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Research Article

Kimpul (*Xanthosoma sagittifolium*) liquid sugar with a low glycaemic index

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Abstract

Kimpul (*Xanthosoma sagittifolium*) is one type of local tuber plant that has high carbohydrate content (34.2 g/100g). This plant provides an opportunity to be utilized as an alternative source of sugar. The use of kimpul as liquid sugar becomes an alternative sweetener that needs testing from the perspective of nutrition and health. The Glycaemic Index (GI) is a term that is closely related to carbohydrate metabolism, which has the index (level) of food according to its effect on blood glucose levels. The study of the formulating process of kimpul liquid sugar that has a lower GI attempts the use of sugar from kimpul can be more appropriate and well-targeted. This study aimed to determine the engineering process to decrease the GI value of liquid sugar from kimpul through the treatment of tea extract addition and identify the nutritional value, calorific value, GI value, and tannin content in the kimpul liquid sugar as the result of the engineering process. The results showed that the addition of black tea extract with a 2% concentration could reduce the GI value of the kimpul liquid sugar. Thus, kimpul liquid sugar can use as a source of natural sugar with a low GI.

Keywords: engineering process, glycaemic index, kimpul liquid sugar, tea extract

Abbreviations:
AHP – Analytical Hierarchy Process;
AOAC – Association of Official Analytical Chemists;
BMI - Bone Mass Index;
DNA - Deoxyribonucleic Acid;
GI - Glycaemic Index

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Introduction

Sugar is the basic needs of people, especially its role as a sweetener, and the demand is increasing. The Ministry of Industry of the Indonesia Republic noted cane-based sugar production in 2018 amounted to 2.17 million tons. Meanwhile, the need for national sugar reaches 6.6 million tons. For this reason, it is essential to look for an alternative to have other sweeteners, such as developing glucose syrup (liquid sugar) from starch hydrolysis.

Glucose syrup is a dilute solution of glucose, maltose, and other nutrient saccharides obtained from starch, odourless and colourless, but has a great sweet taste. Liquid sugar, including glucose and fructose produced from several sources such as water hyacinth (Das et al. 2015), starch from rotten potatoes (Yadav et al. 2017), malted grains (Ojewumi et al. 2018), red sorghum (Permanasari et al. 2018), and corn (Parker et al. 2010).

Kimpul (*Xanthosoma sagittifolium*) is tuber plants that are likely to be developed because it has various benefits and can cultivate easily. Kimpul can plant as a potential non-rice carbohydrate producer. Besides, according to Ndabikunze et al. (2011), kimpul tubers contain high carbohydrate, which is 20.95 g/100g. More specifically, Puspitasari et al. (2015) mention that the kimpul flour has the following chemical composition: 12.35% of water content, 82.05% of carbohydrate content, 2.71% of protein content, 0.23% of Ca content, 2.70% of ash content, 0.22% of fat content, 22.03% of amylose content, 34.27% of amylopectin content, 56.26% of starch content, 3.43% of crude fiber content, gel strength at 0.23N, gelatinization temperature at 90,67°C, and the absorption of flour against water at 7.95.

The research results of Reeks et al. (2017) show that the liquid sugar from the enzymatic hydrolysis results still has a high glycaemic index value of 80.63. The concept of the GI was initially introduced as a way to classify various sources of carbohydrates (CHO) and foods rich in CHO in food, according to their effects on postprandial glycaemia (Jenkins et al. 1981). This concept assumes that all carbohydrate foods of the same quantity will produce unequal effects on blood glucose levels. Low-GI foods help people to control hunger, appetite, and blood sugar levels so that the low-GI foods can help reduce the excess of body weight.

There were no differences in metabolic or endocrine responses between liquid sugar and sucrose associated with obesity or other adverse health outcomes. This equality is not surprising given that these two sugars contain approximately the same amount of fructose and glucose, contain the same amount of calories, have the same sweetness level, and are absorbed identically through the digestive tract (Rippe et al. 2013). Therefore, we need process engineering to reduce the GI value by adding tea extracts.

