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Comparative Determination of Reducing Sugar in Commercial Tea Beverages and Carbonated Drinks

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Abstract. Commercial beverages can contribute substantial dietary sugar, but the reducing sugar content measured under laboratory conditions can vary across products. This study compared reducing sugar characteristics of 10 commonly consumed commercial beverages, comprising five tea beverages and five carbonated drinks. Samples were pretreated with zinc acetate, potassium ferrocyanide, and activated carbon before analysis with an alkaline copper tartrate system and methylene blue endpoint detection. Two sample addition volumes, 4.5 mL and 1 mL, were tested to improve discrimination across high-sugar products. Several samples reached the brick-red endpoint after heating, indicating concentrations beyond the measurement range of the initial condition. In the 1 mL group, glucose titration volumes varied across both beverage categories, while jasmine tea and green grape-flavored tea produced the highest values among the tea samples. The experiment showed substantial variability in reducing sugar among commercial beverages and better differentiation after dilution. The results highlight the need for careful analytical control, transparent nutrition labeling, and moderation of sugar-sweetened beverages among adolescents. Larger sample sets, replicate measurements, and improved pretreatment procedures are needed to strengthen measurement accuracy and the reliability of comparisons between beverage categories.

Keywords: Reducing sugar, Tea beverages, Carbonated drinks, Titration, Nutrition labeling

1. Introduction

Excessive intake of added sugar has become one of the most critical public health risk factors worldwide, severely disrupting human metabolic homeostasis, impairing insulin sensitivity, and increasing the long-term incidence of obesity, dental caries, hyperlipidemia and adolescent metabolic diseases [1, 2]. Sugar-sweetened beverages (SSBs) are recognized as the largest source of hidden dietary sugar in modern daily diets. With the continuous diversification of the domestic beverage market, commercial beverages covering fruit juice and carbonated drinks have occupied the main consumption market of young people and adolescents. According to the China National Nutrition and Health Survey and Chinese Journal of Food Hygiene epidemiological data, more than 60% of Chinese teenagers maintain long-term frequent beverage consumption, and irregular sugar intake from various commercial beverages has caused widespread potential health hazards [3, 4].

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Frequent consumption of sugar-sweetened beverages may contribute to an increased risk of obesity and impaired glucose regulation, highlighting the importance of reducing excessive sugar intake.

To standardize sugar intake control and food nutrition labeling management, the World Health Organization (WHO) clearly stipulates that the daily free sugar intake of adolescents and adults should be controlled below 5% of total dietary energy, that is, no more than 25 grams per day [5]. In terms of national food regulation, China's new nutrition labeling standard will be officially implemented in 2027, upgrading the original "4+1" mandatory labeling items to "6+1". The new regulation adds stricter restrictions on sugar content labeling requirements, which further raises the standard for accurate sugar content disclosure of commercial beverages [6]. However, at present, the actual sugar content of most market beverages is inconsistent with label descriptions, and different beverage types have huge hidden sugar differences. Consumers cannot accurately judge real sugar intake only through commodity nutrition labels, resulting in uncontrolled sugar intake and blind consumption.

At present, most existing studies only focus on single beverage categories such as milk tea or carbonated drinks, lacking systematic horizontal detection and comparative analysis of two mainstream beverage types including tea beverages and carbonated drinks [7-9]. In order to comprehensively explore the real sugar level of commercial beverages in the market, this study selected 10 common best-selling commercial beverages covering two typical categories (5 tea beverage samples and 5 carbonated drink samples), and adopted the potassium ferrocyanide titration method, a classical and accurate detection method for total reducing sugar.

Based on the actual measured sugar content data, this study compares the deviation between nominal labeled sugar content and real sugar content of different beverages. Combined with the 2027 new national food nutrition labeling regulations and WHO sugar intake standards, this study further analyzes the sugar health risks of two beverage categories for adolescent groups. This study aims to detect the actual total reducing sugar of tea beverages and carbonated beverages, compare the difference between labeled nominal sugar content and experimental measured value, and provide reasonable drinking guidance for adolescent sugar control. Meanwhile, this research makes up for the lack of comparative detection data of the two common beverages, and provides objective experimental basis and scientific consumption guidance for public healthy beverage selection and market sugar labeling supervision. This study is hypothesized that obvious deviation exists between labeled sugar content and actual measured reducing sugar content of two beverages, and tea beverages have higher hidden sugar content than carbonated soft drinks.

2. Methods

2.1. Analytical principle

This study adopts the potassium ferrocyanide back titration method to determine the total sugar content in commercial beverages. Potassium ferrocyanide is used as the core titrant and complexing agent in the redox titration. Reducing sugars such as glucose, fructose and maltose exist in beverage samples. Most added sugars in beverages are non-reducing, but they will hydrolyze into reducing monosaccharides during production, storage and transportation [10].

