice weight ratio

B4 = 55% malt-to-rice weight ratio

B5 = 65% malt-to-rice weight ratio

The Preparation of Malt

Malt preparation was conducted following the method described by Phieter et al. (2020), with modifications. Local Junjuang variety rice grains were used as the main material. The process consisted of three stages: steeping, germination, and kilning. During the steeping stage, the rice grains were washed and soaked in water at a 1:3 (w/v) ratio for 24 hours, with the soaking water replaced once. In the germination stage, the grains were drained, placed in trays, covered with cloth, and incubated at room temperature. The

grains were moistened twice daily for 48 hours. During the kilning stage, the germinated grains were sun-dried for 4 days. The dried grains were then ground into malt powder for further use.

The Preparation of Rice Sugar Syrup

The preparation method was adapted from Ofoedu et al. (2019), Ojewumi et al. (2018), Shaw and Sheu (1992), and Wee et al. (2016) with modifications. Five batches of 60 g of rice were ground and mixed with 150 ml of water (1:2.5 w/v). The rice slurry was heated to 100°C for 7 minutes and then cooled to room temperature. Malt was added according to the treatment concentration (25%, 35%, 45%, 55%, or 65% malt-to-rice weight ratio). An additional 150 ml of water was added, and the mixture was covered with aluminum foil. Hydrolysis was conducted in a water bath at 55°C for 5 hours. The resulting mixture was filtered through a 100-mesh cloth to obtain the filtrate. The filtrate was then evaporated using a hot plate to yield approximately 65 ml of rice sugar syrup per batch.

Starch (Sutamihardja et al., 2017)

A sample of 5–10 drops from the filtrate of the hydrolysis process was placed into a test tube, and a small amount of water was added to facilitate observation. Subsequently, 3–5 drops of Lugol's iodine solution were added into each test tube. The color change was then observed. If the sample solution turned dark blue or purple, it indicated a positive result for the presence of starch.

Total Soluble Solids Test

The refractometer prism was cleaned using lens paper or tissue. A sample was then taken with a dropper and placed onto the prism surface. Total soluble solids were measured using a digital refractometer. The °Brix value indicated the total sugar content in the solution. After use, the refractometer was cleaned again.

Color

The color test was conducted using a color box measuring 50 cm × 50 cm × 50 cm, equipped with four 8-watt neon lamps positioned at a 45° angle relative to the sample. A Samsung SM-A205F camera (13 MP, F1.9, 1/50s, 3.60 mm, ISO 40) was used for image capture. The procedure was as follows: A 30 ml sample was placed in a cup with a white background. The sample was positioned inside the color box and photographed from the center, maintaining approximately a 10 cm distance between the camera and the color box opening, at a 90° angle. The captured sample image was analyzed using the "Color Picker" tool available at <https://id.rakko.tools/tools/64/> to obtain RGB values and the color hexadecimal code. The RGB values were then converted into the CIE-LAB color system using the website <https://www.colorhexa.com/>. Finally, the ΔE (color difference) value was calculated using equation below (Ulyarti et al., 2018).

$$\Delta E = \sqrt{(L_1 - L_0)^2 + (a_1 - a_0)^2 + (b_1 - b_0)^2}$$

Note:

ΔE = Color difference value

L₁ = Lightness level of the sample

L₀ = Lightness level of the control

a₁ = Red-green color component of the sample

a₀ = Red-green color component of the control

b₁ = Yellow-blue color component of the sample

b₀ = Yellow-blue color component of the control

Viscosity

The viscometer was prepared by attaching the spindle to be used. In this measurement, spindle number 62 was utilized. The sample was then measured by immersing the spindle until the meniscus level was exactly at the center of the sample liquid. The rotational speed (RPM) of the viscometer was adjusted so that the torque value ranged between 10% and 100%. The viscosity reading was recorded once the measurement stabilized. The spindle was cleaned before measuring the next sample.