Tea (*Camellia sinensis*) contains many polyphenol compounds. According to Dorkbuakaew et al. (2016), the tea leaf bud, and the two youngest leaves contain water-soluble phenolic compounds. Green tea contains 30-40% polyphenols (Sharangi 2009). The polyphenol compound has an active ingredient in the form of catechin, which is a condensed tannin derivative. Besides, a polyphenol compound due to its many hydroxyl functional groups. Catechin in tea plays a role in controlling glycaemia (Sampath et al. 2017; Snoussi et al. 2014). Added by Amorim et al. (2018), that green tea is beneficial for diabetics and osteoporosis. Green tea contributes to increasing bone mineral levels of diabetics.

Black tea is a tea that made through a fermentation process, namely the enzymatic oxidation process of catechins by polyphenol oxidase. Black tea has various health benefits, including reducing the risk of coronary heart disease and stroke, preventing and controlling cancerous growth, preventing dental caries, increasing Bone Mass Index (BMI), and antidiabetic effects. Tea polyphenols can reduce blood glucose by inhibiting starch-breaking enzymes, namely amylose (Hara et al. 1990). Catechin compounds act as antioxidants that can prevent or inhibit uncontrolled attacks on body cell groups such as cell membranes, Deoxyribonucleic Acid (DNA), and fat by free radicals and active oxygen compounds. The content of substances (phytochemicals) in the tea itself, especially phenolic acid, flavonoids, catechin (C), epicatechin (EC), epicatechin-3-gallate (ECG), gallocatechin

(GC), epigallocatechin (EGC) and epigallocatechin-3-gallate (EGCG) and other flavanol derivatives (Baibado et al. 2011; Chen et al. 2001; Graham 1992; Lin et al. 2003). Polyphenolic compounds often referred to as tannins. This nutrient can reduce the digestibility of protein and starch so that the glycaemic response decreases. The impact of tannins is the formation of complex compounds with insoluble proteins that tend to reduce the digestibility of proteins and starches.

This study aimed to provide alternative natural sweetener ingredients with local resource ingredients, in the form of kimpul liquid sugar, by conducting an engineering process to reduce the value of the glycaemic index of liquid sugar by adding tea extracts. The liquid sugar from the process then determines the nutritional value, calories, Glycaemic Index value and tannin content, so that its utilization can be more effective and on target.

Materials and Methods

Materials and tools. The tools used for analysis include analytical scales, drying ovens, Muffle furnaces, water bath, glassware, injection syringe, glucose test.

The materials used in this study were bulb, $NaCO_3$, α-amylase enzyme and glucosidase enzyme, 1% of NaOH, black tea, green tea, petroleum ether, H_2SO_4, NaOH, boric acid, blue methylene, and HCl.

Research design. The engineering process of liquid sugar from kimpul, with the addition of tea extract, utilized the Randomized Block Design with two factors. The first factor was tea types (T) with two levels, namely T1: green tea and T2: black tea. Meanwhile, the second factor was the concentration of tea extract (K), with three levels: K1: 1%, K2: 2%, and K3: 3%.

The stages of processing liquid sugar are as follows make a 30% starch solution by dissolving 300 g of starch into 1,000 ml of water. Furthermore, the pH adjusted by adding citric acid to pH 5. Do the gelatinization process by heating the solution at 105°C. Next, do the liquidation by adding 3 ml α-amylase enzyme and tea extract with the appropriate concentration of treatment, then carry out the hydrolysis process at a temperature of 100°C for 60 min. Then cool the results of liquefaction to a temperature of 60°C, then add the enzyme glucosidase 1 ml/kg and hydrolysed at a temperature of 60°C for 72 h. During the hydrolysis, stirring carried out every 12 h. Blanching process by adding activated carbon as much as 0.5 - 1.0% of the weight of starch, then filtered. The last step is evaporation to get glucose syrup. Conduct evaporation until a 60 - 80°Brix syrup solution obtained.

The method of extracting black tea and green tea did by soaking black tea and green tea in hot water at a temperature of 70°C for 15 min with a ratio of tea and water of 1:3, then a filtering process is carried out to get black tea and green tea extracts.

Observation parameters. In the present study, the parameters tested were brix degree (hand refractometer), water content (Bradley Jr. 2010), sugar reduction content (AOAC 1990), tannin content (AOAC 1990), calorie value (AOAC 1990), Glycaemic Index (Brouns et al. 2005), and organoleptic test on flavour, color and aroma.