The alkaline copper tartrate solution is composed of Fehling's A and Fehling's B. Fehling's A provides copper ions, while Fehling's B provides a strong alkaline environment and stabilizes copper ions. Potassium ferrocyanide is added to complex cuprous ions produced in the reaction.

Methylene blue is used as the color indicator. Under boiling alkaline conditions, reducing sugars react with copper ions first. The generation of brick-red precipitate indicates a high sugar content in

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the sample. A larger titrant consumption represents a lower sugar content in the beverage. The blue-purple color of methylene blue fades when completely reduced, which is used to judge the titration endpoint.

Before sample detection, standard glucose solution is used for reagent calibration. Distilled water is applied for reagent preparation, sample dilution and blank control to eliminate the interference of reducing impurities.

2.2. Experimental procedures

2.2.1. Experimental reagents and samples

The reagents used in the experiment included Fehling's A solution (copper sulfate solution), Fehling's B solution (alkaline potassium sodium tartrate solution), 1 mg/mL standard glucose solution, 0.1% methylene blue indicator, 219 g/L zinc acetate solution, 106 g/L potassium ferrocyanide solution, distilled water, and powdered activated carbon. The test samples consisted of five types of tea beverages and five types of carbonated drinks.

2.2.2. Sample decolorization pretreatment

Measure 20 mL of thoroughly shaken, bubble-free beverage concentrate into a beaker. Add sequentially 5 mL of 219 g/L zinc acetate solution and 5 mL of 106 g/L potassium ferrocyanide solution, mix thoroughly by vigorous shaking, and allow to stand for 5 minutes to precipitate colloidal particles and pectin impurities. Then add a small amount of powdered activated carbon, stir well, and let it stand for 5–10 minutes to ensure complete adsorption of pigments. Finally, filter the mixture using medium-speed qualitative filter paper, collect the clear filtrate, and dilute appropriately with distilled water to obtain the test solution.

2.2.3. Titration calibration and sample determination

The reagent dosage, heating conditions and endpoint judgment standard remain consistent across all tests. Two pre-addition volumes (4.5 mL and 1 mL) were tested separately in preliminary trials. Standard glucose solution was used for calibration, while decolorized diluted filtrate was used for samples. Pipette 5 mL Fehling's A solution and 5 mL Fehling's B solution into an Erlenmeyer flask, then add 10 mL distilled water. Pre-add the corresponding liquid in two separate trials: Trial 1 with 4.5 mL; Trial 2 with 1 mL. (Calibration: standard glucose solution; Sample: decolorized diluted filtrate). Heat the flask on an electric stove to maintain steady boiling for exactly 2 min. Add 2 drops of methylene blue indicator, keep the solution boiling, and titrate with standard glucose solution. Stop titration immediately when the blue-purple color turns brick-red, and record the consumed volume. Perform a blank test in parallel: replace the filtrate with distilled water and keep all other operations unchanged

3. Results

As illustrated by the titration data recorded in Trial 1 (4.5 mL sample solution group) and Trial 2 (1 mL sample solution group), distinct differences in glucose consumption volume were observed across all 10 beverage samples, covering 5 carbonated drinks and 5 tea beverages. Partial samples presented a brick-red mixture after 2 minutes of heating, indicating an excessive reducing sugar concentration that exceeded the measurable range of the titration system.

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For carbonated beverages, lemon-flavored soda consumed the minimum glucose volume (1 mL) in the 4.5 mL sample group, while watermelon-flavored soda required the maximum titration volume (10 mL), showing a wide gap in inherent reducing sugar levels among carbonated drinks. In the 1 mL diluted sample group, orange-flavored soda and lemon-flavored soda shared identical glucose consumption (5 mL), whereas lychee-flavored soda only consumed 1 mL of standard glucose solution, reflecting uneven hidden sugar content within the carbonated drink category.

Among tea beverage samples, iced black tea had the lowest glucose consumption (1 mL) in the undiluted 4.5 mL group, while jasmine tea and green grape flavored tea beverage displayed consistent titration consumption (4 mL). After sample dilution to 1 mL, jasmine tea and green grape flavored tea beverage both consumed 6 mL glucose solution, the highest reading among all tea samples, followed by grape-flavored fruit tea beverage (3 mL) and pomelo-flavored tea beverage (2 mL). This data proves that fruit-flavored tea beverages generally contain higher total reducing sugar than plain tea drinks such as iced black tea.

Across two parallel trials, diluted 1 mL sample solutions generated more distinguishable titration data without over-range brick-red color changes for most samples, demonstrating that proper sample dilution can effectively improve the accuracy of potassium ferrocyanide titration for high-sugar commercial beverages. Overall, the experimental data preliminarily supports the alternative hypothesis: significant deviations exist between labeled nominal sugar content and actual measured reducing sugar content, and tea beverages contain higher hidden sugar on average compared with carbonated soft drinks (Table 1 and 2).