Sensory Tests

1. Ranking Test

The ranking test procedure was based on Setyaningsih et al. (2010). This ranking test aimed to evaluate the sweetness of five rice sugar syrup samples. Five syrup samples were prepared and randomly coded with three-digit numbers. Each sample was presented in a cup along with a tasting spoon. Drinking water was provided for panelists to neutralize their palate between samples. Panelists were asked to rank the syrup samples according to their perceived sweetness levels (1, 2, 3, 4, and 5), where rank 1 was the sweetest and rank 5 the least sweet. The rankings were recorded in the provided questionnaire. The test results were then analyzed after transforming the ranking data using the Fischer and Yates method.

2. Hedonic Test

The hedonic test aimed to determine panelists' preferences regarding the color, aroma, taste, viscosity, and overall acceptance of the five rice sugar syrup samples. A total of 20 panelists participated in the evaluation. Panelists were asked to express their preferences using a 5-point hedonic scale: 1 = Like very much, 2 = Like, 3 = Somewhat like, 4 = Dislike, 5 = Dislike very much. The sample presentation and evaluation procedures were carried out simultaneously with the ranking test, and the results were recorded in the provided questionnaire.

Data Analysis

Quantitative data were analyzed using Analysis of Variance (ANOVA) at a significance level of $\alpha = 0.05$ and 0.01 . Significant results were further analyzed with Duncan's New Multiple Range Test (DNMRT) at $\alpha = 0.05$. Statistical analysis was conducted using Microsoft Excel 2010 and SPSS version 26.

3. Results and Discussion

Sugar Syrup

In this study, rice sugar syrup refers to a sweetened syrup or liquid sugar product made from rice and rice malt (Figure 1). Rice sugar syrup is defined as a processed liquid resulting from the hydrolysis of sugars or rice starch, utilized as a sweetener and topping for beverages and confectionery products. The production of rice sugar syrup, employing various concentrations of rice malt, is based on the principle that enzyme activity is influenced by enzyme concentration. In this context, the hydrolysis reaction was catalyzed by rice malt enzymes at different concentrations result in rice sugar syrup which exhibiting distinct characteristic.

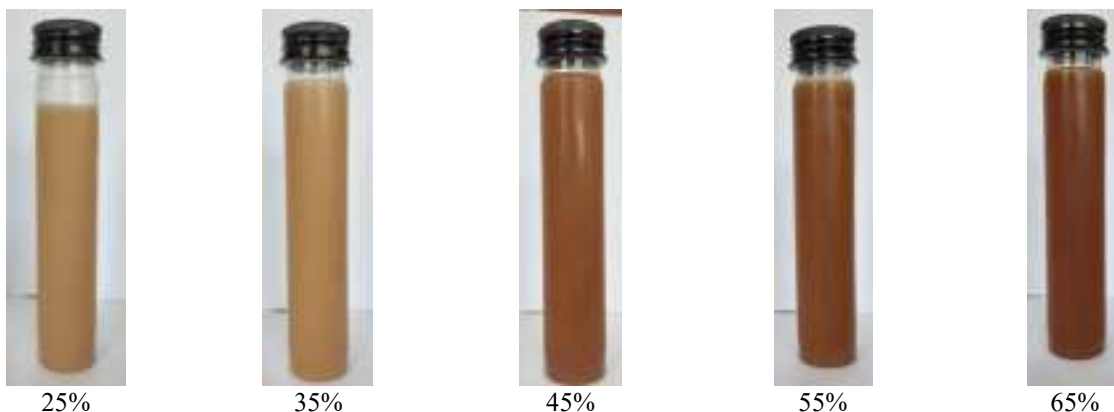


Figure 1. Sugar syrup produced using different concentration of rice malt

Starch

Hydrolysis of rice using rice grain malt produced simple sugar compounds in the rice sugar syrup, primarily reducing sugars. According to Lin et al. (2013), the hydrolysis of rice starch yields maltose, glucose, isomaltose, maltotriose, maltotetraose, maltoheptaose, and maltohexaose as reducing sugars. At 65% malt

concentration, the syrup showed minimal starch content, suggesting more complete hydrolysis (Table 1). Higher enzyme (malt) concentration led to a greater conversion of starch into simple sugars.