Reducing sugar content. Determining of reducing sugar content used to the Park-Johnson method (AOAC 1990). A sample of 1 ml added to 0.5 ml of sodium carbonate-sodium hydrogen carbonate buffer solution (4.8 g Na_2CO_3, 9.2 g $NaHCO_3$ and 0.65 g KCN dissolved in 1 L aquadest). After that add 0.5 ml of potassium ferricyanide 0.1% (w/v. The mixture of the solution is heated for 15 min in boiling water (cover the test tube with marbles) and cooled in running water for 10 min. Next 2.5 ml of ferrous ammonium sulfate (3 g $(NH_4)Fe(SO_4)_2.12H_2O$ solution added in 1 L of 50 mM H_2SO_4 solution) and mixed using vortex and allowed to stand for 20 min at room temperature and read at 715 nm wavelength with using a spectrophotometer. The creation of a standard curve did in the same way as for the sample, but the sample replaced with glucose with concentrations of 2, 4, 6, 8 and 10 ppm.

Water content. Determination of water content used the distillation method (Bradley Jr. 2010). A sample of 5 g put into a 250 ml Erlenmeyer, then 50 ml of toluene was added. The sample is boiled on a hot plate and waits for ± 10 min after boiling, then the volume of water is read with a measuring cup. The determining of moisture content by Equation 1.

$$KA\ (\%) = \frac{Water\ Volume\ (mL)}{Material\ Weight\ (g)} x100\% \quad (1)$$

Protein content. Measurement of protein content performed using the Kjeldahl semi-micro method (AOAC 1990). Samples were weighed as much as 0.1 - 0.5 g, put in 100 ml Kjeldahl flasks, then added 50 mg Hg_2O, 2 mg K_2SO_4 and 2 ml H_2SO_4, boiling stones and boil for 1.5 h until the liquid becomes clear. After that, the solution is cooled and diluted with distilled water. Samples distilled with the addition of 8 - 10 ml of NaOH - $Na_2S_2O_3$ solution (made with a mixture: 50 g NaOH + 50 ml H_2O + 12.5 $Na_2S_2O_3$ $5H_2O$). The distillation results stored in an Erlenmeyer that contains 5 ml of H_3BO_3 and 2-4 drops of PP indicator. The obtained distillate is then titrated with 0.02 N HCl solution until the color changes from green to grey. The same thing did with blanks. The results obtained are total N, which then expressed in a 6.25 conversion factor. The following formula calculates determination of protein content used to Equation 2.

$$\%\ Proteins = Va - Vb\ HCl\ x\ N\ HCl\ x\ 14.007\ x\ 6.25\ W\ x\ 100\% \quad (2)$$

Where:

Va 1= ml HCl for sample titration

Vb = ml HCl for blank titration

N = normality of the standard HCl used 14.007; correction factor 6.25

W = sample weight, g

Fat content. Fat content testing is done based on the method of AOAC (1990). The distilled flask used is dried in an oven at 100 - 110°C for 30 min, cooled in a desiccator and weighed. The sample was weighed as much as 5 g and put into a Soxhlet extractor that had contained hexane solvent. Reflux carried out for 5 h (minimum), and hexane solvents are in the distilled fat flask. Then the fat flask containing extracted fat is heated in an oven at 100°C until the weight is constant, cooled in a desiccator and weighed. The following formula calculates determination of fat content used to Equation 3.

$$\%\ Fats = fat\ weight\ g\ /\ sample\ weight\ g\ x\ 100\% \quad (3)$$

Ash content. Ash content testing carried out using gravimetric methods (AOAC 1990). Porcelain dishes are dried in a 105°C oven for about 1 hour, cooled in a desiccator for 20 - 30 min then weighed. A total of 2 g of the sample was weighed and put in a porcelain cup. Then the sample is burned on the flame of the burner until it is no longer smoky, then carried out ignition in an electric furnace at a maximum temperature of 550°C for 4 - 6 h or until white ash is formed. The sample cooled in a desiccator, then weighed. They were drying repeated until a constant weight obtained. The following formula calculates determination of ash content used to Equation 4.

$$\%\ Ash\ Content = B - CA\ x\ 100\% \quad (4)$$

Where:

