

Qualitative and Semi-Quantitative Testing and Analysis of Sugar Content in Several Sweetened Beverages

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Abstract. The increasing popularity and availability of sweetened beverages has contributed to a higher risk of metabolic diseases. This study analyzed the sugar content of various sweetened beverages using sequential laboratory tests. Qualitative analysis employed glucose paper strips to detect glucose presence, while semi-quantitative analysis used a refractometer to estimate total sugar content based on a standard curve. A total of 53 samples was selected due to their accessibility in the market and frequently consumed by the community, classified into nine categories by subject matter experts, were tested. Qualitative results indicated that 33 samples contained glucose, whereas 20 samples did not. Semi-quantitative analysis revealed that estimated total sugar content often exceeded the values stated on packaging labels, particularly in health supplement drinks, ready-to-drink coffee, and ready-to-drink tea. Several samples lacked sugar content information on their packaging despite exhibiting high sugar levels. The highest estimated total sugar content was observed in the energy drink category, followed by ready-to-drink tea and fruit juice. These results underscore the necessity for increased consumer awareness regarding excessive sugar intake and highlight the importance of regulatory oversight of nutritional labeling. Further analysis utilized a data mining approach, specifically the K-Medoids Clustering algorithm. The dataset was represented in two dimensions: qualitative features (glucose test results, binary Yes/No) and quantitative features (estimated total sugar content). Silhouette Score evaluation determined that three clusters were optimal. The first cluster comprised all samples without glucose, while the remaining two clusters separated glucose-containing samples by high and low sugar content. These results demonstrate the potential of data mining techniques to enhance sugar content analysis and characterize sweetened beverage test data.

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1 Introduction

Sweetened beverages, such as soda, bottled tea, energy drinks, and fruit-flavored drinks, are becoming increasingly common. They are now a primary choice in social activities and daily lifestyles. In recent years, consumption of sweetened beverages in Indonesia and various countries has sharply increased, especially among young people [1]. This trend is strongly influenced by changing consumer behavior due to urbanization. The convenience of ready-to-eat foods and beverages also plays a role. Additionally, the beverage industry drives this trend by developing products with various flavors and packaging [2]. Consumption of sweetened beverages correlates with increases in type 2 diabetes, obesity, heart disease, and other metabolic disorders, even at a young age [3].

After High sugar content can increase blood sugar levels, and excessive consumption can lead to body fat accumulation and insulin resistance [4]. The maximum safe daily sugar intake is 50 grams per person, or approximately 4 tablespoons per day. Consumption of sweetened beverages often exceeds the recommended daily intake and exceeds the recommended daily intake for a single drink [5]. Sweetened beverages (packaged sweetened beverages) typically contain added sugars such as sucrose, glucose, fructose, or high-fructose corn syrup (HFCS). These products include soft drinks, packaged tea and coffee, energy drinks, and even processed fruit juices, all of which contain sugars far exceeding the recommended daily intake limit set by the Indonesian Ministry of Health [6].

Consumers should consume sweetened beverages according to the serving size, paying attention to the total calorie and carbohydrate content, especially the sugar content listed on the product's nutritional information package. However, the sugar content listed on nutritional information packaging does not always correspond to the total sugar content analyzed in the laboratory [7]. Consumers can use paper strips for a portable glucose test within 7 minutes [8]. The refractive index of total sugar can be detected by a Refractometer by determining the total dissolved solids content [9]. Total dissolved solids (oBrix) indicate the relative sugar concentration, while the researchers can also apply an ABBE refractometer to measure sugar content.

The balanced nutrition guidelines by the Indonesian Ministry of Health emphasize limiting the consumption of sweetened beverages and replacing them with water, unsweetened milk, or unsweetened natural juices [10]. These guidelines support a diet that prioritizes energy sources from complex carbohydrates, protein, healthy fats, fruits, and vegetables, so the habit of consuming packaged sweetened beverages is not in line with efforts to implement balanced nutrition in the community [11].