Table 1. Qualitative analysis of starch in sugar syrup at different concentration of rice malt

Rice Malt	Starch
25%	+ (positive)/ Purple ring was formed
35%	+ (positive)/ Purple ring was formed
45%	+ (positive)/ Purple ring was formed
55%	+ (positive)/ Purple ring was formed
65%	+ (positive)/ Faint purple was formed

Total Soluble Solid

Total soluble solids refer to the amount of all solid that dissolved in the sample. In this study, total soluble solids mainly show the number of sugars dissolved in the rice sugar syrup. In the syrup or liquid sugar industry, total dissolved solids are a key quality standard, with a minimum requirement of approximately ± 80 °Brix. However, syrups are categorized into four groups based on their total dissolved solids concentration: low sugar syrup (40–55 °Brix), medium sugar syrup (55–70 °Brix), high sugar syrup (70–80 °Brix), and very high sugar syrup (above 80 °Brix). As shown in Table 2, the concentration of rice malt significantly affected the total soluble solids of the rice sugar syrup. A higher malt concentration resulted in higher total soluble solids in the rice syrup. The highest average value, 64.95 °Brix, was observed with a 65% malt concentration, categorizing the syrup as medium sugar syrup.

Table 2. Total soluble solids (TSS) and ΔE of rice sugar syrup at various malt concentrations

Malt Concentration	TSS (°Brix)	ΔE
25%	41.95 \pm 1.69 ^a	33.41 \pm 1.47 ^a
35%	42.15 \pm 4.40 ^a	30.89 \pm 1.68 ^a
45%	51.57 \pm 4.39 ^{ab}	24.02 \pm 1.08 ^b
55%	52.97 \pm 3.96 ^b	16.90 \pm 2.26 ^c
65%	64.95 \pm 13.37 ^c	12.65 \pm 1.26 ^d

Note: Means with different superscripts within the same column are significantly different according to DnMRT ($p < 0.05$).

The use of various malt concentrations influenced the activity of hydrolytic enzymes in breaking down the rice starch substrate. Differences in total soluble solids were observed between rice sugar syrups produced with 25% to 45% malt concentrations compared to those with 55% and 65% malt concentrations. This indicates that the hydrolytic enzyme activity in the 25% to 45% malt treatments was lower in converting starch into simple sugars compared to that in the 55% malt treatment. The differences were most profound when compared to 65% malt rice. These results are related to enzyme kinetics, wherein the reaction rate of the rice malt hydrolytic enzymes during the hydrolysis process increases proportionally with the enzyme concentration.

Color

Color is one of the quality attributes that determine the acceptability of food products and serves as an important quality control parameter in food production. In the production of rice sugar syrup, color testing becomes crucial due to the visibly noticeable differences in the resulting syrup. The color of rice sugar syrup originates from chemical compounds such as melanoidins. Factors contributing to the coloration of the syrup include the presence of reducing sugars and amino acids (Osuji et al., 2020).

In this study, color was evaluated using the ΔE color value as a parameter to characterize the rice sugar syrup. As shown in Table 2, the decrease in color values is significantly different. The highest average ΔE value was observed in the syrup produced with a 25% malt concentration, reaching 33.410. In contrast, the lowest average ΔE value was found in the syrup produced with a 65% malt concentration, which had a ΔE value of 12.648. A higher ΔE value indicates a greater color change, characterized by a brighter, redder, and

more yellowish hue. Conversely, a lower ΔE value reflects a darker color change with reduced red and yellow intensity.

According to Osuji et al. (2020), observable differences in syrup color can be classified as follows: very different ($\Delta E > 3$), different ($1.5 < \Delta E < 3$), and slightly different ($\Delta E < 1.5$). The ΔE values of rice sugar syrup in this study ranged from 12.648 to 33.410, indicating that the color differences across treatments are classified as very different ($\Delta E > 3$). This finding is supported by Wee et al. (2016), who reported high ΔE values for rice sugar syrup, ranging from 74 to 81.