A = sample weight, g
B = Cup weight + ash, g
C = Cup weight, g

Tannin content. Tannin content testing is done based on the method of AOAC (1990). Weigh 1.5 g of the sample, then add 50 ml of water and heat at 40 - 60°C for 30 min. Then the filtering process is carried out into a 250 ml volumetric flask and adding distilled water to the marked line. Take 25 ml of the solution, add 20 ml of indigo carmine solution and titrate with 0.1 N $KMnO_4$ solution until the color changes to golden yellow. Suppose a titrant volume of A ml is required. Then determine the blank by piping 20 ml of indigo carmine solution into the Erlenmeyer and adding water then titrated like the example above. For example, a titrant volume of B ml required. Tannin content can calculate using the Equation 5.

$$\%Tannin = \frac{10(A-B)xNx0.00416}{Sample(g)} x100\% \quad (5)$$

Where:

A = tannin titration volume, ml
B = titration volume blank, ml
N = normality of $KMnO_4$ standard, N
10 = Dilution factor,
1 ml $KMnO_4$ 0.1 N = the equivalent of 0.00416 g of tannin

Glycaemic index. Analysis of the Glycaemic Index using rat (*Rattus norvegicus*) Wistar strain weighing 120 - 200 g, male and two months old. The experiment carried out using five animals for each treatment. Mice gave a standard glucose solution and 1 ml of liquid sugar solution orally. Furthermore, rat blood sampling carried out at 0, 15, 30, 60, 90 min after administering the test material. Blood from the tail of the rat drawn, the rat's tail is cleaned and then massaged slowly, then the tip is pricked with a needle. Blood glucose levels are measured using glucose test devices.

Data analysis. The processing of organoleptic test data, which was ordinal data in the study used the Friedman Test. Meanwhile, the processing of chemical test data accomplished by analysing the variance. If there were differences, the Duncan test implemented with a 95% confidence level.

Alternative selection. The alternative selection was completed to determine the best treatment in the production process of liquid sugar from kimpul with enzymatic hydrolysis. The concept of expected value was to choose a decision that had a maximum pay off (profit or usefulness) or minimum cost (loss or sacrifice). For liquid sugar product from kimpul, the quality parameters used for the selection of the best process alternative were aroma, colour, flavour, sugar reduction content, tannin content, calories, and GI. Determination of the importance weight of each parameter using the Analytical Hierarchy Process (AHP) method (Saaty et al. 2013).

Results and Discussion

Organoleptic properties. Sensory tests were carried out using 30 semi-trained members with five hedonic scales, namely 1: immensely dislike, 2: dislike, 3: neutral (neither like nor dislike), 4: like, and 5: immensely like. The sensory attributes tested were taste, aroma, and colour. The percentage of the score for the parameter of taste, aroma, and colour based on the Frequency Analysis results shown in Table 1.

Taste. Table 1 showed that the higher concentration of tea extract added, it will also increase the sense of panelists' dissatisfaction with the taste of liquid sugar generated from *kimpul*. Besides, the type of tea added also affects the panelists' preferred level of the taste of liquid sugar from *kimpul*. Here, the addition of green tea extract tends to be preferable to panelists compared to black tea. It assumed that black tea has a more dominant sugarless (bitter) taste as a result of the fermentation process. According to Khasnabis et al. (2015), black tea has more tannin content than green tea. The most preferred taste of liquid sugar from consumers is T1K1 treatment (addition of the green with a concentration of 1%), with the average score 3.50 ± 0.51.

The result of the Friedman test showed that the obtained score of the taste of *kimpul* liquid sugar indicates that there was a significant difference between treatments ($p < 0.05$), with the F_{value} of 107.052. The result of an organoleptic test on the taste of *kimpul* liquid sugar indicates that, on average, panelists do not like the sweet taste of *kimpul* liquid sugar. That was probably due to the taste of sugarless taste as a result of the addition of tea extract. Here, tea contains a polyphenol compound known as tannin, which has a distinctive taste as sugarless. According to (Matsubara et al. 2006), the bitter taste and astringency of tea caused by the catechin compounds found in tea.

