

ORIGINAL RESEARCH ARTICLE

Sugar content and health risk assessment in freshly made sugary commercial beverages: A cross-sectional study

DOI: 10.29063/ajrh2025/v29i8s.13

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Abstract

Excessive sugar intake from beverages has become a growing concern due to its links to various health problems, such as obesity and diabetes. This study aims to evaluate the sugar content in commercial beverages and assess the associated health risks based on WHO guidelines. A cross-sectional analysis was conducted on 366 samples, where high-performance liquid chromatography was used to measure the presence of five types of sugars. The average total sugar content was 5.98 ± 3.24 g/100 mL, with sucrose being the most common sugar detected. Interestingly, 64.2% of the products were labeled as “low sugar,” but 50% exceeded the WHO’s recommended daily intake of 25g per serving, and 9.8% surpassed 50g. Additionally, beverages with larger volumes (500mL) were more likely to exceed the recommended intake with potentials to increase health risks. These results highlight significant discrepancies between product labeling and actual sugar content. (*Afr J Reprod Health 2025; 29 [8s]: 131-142*).

Keywords: Commercial beverages; Sugar content; Health risk assessment

Résumé

La consommation excessive de sucre dans les boissons est devenue une préoccupation croissante en raison de ses liens avec divers problèmes de santé, tels que l'obésité et le diabète. Cette étude vise à évaluer la teneur en sucre des boissons fraîchement préparées et à évaluer les risques sanitaires associés, conformément aux recommandations de l'OMS. Une analyse transversale a été menée sur 366 échantillons, où la chromatographie liquide haute performance a permis de mesurer la présence de cinq types de sucres. La teneur totale moyenne en sucres était de $5,98 \pm 3,24$ g/100 ml, le saccharose étant le sucre le plus fréquemment détecté. Il est intéressant de noter que 64,2 % des produits étaient étiquetés « à faible teneur en sucre », mais que 50 % dépassaient l'apport quotidien recommandé par l'OMS de 25 g par portion, et 9,8 % dépassaient 50 g. De plus, les boissons de plus grand volume (500 ml) étaient plus susceptibles de dépasser l'apport recommandé, augmentant ainsi les risques pour la santé. Ces résultats mettent en évidence des écarts importants entre l'étiquetage des produits et la teneur réelle en sucre. (*Afr J Reprod Health 2025; 29 [8s]: 131-142*).

Mots-clés: Boissons fraîchement préparées; Teneur en sucre; Évaluation des risques pour la santé

Introduction

The beverage industry is rapidly developing globally, especially in the Asian region. Taking China as an example, according to the China Chain Store Association (CCFA), the average annual compound growth rate of the beverage market has remained above 15% in the past five years, and new-style tea drinks have become one of the fastest-growing sub-sectors in the catering industry¹. The scale of China's beverage market will reach 215.7

billion yuan in 2023, a year-on-year increase of 12.3%, and is expected to exceed 300 billion yuan by 2025². Among them, young consumers aged 18-35 years account for as much as 78%, with an average weekly consumption frequency of 3-4 times³. Unlike traditional packaged beverages, freshly made beverages face unique challenges in product standardization and quality control due to their personalized customization and on-site production characteristics⁴. Excessive intake of sugar, especially sugary drinks (SSB), has become a

significant global public health issue. The World Health Organization (WHO) recommends that the intake of free sugars should be controlled below 10% of the total daily energy, preferably not exceeding 5%⁵. There is a strong correlation between the intake of sugary drinks and the increased risk of type 2 diabetes, cardiovascular disease and all-cause mortality in the population⁶. Both surveys among college students and children further confirm that long-term heavy intake of sugary drinks is significantly associated with obesity^{7, 8}. Therefore, obtaining accurate sugar content data in freshly made beverages can help reduce the occurrence of various diseases and the obesity rate in adolescents.

There are currently three main limitations to research on freshly made commercial beverages. Firstly, existing studies mainly focus on pre-packaged beverages^{9, 10}, with few studies involving freshly made beverages and sample sizes not exceeding 100^{11, 12}. Secondly, these studies are often limited to a single category or brand, lacking systematic comparisons¹³. Thirdly, most existing studies use single sugar detection methods, which fail to fully reflect the distribution characteristics and potential health risks of different sugars¹⁴.

At the policy level, the "Chinese Dietary Guidelines for Residents (2022 Edition)" recommend that adults should not exceed a daily intake of 50g of added sugar, preferably controlled below 25g¹⁵. However, due to the diversity of formulas and non-standard production processes, the implementation of these guidelines faces unique challenges in the freshly made beverage industry¹⁶. The lack of comprehensive data on sugar content in freshly made beverages hinders effective policy-making and consumer education¹⁷. Conducting risk assessments based on standards can help consumers better control their daily intake of added sugars. This study aims to:

- (1) use high-performance liquid chromatography (HPLC) to analyze the content and distribution of five main sugars (fructose, glucose, sucrose, maltose, and lactose) in freshly made beverages, providing a more comprehensive analysis of sugar content; and
- (2) compare the differences in sugar content between different beverage categories and sweetness levels;

According to the recommendations of the World Health Organization, an exposure assessment model based on two standard doses of 300ml and 500ml has been established, which is more in line with actual consumption scenarios. The results will enable us to evaluate health risks and provide scientific references for consumer education and industry standard setting.