The aim of this study was to qualitatively test and analyze the sugar content in several sweetened beverages using glucose paper strips and semi-quantitatively using a refractometer. Information on the type and amount of actual sugar contained in these sweetened beverages, both qualitatively and semi-quantitatively, can help consumers understand the risk of excessive sugar consumption from beverages, support public education, and provide basic guideline data for food and health supervisors, especially in optimizing the limitation of daily sugar consumption by consumers.

2 Material and methods

Fifty-three sweetened beverage samples were collected from around Depok City, West Java, Indonesia, namely energy drinks (A1-A6), flavored/jelly drinks (B1-B3), natural isotonic drinks (C1-C2), health supplement drinks (D1-D10), carbonated soft drinks (E1-E4), ready-to-drink coffee drinks (F1-F7), fruit juice drinks (G1-G4), isotonic drinks (H1-H5), ready-to-drink tea drinks (T1-T12). These drinks were selected due to the preferences from teens, accessibility and provided in the market, obtained with various type of packaging i.e. bottles,

cups, cartons, and cans. Information on carbohydrate, sugar, and dietary fibre content is listed on the product nutrition information packaging. However, some roadside drinks did not have product nutrition information on their packaging (not defined/ND).

In general, Figure 1 shows the research stages that include collecting sweetened beverage samples, preparation, followed by sample labelling and laboratory testing, recapitulation of test results, and finally analysis and clustering of test result data. In the preparation stage, the sample was prepared by adding 0.5 mL of 0.5 M HCl and 0.5 mL of dichloromethane, shaking for 30 seconds, and then centrifuging for 3 minutes. The acid and heating time can cause a reverse reaction between glucose and maltose molecules, forming higher, non-reducing oligosaccharides [12]. The upper supernatant from the extraction was stored in a vial for sugar content testing.

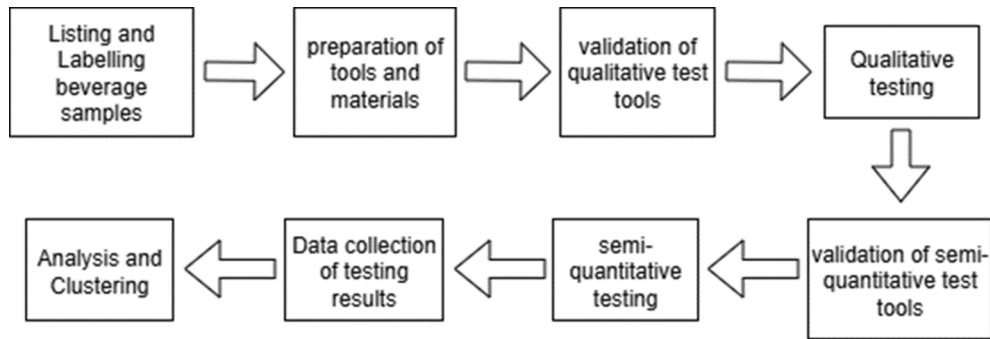


Fig. 1. Research stages.

Glucose in beverages was qualitatively measured using glucose paper strips (Bartovation, USA). The glucose paper was cut and dipped into the beverage sample for 1-2 seconds, then left for 60 seconds to be compared with the test strip color chart on the packaging. The color chart on the glucose paper strips displays 5 colors that indicate the glucose levels in the sample: 0%, 0.1%, 0.25%, 0.5%, and 2%, as shown in Figure 2. The color of the paper when dipped in a liquid that does not contain glucose will not change, namely, yellow. If dipped in a solution containing glucose, the color of the paper will change to greenish. The more intense the green color, the higher the glucose concentration in the solution.



Fig. 2. Glucose paper as a qualitative testing tool.

Relative sugar content ($^{\circ}$ Brix) and total sugar (g/100 mL) were analyzed using an ABBE RF-AM refractometer (SCITEK). 2-3 drops of the prepared beverage sample were placed directly on the surface of the primary prism of the ABBE refractometer. The sample liquid must be evenly covered by the secondary prism by locking the secondary prism. The illuminator scale was adjusted to the correct halftone boundary line by focusing the eyepiece

so that the refractive index and oBrix values from the scale could be read. The refractive index was then included in the calculation of total sugar content. Total sugar content was obtained from the calculation of the standard curve based on the results of the qualitative glucose test using glucose paper strips. Observations were carried out 3 times.