Aroma. In Table 1, it appears that panelists tend to prefer the aroma of liquid sugar plus green tea extracts compared to black tea. Besides, an increase in the amount of concentration in each type of tea will cause a decrease in panelists' preference for the aroma of the liquid sugar produced. The most preferred aroma of liquid sugar from consumers is T1K1 treatment (addition of the green with a concentration of 1%), with the average score of 3.53 ± 0.51.

Based on the Friedman test, it identified that the obtained aroma score of liquid sugar from *kimpul* shows the significant difference between treatments ($p < 0.05$), with an F_{value} of 114.799. Moreover, the result of an organoleptic test shows that the average panelists do not like the aroma of liquid sugar produced by the addition of tea extract. That was probably due to the aroma of tea extract is very dominant, thus affecting the aroma of liquid sugar generated from *kimpul*. It also is seen that the higher the concentration of tea extract that added, the more the panelists dislike the aroma of liquid sugar produced from *kimpul*.

Table 1. Score average of taste, aroma, and colour parameters

Parameter	Score average					
	T1K1	T1K2	T1K3	T2K1	T2K2	T2K3
Taste	3.50 ± 0.51	2.37 ± 0.49	1.80 ± 0.55	3.33 ± 0.66	1.90 ± 0.55	1.63 ± 0.56
Aroma	3.53 ± 0.51	2.80 ± 0.41	2.00 ± 0.64	2.87 ± 0.63	1.97 ± 0.41	1.33 ± 0.48
Colour	3.40 ± 0.56	2.03 ± 0.41	1.60 ± 0.50	2.80 ± 0.61	1.80 ± 0.48	1.40 ± 0.50

Note: T1: green tea, T2: black tea, K1: 1%, K2: 2%, and K3: 3%

During black tea fermentation, catechins oxidized. Oxidized catechins are potent oxidizing agents, which can oxidize other compounds, such as amino acids, carotenoids, and unsaturated fatty acids, resulting in the formation of volatile compounds that contribute to the aroma of black tea (Selvendran et al. 1978).

Colour. Table 1 showed that panelists tend not to like the colour of liquid sugar added with black tea extract. Besides, panelists also tend not to like the colour of liquid sugar, along with the increased concentration of the added tea extract. The most preferred colour of liquid sugar from consumers is T1K1 treatment (addition of the green with a concentration of 1%), with the average score of 3.40 ± 0.56.

Based on the Friedman test results, the colour score obtained of liquid sugar from kimpul showed that the treatments have a significant difference ($p < 0.05$), with an F-value of 107.052. Besides, it is clear from Table 1 that the higher concentration of tea extract added, the more the panelists' displeasure with its color. That was because, with the increase in tea extract concentration, the resulting liquid sugar has a darker brown color, while the expected liquid sugar has a bright yellowish color. In the study, the darker brown color is due to the oxidation reaction of polyphenolic compounds present in tea, which is triggered by the presence of oxygen, high temperature and heating time (Dabas 2016).

Chemical properties

Degree of Brix (ºBrix). The measurement of ºBrix was performed to determine the degree of sweetness of *kimpul* liquid sugar, with the treatment of tea extract concentration and the type of tea added. In relation with this, the data and graph of ºBrix of *kimpul* liquid sugar were presented in Fig. 1. Degree of Brix of *kimpul* liquid sugar produced range between 28.83 ± 0.29 and 29.67 ± 0.76.

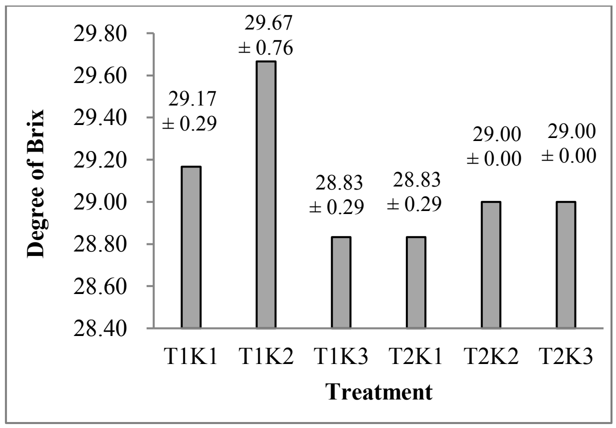

Figure 1. Degree of brix of *kimpul* liquid sugar with tea extract added T1: green tea, T2: black tea, K1: 1%, K2: 2%, and K3: 3%