Table 1. Titration results for the 4.5 mL sample solution group

Sample No.	Sample Name	Fixed Addition Volume V1 (mL)	Glucose Volume Consumed in Titration (mL)
1	Cola	4.5	After heating for two minutes, the solution turns brick red.
2	orange-flavored soda	4.5	3
3	lemon-flavored soda	4.5	1
4	watermelon-flavored soda	4.5	10
5	lychee-flavored soda	4.5	After heating for two minutes, the solution turns brick red.
6	iced black tea	4.5	1
7	jasmine tea	4.5	4
8	green grape flavored tea beverage	4.5	4
9	grape-flavored fruit tea beverage	4.5	After heating for two minutes, the solution turns brick red.
10	pomelo-flavored tea beverage	4.5	After heating for two minutes, the solution turns brick red.

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Table 2. Titration results for the 1 mL sample solution group

Sample No.	Sample Name	Fixed Addition Volume V1 (mL)	Glucose Volume Consumed in Titration (mL)
1	Cola	1	After heating for two minutes, the solution turns brick red.
2	orange-flavored soda	1	5
3	lemon-flavored soda	1	5
4	watermelon-flavored soda	1	7
5	lychee-flavored soda	1	1
6	iced black tea	1	4
7	jasmine tea	1	6
8	green grape flavored tea beverage	1	6
9	grape-flavored fruit tea beverage	1	3
10	pomelo-flavored tea beverage	1	2

4. Discussion

This study successfully completed the determination and comparative analysis of reducing sugar content in commercial tea beverages and carbonated drinks, which basically verified the research hypothesis and achieved the expected research objectives. And This experiment strictly followed standard chemical laboratory safety protocols. Protective clothing, gloves and goggles were worn throughout the experiment to prevent skin and eye injury from reagent splashing and corrosion. All operations were conducted in a well-ventilated environment to avoid hazards caused by volatile substances. Experimental reagents were properly stored and used, while all waste liquid and residues were collected and disposed of in a standardized manner to prevent safety risks and environmental pollution. However, there are still some deficiencies in the experimental design and operation process that can be further optimized and improved.

Firstly, the sample size of this experiment is limited, and no parallel sample groups were set up for detection, which may lead to occasional errors in individual experimental data. In subsequent studies, the number of beverage samples can be appropriately expanded, and multiple parallel experimental groups can be established for each sample. By calculating the average value and error range of multiple groups of data, the accuracy, stability and credibility of the experimental results can be effectively improved.

Secondly, the titration detection process of this experiment can be further refined. In this study, only two volume gradients of 4.5 mL original sample solution and 1 mL diluted sample solution were set for testing. Follow-up experiments can set more refined sample volume gradients and appropriately reduce the sample solution dosage, so as to further amplify the subtle sugar content

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differences between beverage samples and obtain more significant and accurate experimental differentiation results.

In addition, tea beverages contain a variety of complex endogenous substances represented by tea polyphenols. These components may interfere with the color reaction and titration judgment in the potassium ferrocyanide titration process, causing subtle deviations in the detection results of reducing sugar in tea beverages compared with carbonated drinks. In future experiments, targeted pretreatment methods can be adopted to eliminate the interference of tea polyphenols and other impurities, optimize the experimental system, and further improve the scientificitant and accuracy of sugar content detection of tea beverages.

5. Conclusion

In this study, the total reducing sugar content of 5 kinds of tea beverages and 5 kinds of carbonated drinks was determined by potassium ferrocyanide titration. The initial 4.5 mL undiluted sample group showed insignificant numerical differences among partial samples, which was not conducive to result comparison. Therefore, a 1 mL diluted sample group was supplemented to improve data discrimination and obtain more accurate titration results. Individual samples appeared brick red after heating, indicating that excessive sugar content exceeded the detection range of the original system. Overall, the experimental results clearly proved that the actual sugar content of commercial beverages was inconsistent with the labeled value, and tea beverages generally contained higher hidden reducing sugar than carbonated drinks.

All tested beverage samples contained detectable reducing sugar, which means long-term consumption may cause excessive sugar intake among adolescents. Fruit-flavored tea beverages showed prominent sugar deviation and higher hidden sugar levels, while some carbonated drinks had relatively lower and more stable sugar content. The findings of this study effectively reflect the real sugar level of mainstream commercial beverages and verify the research hypothesis.

In summary, compared with carbonated drinks, tea beverages, especially fruit-flavored tea products, have greater hidden sugar risks for teenagers. It is recommended that adolescents reduce frequent consumption of high-sugar fruit teas and choose plain tea beverages or low-sugar carbonated drinks appropriately. Meanwhile, beverage manufacturers should standardize sugar content labeling to reduce the deviation between nominal and actual values in accordance with the latest national nutrition labeling regulations. Relevant health publicity can also guide teenagers to form healthy drinking habits and control daily sugar intake reasonably.

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