In qualitative test process, if the qualitative test results with glucose paper produce a yellow color, the refractive index as the x value will be included in the sucrose standard curve. If the qualitative test results with glucose paper produce a green color, the refractive index, as the x value, will be included in the standard curve (a mixture of glucose and sucrose). The correction factor (g/100L) is subtracted from the calculated total sugar content (g/100mL). This correction factor is obtained from the calculation of the refractive index of salt (Sodium) listed on the nutritional information label for each beverage product.

The calibration standard curve is obtained by measuring the refractive index of several sucrose concentrations (%) namely 2.5, 5, 10, 15, 20, 25, 30, 40, 50, and 60 on an ABBE refractometer. The listed values are then entered into a linear equation that produces the sucrose standard curve. The creation of the standard curve (glucose, sucrose) uses a 1:1 ratio, carried out with the same concentration and method as the creation of the sucrose standard curve. The standard curve equations obtained and used in this study are presented in Table 1.

Table 1. Setting Word's margins.

Margin	mm	
Top	24	
Bottom	16	

Cluster analysis, first conceptualized by Tryon, represents an unsupervised learning methodology aimed at systematically grouping objects into internally homogeneous clusters. This approach facilitates the identification of inherent data structures and latent patterns within a dataset by employing similarity measures, such as geometric distance. In this study, the k-Medoids clustering algorithm was used to perform the clustering task. This algorithm was selected to construct the model with the purpose of characterizing beverage samples based on the presence of glucose content and the estimated sugar levels in each sample. The k-Medoids approach was considered appropriate for this research because it performs well on small- to medium-sized datasets and can handle both numerical and categorical data types by using an appropriate distance measure.

For this reason, the Gower distance was applied to compute pairwise dissimilarities among samples, as it is suitable for mixed-type data containing both numerical and categorical attributes (13). To evaluate the quality of the clustering results, the Silhouette score was employed as the main performance metric. The Silhouette coefficient remains a key evaluation metric for clustering algorithms, quantifying both cohesion and separation (14), (15). This score measures how similar each object is to its own cluster compared to other clusters. It is calculated using the following formula.

$$s(i) = (b(i) - a(i)) / \max\{a(i), b(i)\} \quad (1)$$

where $a(i)$ is the average distance between a sample and all other samples in the same cluster, and $b(i)$ is the average distance to samples in the nearest neighboring cluster. The overall Silhouette score is the mean of all (i) values, where scores close to +1 indicate well-separated clusters, values near 0 suggest overlapping clusters, and negative values imply incorrect assignments.

3 Results and discussion

Figure 3 shows the results of qualitative glucose observations using glucose paper strips at several concentrations of glucose and sucrose solutions. Figure 3 indicates that the glucose paper is not sensitive to sucrose in the solution, so it does not show a color change reaction. The appearance of the glucose paper tends not to change color, remaining yellow, as it was before being reacted with the liquid or test solution. The next experiment was to make glucose solutions with various concentration levels, using standard glucose solution for analytical chemistry. The experimental results showed that glucose paper strips can specifically detect glucose in solutions, but do not show a striking color difference in solutions with varying high glucose concentrations.