The result of the variance analysis showed that there was no significant difference between the treatments of °Brix in the kimpul liquid sugar produced ($p > 0.05$). Tannin compounds present in tea can precipitate certain proteins, alkaloids, and polysaccharides. Also, contained hydroxyl groups and other groups such as carboxylates. There were to form complexes with proteins and other macromolecules. The α-amylase enzyme is a protein that can break down the carbohydrates into simple sugar groups. The complex formation of proteins and polyphenol compounds will interfere with the carbohydrate hydrolysis (Palupi et al. 2007). Afterward, the addition of tea extract in the process of liquid sugar from kimpul assumed has not caused a decrease in the activity of α-amylase enzyme and glucoamylase, so that °Brix of sugar produced is not significantly different ($p > 0.05$).

Reducing sugar. The results of the measurement of reducing sugar of kimpul liquid sugar shown in Fig. 2. It showed that the addition of black tea extract tends to increase the reducing sugar content of kimpul liquid sugar produced. Besides, the increased concentration of tea extract added also tends to increase the level of reducing sugar of kimpul liquid sugar produced.

The result of the statistical analysis indicates that there was no significant difference in treatment interaction ($p > 0.05$). However, the treatment of tea extract concentration showed a significant difference between reducing sugar content produced ($p < 0.05$) (Table 2).

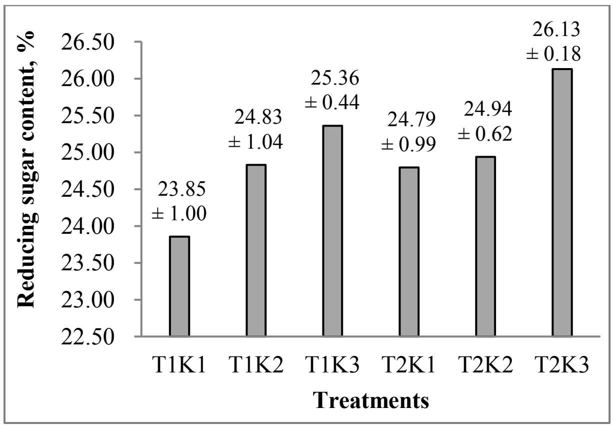

Figure 2. Reducing sugar of kimpul liquid sugar with the addition of tea extract T1: green tea, T2: black tea, K1: 1%, K2: 2%, and K3: 3%

Here, in Figure 2, it showed that the higher concentration of tea extract added, the reducing sugar content of the kimpul liquid sugar generated was also higher because the addition of the tea extract does not have an inhibitory effect on the action of the enzyme.

That was following the opinion of Majumdar et al. (1994) that the activities of amylase, lipase, and trypsin did not influence with low concentration of tannic acid.

Energy value. The results of measurements of energy values of liquid sugar shown in Fig. 3. It showed that the calories of kimpul liquid sugar by the addition of tea extracts produced ranged from 109.56 ± 2.06 to 115.13 ± 1.45.

Table 2. Duncan test notation for *kimpul* liquid reducing sugar content

Treatment	Reducing sugar content, %
K0	23.20 ± 0.25 [c]
K1	24.32 ± 0.66 [b]
K2	24.88 ± 0.08 [ba]
K3	25.74 ± 0.54 [a]

Note: Different letters indicate significant differences ($p < 0.05$)

The statistical analysis result in the study showed that there was no significant difference between the treatments of the calorie value of kimpul liquid sugar generated ($p > 0.05$). That was because the reducing sugar content that is the source of calories has the same value in all treatments.

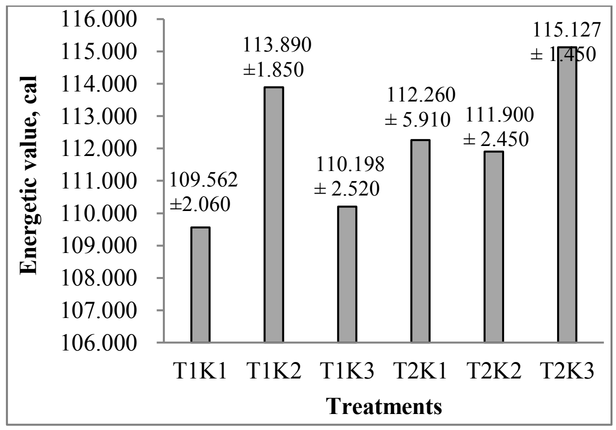

Figure 3. Energetic value of kimpul liquid sugar with the addition of tea extract T1: green tea, T2: black tea, K1: 1%, K2: 2%, and K3: 3%