The Maillard reaction, which forms melanoidin compounds, results in the brown color of the syrup. The amount of melanoidin formed through the Maillard reaction is influenced by amount of their precursors: amino group from amino acid, peptides or protein and the carbonyl groups of reducing sugars (Singh et al., 2021). A high content of reducing sugars is essential in rice sugar syrup production to achieve an optimal color (Osuji et al., 2020). Therefore, increasing the malt concentration in rice sugar syrup production results in a higher reducing sugar content, which promote the formation of more melanoidin compounds. This, in turn, imparts a darker brown color to the syrup and leads to a lower ΔE value.

Viscosity

The rice sugar syrup produced in this study was observed to have varying levels of thickness (viscosity). The viscosity of rice sugar syrup originates from the main component—dissolved sugars—in the syrup solution. The hydroxyl groups in sugar forms hydrogen bonds within the solution, resulting in a thick syrup consistency. Heating the sugar syrup filtrate using a hotplate transforms the syrup from a liquid into a thicker form. The average viscosity of rice sugars from this study is illustrated in Figure 2. ANOVA shows that the average viscosity of rice sugar syrup were not statistically significant despite a significant effect on TSS. Other factor such as dextrose equivalent may influence this result.

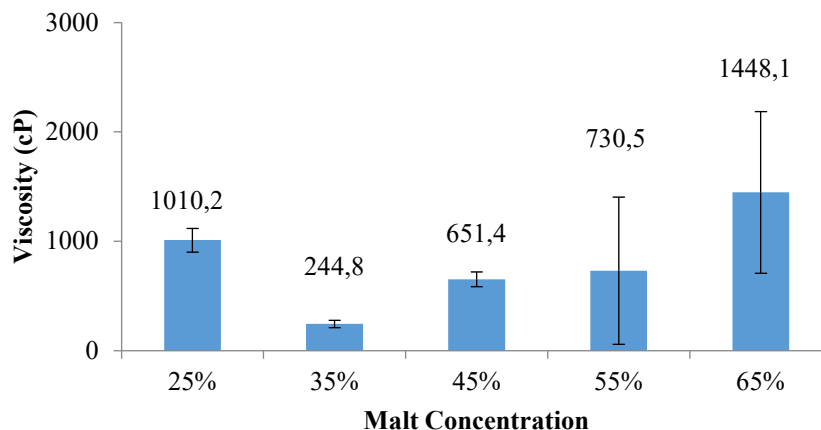


Figure 2. Viscosity of rice sugar with different concentration of malt

Sensory Properties

In this study, a ranking test was conducted on the sensory attribute of sweetness. Sweetness is a characteristic of sugar syrup that can be assessed subjectively and is generally influenced by factors such as concentration, temperature, pH, viscosity, and the presence of other constituent components (Hull, 2010). Sugar syrups composed of different carbohydrates exhibit varying levels of sweetness. Rice sugar syrup, produced from the hydrolysis of complex rice starch carbohydrates using rice malt, results in a syrup primarily composed of simple carbohydrates that contribute to its sweetness. According to Ojewumi et al. (2018) and Lin et al. (2013), the primary carbohydrate in sugar syrup produced via malt-based hydrolysis of rice starch is maltose.

The results of the ranking test are presented in Table 3. These findings indicate that the concentration of rice malt significantly influences the sensory attribute of sweetness in rice sugar syrup. A higher concentration of rice malt leads to a higher perceived sweetness in the syrup. In this study, the syrup produced

with 65% rice malt concentration received the highest sweetness ranking (Rank 1). The higher the sweetness level, the better the overall quality of the rice sugar syrup product. This suggests that the maltose concentration—one of the primary components contributing to sweetness in rice sugar syrup—is directly affected by the amount of rice malt used. As the concentration of rice malt increases, the maltose content in the syrup also increases, which corresponds with the observed increase in sweetness.

Table 3. The ranking and sensory properties of rice sugar syrup at various malt concentrations

Malt Concentration	Ranking	Color	Aroma	Taste	Viscosity	Overall Acceptance
25%	5	3.6±0.91	3.56±0.96	3.56±0.76	3.32±0.80 ^a	3.60±0.86
35%	4	3.88±0.72	3.52±0.82	3.84±0.74	3.48±0.65 ^a	3.76±0.83
45%	3	3.84±0.74	3.88±0.72	4.00±0.57	3.72±0.67 ^{ab}	4.16±0.68
55%	2	3.6±0.64	3.92±0.75	3.72±0.73	3.92±0.64 ^b	3.96±0.73
65%	1	3.36±0.63	3.48±0.83	3.48±0.77	4.00±0.76 ^b	3.56±0.76

Note: Means with different superscripts within the same column are significantly different according to DnMRT ($p < 0.05$).