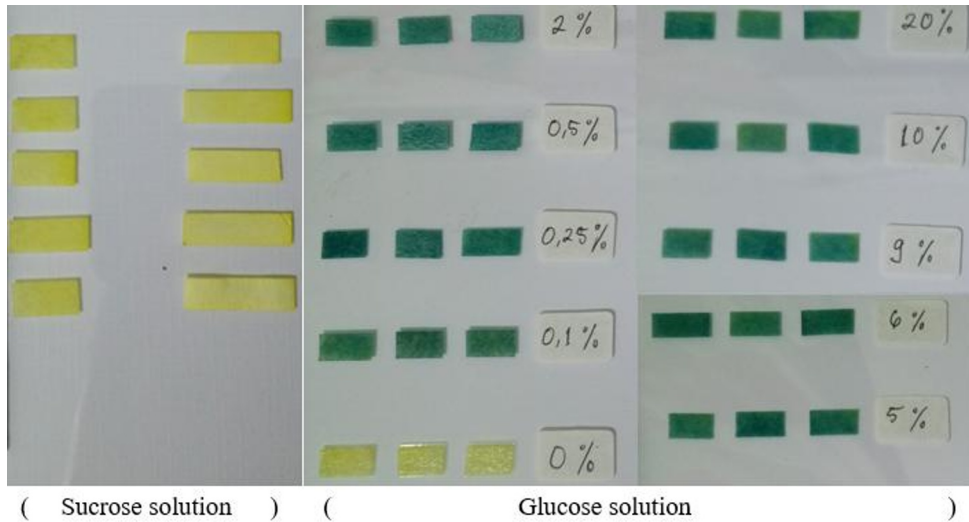







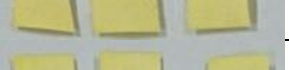
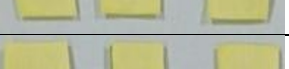
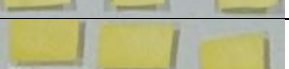
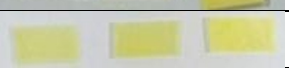



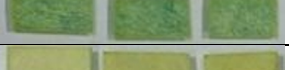
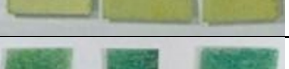




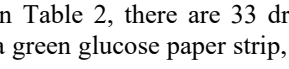



Fig. 3. The results of the glucose paper test at several concentrations of sucrose solution and glucose solution.

Solutions with glucose concentrations of 0.1%, 0.25%, 0.5%, 2%, 5%, and up to 30% have almost the same color output as glucose paper strips. Therefore, glucose paper strips are only used for qualitative analysis or to determine the presence or absence of glucose content in a drink. Some results of qualitative and semi-quantitative testing are presented in Table 2.

Table 2. Results of glucose and total sugar analysis in beverage samples.

Sample labels	Glucose paper test result (triplo)	Brix Concentration (%)	Concentration Estimations (g/100 mL)	Manufacturer's label (g/100 mL)
A1		5.3	5.62	4.12
A2		6.3	6.73	5.60
A3		19.1	22.54	16.67
A4		18.5	21.51	ND
A5		11.7	13.31	ND

A6		10.4	12.92	10.80
B1		6.5	7.14	7.42
B2		12.0	13.69	9.71
B3		7.3	8.08	7.22
C1		6.5	7.11	2.80
C2		6.7	7.15	2.73
D1		8.7	9.79	6.40
D2		6.3	6.68	ND
D3		11.6	12.57	ND
D4		11.3	11.82	9.20
D5		13.3	14.36	ND
D6		9.6	12.18	10.00
D7		14.3	15.39	14.29
D8		11.5	10.18	11.43
D9		6.7	7.35	ND
D10		14.3	17.15	ND
E1		6.5	7.14	7.20
E2		10.3	11.57	10.80
E3		4.7	5.22	4.40
E4		4.5	4.83	4.80
F1		7.5	7.88	7.50
F2		6.5	6.84	9.60

Based on Table 2, there are 33 drinks that qualitatively indicated to contain glucose, marked by a green glucose paper strip, while the remaining 20 drinks are yellow, indicating

that they does not contain glucose. Based on the predetermined categories, the drinks that did not contain glucose were mostly health supplement drinks, followed by ready-to-drink coffee drinks and ready-to-drink tea drinks. Health supplement drinks (D1-D10) did not contain glucose in 7 of the 10 drinks tested. The total sugar content of health supplement drinks was 6.68 to 17.15 g/100 mL. This is quite different from the sugar content listed on the packaging, which is around 6.40 to 14.29 g/100 mL. The D10 health supplement drinks were indicated to contain glucose, with a sugar content analysis result of 17.15 g/100 mL, with an information label on the packaging that does not list the sugar content (ND). This is certainly very dangerous if consumed by people with Diabetes Mellitus because it has the potential to increase insulin drastically. High sugar consumption can increase the risk of obesity, type 2 diabetes, and heart disease [15].