Tannin content. The measurement of tannin content was carried out to determine the kimpul liquid sugar tannin content by treating the concentration of tea extract and the type of tea added. The results of the measurements of kimpul liquid sugar tannin levels shown in Fig. 4. It showed that the tannin content of kimpul liquid sugar by the addition of tea extracts produced ranged from 0.0017 ± 0.0010 % to 0.0043 ± 0.0040 %.

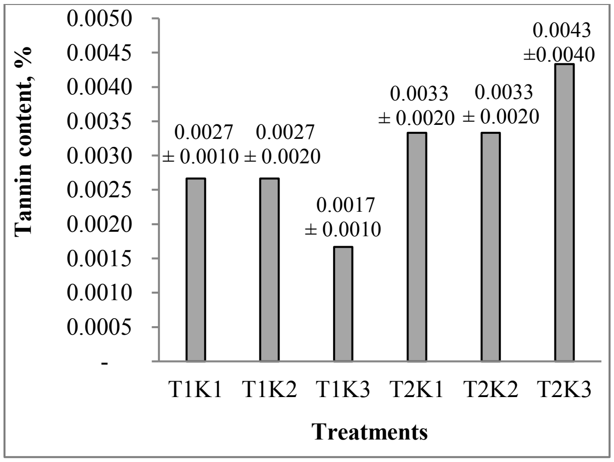

Figure 4. Tannin content of kimpul liquid sugar with the addition of tea extract T1: green tea, T2: black tea, K1: 1%, K2: 2%, and K3: 3%

The results of statistical analysis showed that there was no significant interaction between treatments on the tannin content of kimpul liquid sugar produced ($p > 0.05$). However, the treatment concentration of tea extract significantly affected ($p < 0.05$). Duncan's test results showed that the K0 treatment was significantly different from the treatments K1, K2, and K3, but the treatments K1, K2, and K3 were not significantly different. That was probably due to differences in the concentration of tannins added too small, so that no significant difference in tannin levels has been seen (Table 3).

Table 3. Duncan test notation for *kimpul* liquid sugar tannin content

Treatment	Tannin content, %
K0	0.0000 ± 0.0000^{a}
K1	0.0030 ± 0.0004^{b}
K2	0.0030 ± 0.0004^{b}
K3	0.0030 ± 0.0018^{b}

Note: Different letters indicate significant differences (p < 0.05)

According to Towaha (2013), black tea contains catechins as much as 5.91%, while green tea contains more catechins which are 10.04%. This difference caused because, during the processing process, the catechin content has decreased due to the process of withering, enzymatic oxidation, grinding and drying.

Glycemic index. The calculation of GI value was based on the increased blood sugar of experimental animals (mice) during the observation. In this case, the observation of blood sugar content done at minutes 0, 15, 30, 60, and 90 after giving a sample of kimpul liquid sugar products in an animal. The results of the calculation of the GI value of kimpul liquid sugar shown in Table 4. The kimpul liquid sugar with the addition of tea extracts has GI values ranging from 31.34 to 64.50.

Table 4. Glycemic index value of kimpul liquid sugar with tea extract added

Treatment	Area width	GI value
Glucose	25,315.83 ± 6.09	100.00 ± 0.00
Control	20,712.42 ± 2.91	81.82 ± 0.01
T1K1	16,329.24 ± 0.98	64.50 ± 0.02
T1K2	12,273.03 ± 8.89	48.48 ± 0.01
T1K3	13,642.92 ± 10.39	53.89 ± 0.01
T2K1	15,708.69 ± 10.00	62.05 ± 0.05
T2K2	7,933.68 ± 10.00	31.34 ± 0.02
T2K3	9,858.24 ± 5.29	38.94 ± 0.00

Note: T1: green tea, T2: black tea, K1: 1%, K2: 2%, and K3: 3%

Based on the calculation of GI value, the kimpul liquid sugar with the addition of black tea extract with 3% concentration causes the decrease in GI value, so that it enters in the low GI group (GI < 55). Here, the decline of GI is thought to be caused by the added tea extract containing polyphenolic compounds (tannin). The study of the US Agriculture Department (Anderson et al. 2002) claims that black tea's ability to increase insulin activity is higher than the power of green tea and oolong tea. Besides, Palupi et al. (2007) argue that tannins will form complex compounds with insoluble proteins that tend to decrease protein digestibility and starch.