The rice sugar syrup products produced using various concentrations of rice malt were evaluated based on consumer preference or dislike. A 5-point hedonic scale was used in this test, ranging from "strongly like," "like," "somewhat like," "dislike," to "strongly dislike." The hedonic evaluation in this study was conducted using the parameters of color, aroma, taste, viscosity, and overall acceptability. The results of the hedonic assessment by panelists are presented in Table 3.

Color is the first sensory characteristic of food products that is immediately recognized by consumers, making it a critical factor in determining product preference. Rice sugar syrup with varying rice malt concentrations exhibited different color appearances, ranging from cream brown to dark brown. However, based on ANOVA analysis, the color of the rice sugar syrup did not have a significant effect on panelists' preference. Likewise, the different malt concentrations had no statistically significant effect on the panelists' liking of the syrup's color. Panelist preferences for the syrup's color ranged from a low of 2.12 to a high of 2.64, indicating that panelists generally liked the rice sugar syrup across all malt concentration treatments.

Aroma is considered one of the key factors in evaluating a food product. Aroma generates a sensory experience that allows individuals to perceive whether a product is pleasant or unpleasant. Rice sugar syrup produced with varying concentrations of rice malt exhibited a characteristic aroma resembling that of rice or boiled corn. This aroma developed during the syrup thickening process using a hot plate and remained present in the final product. Similar to the color attribute, the aroma attribute did not have a statistically significant effect on panelists' preference for the rice sugar syrup across different malt concentrations. Panelists generally liked the aroma, with hedonic scores ranging from 2.08 to 2.52 on the 5-point scale.

Taste is the human sensory response to chemical stimuli, with the tongue as the primary organ for taste perception, making it a central attribute in determining food preference. The rice sugar syrup at all malt concentrations had a sweet taste, which is a basic taste typically associated with positive liking. This aligns with the hedonic test results, where panelists rated the taste between 2.00 and 2.52, indicating general liking. However, the variation in malt concentration did not significantly affect the taste preference among panelists.

Viscosity is a complex food product characteristic, as its evaluation involves a combination of tactile, visual, and even auditory perception. The rice sugar syrup produced with different malt concentrations exhibited varying levels of thickness, although all remained in liquid form. These differences in viscosity showed a statistically significant effect on panelists' preference. Hedonic ratings for viscosity ranged from 2.00 (liked) to 2.68 (somewhat liked). Panelists tended to prefer syrups with higher viscosity, which corresponded to higher malt concentrations.

Overall acceptance of a food product depends on each consumer's individual preferences, which are influenced by diverse backgrounds and experiences. In this study, the overall acceptance of rice sugar syrup made with different concentrations of rice malt did not differ significantly across treatments. Panelists' overall hedonic ratings ranged from 1.84 to 2.44, indicating a general level of liking for all syrup samples regardless of malt concentration.

4. Conclusion

Rice syrup contains reducing sugars as a result of starch hydrolysis by rice malt. However, the starch in the rice was not fully hydrolyzed, as starch components were still detectable. Higher concentrations of rice malt produced rice syrup with higher Brix values and darker color (less red and less yellow), as well as a higher sweetness level. However, the viscosity of the rice syrup was not influenced by the concentration of rice malt. Regarding the hedonic preference for thickness, the higher the concentration of rice malt in the hydrolysis process, the more preferred the resulting rice syrup was. Overall, panelists favored the rice syrup in terms of color, aroma, taste, thickness, and general acceptability. In this study, a rice malt concentration of 0.65 produced the best results, with a TSS of 64.95 °Brix, a color ΔE of 12.648, viscosity of 1448.1 cP, highest sweetness rating, and overall best preference score.

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