In the ready-to-drink coffee beverage category (F1-F7), just 1 in 7 beverages contained glucose. Ready-to-drink coffee beverages F1, F2, F6, and 32 had a brownish-yellow glucose strip color due to the concentration and color of the coffee beverage. Ready-to-drink coffee beverages had a total sugar content of 6.84 to 14.00 g/100 mL. In general, this value was slightly lower than the sugar content listed on the packaging labels of 7.50 to 12.57 g/100 mL. This was likely due to suboptimal sample preparation, resulting in insufficient solution purity to obtain a refractive dissolved solids value. Ready-to-drink coffee beverages F3 and F4 did not list their sugar content on the packaging but had the highest total sugar content values, at 14.00 and 11.32 g, respectively, despite not containing glucose. Ready-to-drink coffee drinks can contain significant amounts of sucrose, requiring hydrolysis and breakdown through the body's metabolism to produce glucose. The total sugar content of ready-to-drink (RTD) beverages is approximately 2.7–12.4 g/100 mL, with sucrose being the most abundant sugar (85.7%) [15].

In the ready-to-drink tea category (T1-T12), glucose content was indicated in approximately 33% of the samples (4 of 12) tested. The total sugar content of the analysis results ranged from 0 to 22.15 g/100 mL, significantly different from the sugar content listed on the packaging label, which is approximately 0 to 10.00 g/100 mL. Sweet iced tea has a glucose content of 1.5 to 66.5 g and a total sugar content of 23 to 70 g (15). Ready-to-drink tea sample 52, claiming zero sugar and no calories, was proven to contain 0 g/100 mL of total sugar, in accordance with the sugar content stated on the packaging label. Ready-to-drink (RTD) beverages can display the healthier logo if they contain a maximum of 6 g/100 mL of sugar (all monosaccharides and disaccharides except lactose). Ready-to-drink tea drinks T1-T5 have a total sugar content that tends to be higher than other ready-to-drink tea drinks. This indicates that drinks without nutritional information tend to have a higher total sugar content than drinks that list their sugar content on the packaging, possibly due to labeling regulations.

High total sugar content was also found in drinks that did not list sugar content on the packaging, at 21.51 and 13.31 g/100 mL, respectively. Energy Drink A4 had the second-highest total sugar content of the six energy drinks tested. All of the energy drinks tested (A1-A6) tended to contain glucose, making them highly recommended for people with diabetes. The total sugar content of the test results differed slightly from the sugar content listed on the packaging, except for Energy Drink A3.

Other glucose content was found in flavored/jelly drinks (B1-93), natural isotonic drinks (C1-C2), and isotonic drinks (H1-H5). Isotonic drinks contain total sugars of around 4.44 to 7.11 g/100 mL, while natural isotonic drinks contain total sugars of 7.11 to 7.15 g/100 mL. The total sugar content in isotonic drinks and natural isotonic drinks tends to be lower than flavored/jelly drinks, which range from 7.14 to 13.69 g/100 mL. Flavored/jelly, isotonic and natural isotonic drinks have a higher total sugar content than the sugar content listed on the packaging label information, especially in isotonic drinks which differ around 4.31 - 4.42 g/100 mL. The total sugar content is generally slightly higher than the value listed on the packaging label.

Total sugar content that does not differ significantly from the sugar content listed on the packaging label information is also found in carbonated soft drinks (E1-E4). The difference between sugar content values ranges from 0.03 to 0.77 g/100 mL. Carbonated soft drinks do not contain glucose in 1 of the 4 drinks tested. This also occurs in fruit juice drinks (G1-G4), although the total sugar content observed in fruit juice drinks tends to be higher than the sugar content listed on the packaging label information, which is around 1.14 to 7.4 g/100 mL. The total sugar content in fruit juice drinks is quite high, at 9.52 ± 1.5 g/100 mL. The glucose, sucrose, and fructose content in drinks tends to fluctuate depending on the sugar variation used [6].