Alternative selection

Analytical hierarchy process. The alternative selection was made in order to choose the best treatment alternative. Meanwhile, the determination of the weight of interest of each selection criterion was performed by using AHP. Here, weight determination was carried out to determine the weight or parameter size of each selection criterion considered. However, in determining the best alternative, we used the method of expectation value. Determination of the importance of each criterion was carried out using AHP. Quality parameters that taken into consideration were aroma, taste, color, reducing sugar content, tannin content, calorie value, and GI value. AHP results showed that the GI and calorie parameters have the highest value with an importance weight of 0.28, while the aroma has the lowest value with an importance weight of 0.03.

Expectation value. The best alternative was the treatment that has the highest expected value. Of the several treatments available, there was one treatment that has the highest expected value that will serve as the best alternative. The results of calculating the expectation value for each treatment shown in Fig. 5. The highest expectation value found in the T2K2 treatment (addition of black tea extract with a concentration of 2%), with the expected value of 5.21. While for the lowest expectation value, there was in the treatment of T1K2 (addition of green tea extract with a concentration of 2%) with an expected value of 3.11.

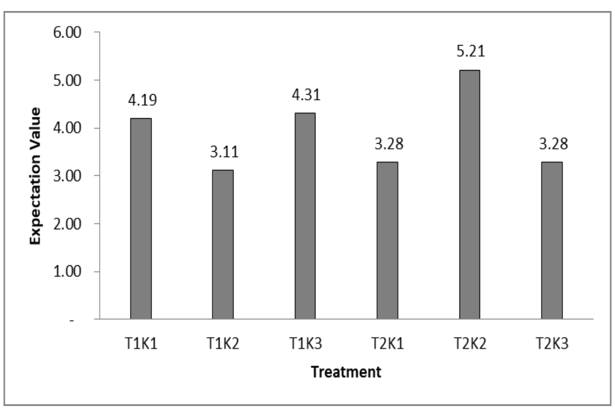

Figure 5. Expectation value of kimpul liquid sugar process on each treatment T1: green tea, T2: black tea, K1: 1%, K2: 2%, and K3: 3%

The alternative process chosen for processing kimpul liquid sugar with the addition of tea extract was T2K2 treatment (addition of black tea extract with a concentration of 2%), with a total expected value of 5.26. The chemical composition of selected kimpul liquid sugar products shown in Table 5.

Table 5. The composition of *kimpul* liquid sugar with the addition black tea of 2% (T2K2)

No	Parameter	Value
1.	Reducing sugar content, %	24.94 ± 0.62
2.	Water content, %	71.91 ± 0.63
3.	Ash content, %	0.13 ± 0.02
4.	Protein content, %	0.012 ± 0.001
5.	Fat content, %	0.009 ± 0.001
6.	Carbohydrate content, %	27.94 ± 0.61
7.	Tannin content, %	0.0033 ± 0.002
8.	Energetic value, cal/g	111.90 ± 2.45
9.	Glycaemic index	31.34 ± 0.02

Conclusions

The research results showed that the addition of tea extracts could reduce the GI value of kimpul liquid sugar. The selected treatment was T2K2 (the addition of black tea extract with 2% concentration) with quality parameter of reducing sugar content of 24.94 ± 0.62%, water content of 71.91 ± 0.63%, tannin content of 0.0033 ± 0.002%, energetic value at 111.90 ± 2.45 cal and GI value at 31.34 ± 0.02. Therefore, this kimpul liquid sugar product can be an alternative natural sweetener with a low GI value. A limitation of this study is that the product has not tested on humans as consumers. Furthermore, further research is needed related to this matter. It is also necessary to conduct research related to market acceptance of kimpul liquid sugar products. Regarding the application of this method to industry, the further study still needed.

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