The highest to lowest total sugar content in order from the beverage categories tested were A3 energy drinks (22.54 g/100 mL), T2 ready-to-drink tea drinks (22.15 g/100 mL), G3 fruit juice drinks (18.65 g/100 mL), D10 health supplement drinks (17.15 g/100 mL), F3 ready-to-drink coffee drinks (14.00 g/100 mL), B2 flavored/jelly drinks (13.69 g/100 mL), E2 carbonated soft drinks (11.57 g/100 mL), C2 natural isotonic drinks (7.15 g/100 mL), and H2 isotonic drinks (7.11 g/100 mL). Energy drinks have a higher total sugar content than fruit juice drinks, carbonated drinks (soda), tea drinks, sports drinks, and coffee drinks (8). This is not significantly different from the total dissolved solids (Brix) value. Research by (11) indicated the initial total carbohydrate content in beverages using the Brix percentage/relative sugar concentration of the liquid sample.

Further analysis can be performed using data mining concepts within the data science framework. Based on the test data collection results and the methods used, the dataset can be viewed as two-dimensional. The first feature is the qualitative test results using glucose paper, and the second feature is the estimated total sugar content from the semi-quantitative test results. The first feature is categorical, with a binary value of “Yes” or “No”. It is “Yes” if it contains glucose (marked in green) and “No” if it does not contain glucose. The estimated total sugar content was chosen as the value for the second feature because not all samples listed their sugar content on their packaging labels, resulting in many missing values.

The data mining method used was clustering, using the K-Medoids Clustering algorithm and the Silhouette Score evaluation metric. The clustering results were generated using Python on the Google Colab platform. Table 3 shows the clustering results, which give the best Silhouette Score of 0.731 for a value of $k = 3$, which means the best number of clusters is three.

Table 3. Clustering results using K-Medoids clustering.

Cluster	Type of Beverage	Presence of Glucose	Range of Estimated Sugar Content Values
1	B1, D2-D8, F1-F4, F6, F7, G1, T1, T3-T5, T7, T11, T12	No	0.00 - 14.36
2	A3-A6, B2, D10, E2, G2-G4, T2, T9	Yes	11.36 - 22.54
3	A1, A2, B3, C1, C2, D1, D9, E1, E3, E4, F5, H1-H5, T6, T8, T10	Yes	3.69 - 9.79

Clustering results show that cluster 1 contains all samples that do not contain glucose, while samples containing glucose are divided into two subclusters, likely determined by the high or low estimated sugar content in each sample. This is likely because samples containing glucose have a wider range of sugar content than samples without glucose, coupled with a relatively high variation in the values.

4 Conclusions and future work

Qualitative and semi-quantitative testing show that the majority of beverage samples tested were indicated to contain glucose and had a total sugar content value higher than the sugar content stated on the packaging label information. Beverages that tended not to be indicated to contain glucose were beverages that fall into the health supplement, ready-to-drink coffee, and ready-to-drink tea categories. Total sugar estimates were generally higher in product groups that did not include sugar content information on their packaging. From the test results obtained, it can be said that in general: estimated total sugar content in energy drinks > ready-to-drink tea drinks > fruit juice drinks > health supplement drinks > ready-to-drink coffee drinks > flavored/jelly drinks > carbonated soft drinks > natural isotonic drinks > isotonic drinks. In further research, further analysis related to this qualitative glucose content can be carried out with validation and quantitative testing using Spectrophotometry and HPLC. The application of data science, especially data mining, can also be used for deeper analysis regarding the relationship between qualitative and quantitative testing, as well as the characteristics of each category of sweetened beverage samples. Clustering methods with higher data dimensions can be used to understand the characteristics of beverage data based on their glucose content. Other data mining methods can also be applied to classification tasks and associations between variables/attributes of glucose content data.

Acknowledgement. We want to thank DRPM Kemendikisaintek Republik Indonesia for the financial support for this research with Grant No. 124/C3/DT.05.00/PL/2025 May 28, 2025, and Laboratory of Pharmaceutical Chemistry Analysis, Faculty of Health Sciences and Pharmacy, Gunadarma University, for research facilities.

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