Methods

Data administration

This study collected samples from Beijing from October to November 2024, selected leading commercial beverage stores based on market share data, and collected samples through online ordering. Beverages are divided into seven categories: milk tea, fruit tea, coffee, pure tea, carbonated drinks, special drinks, and other beverages. The sampling scope covered the top 12 freshly made beverage brands on the sales ranking list, with a total of 366 samples collected. Each sample was recorded with comprehensive information, including beverage category, brand name, portion size, and sweetness (sugar free, low sugar, standard or high sugar).

The sample size calculation adopted the formula: $n = Z^2 * p * (1-p) / d^2$

Where Z is the confidence coefficient (taken as 1.96 at the 95% confidence interval); P is the expected proportion of exceedance (estimated to be 62.6% based on preliminary experiments); D is the allowable error (taken as 5%).

This formula is widely used in cross-sectional studies involving proportion estimation. We chose this formula because our main goal is to estimate the proportion of beverages with sugar content exceeding the recommended level, and it includes preliminary data and statistical reliability parameters.

The theoretical sample size required for calculation was 360. The study collected 366 samples, with a sample adequacy rate of 101.7% and an actual accuracy of 5.0%, fully meeting the research requirements. Considering the diversity and regional differences of freshly made beverages, the sample size set in this study is reasonable and represents the current market situation.

Table 1: Reagents used in the experiment

Reagent name	Manufacturer
Fructose standard	BePure®
Glucose standard	BePure®
Sucrose standard	BePure®
Maltose standard	BePure®
Lactose standard	BePure®
Acetonitrile (chromatographically pure)	Anavo

Table 2: Instruments used in the experiment

Instrument name	Manufacturer
High-performance liquid chromatography	Waters Corporation
chromatographic column	Anavo
Centrifuge	SIGMA
0.45µm, Nylon filtration membrane	Anavo

The sample was immediately placed in a portable refrigerator ($4\pm 1^\circ\text{C}$) and delivered to the laboratory for testing within 24 hours.

Instruments and reagents

Standard sugar references (fructose, glucose, sucrose, maltose, and lactose) were obtained from BePure®. Sample preparation involved centrifugation (SIGMA) and filtration through 0.45µm nylon membranes (Anavo). All standards and reagents were of analytical grade or higher purity (Table 1).

Experimental instruments

The sugar content analysis was performed using high-performance liquid chromatography (Waters Corporation) equipped with an Anavo chromatographic column. Chromatographically pure acetonitrile (Anavo) was used as the mobile phase (Table 2).

Experimental methods

The sugar content was determined using high-performance liquid chromatography (HPLC). First, the sample was thoroughly mixed and then processed according to different types of beverages.

For beverages without carbon dioxide, jam, or fruit granules, 10 mL of the sample was taken and placed in a 15.0 mL centrifuge tube. Then, 50 µL of ice acetic acid was added to precipitate the protein.

The mixture was centrifuged at 10000 r/min for 10 minutes and subsequently filtered through a 0.45 µm membrane. For beverages containing carbon dioxide, they were first ultrasonicated for degassing and then directly filtered through a 0.45 µm membrane. As for beverages with jam or fruit granules, they were centrifuged at 10000 r/min for 10 minutes, and then the supernatant was filtered through a 0.45 µm filter membrane.

After filtration, the sample was separated on an amino chromatography column (250 mm×4.6 mm, 5µm). The column temperature was set at 30 °C. The mobile phase used was acetonitrile/water (70:30, v/v), with a flow rate of 1.0 mL/min. An injection volume of 20 µL was applied. Samples with excessive content were appropriately diluted with the mobile phase before injection.

Risk assessment model

The risk assessment model was developed based on the recommendations of the World Health Organization and the Chinese Dietary Guidelines (2022) for daily intake of added sugars. The World Health Organization (WHO) recommends that adults and children limit their daily intake of added sugars to less than 10% of their total energy intake, with the ideal long-term goal of reducing it to less than 5%. For a 2000 kcal diet, this means adding no more than 50 grams of sugar per day, preferably no more than 25 grams. The "Chinese Dietary Guidelines" (2022) released by the Chinese Center for Disease Control and Prevention recommends that Chinese residents should not exceed a daily intake of 50 grams of added sugar, with an optimal limit of 25 grams. The exposure assessment considered two scenarios: low exposure based on 300mL standard cups and high exposure based on 500mL large cups. Single exposure dose was calculated by multiplying beverage volume (mL) with measured total sugar concentration (mg/mL), divided by 1000. Risk levels were established considering the WHO recommended daily added sugar intake ($\leq 50\text{g/d}$) and the contribution of single consumption to daily intake. The risk categorization was defined as low risk (single intake $\leq 25\text{g}$, representing $\leq 50\%$ of daily recommended dose), medium risk (single intake 25-50g, representing 50-100% of daily recommended dose), and high risk (single intake $> 50\text{g}$, exceeding 100% of daily recommended dose). This model enabled systematic evaluation of potential health

risks associated with sugar consumption from freshly-prepared beverages.

Statistical analysis

Statistical analysis was preformed using SPSS 21.0 software. Measurement data is expressed as mean ± standard deviation (Mean ± SD). Descriptive statistics were conducted on the content of five sugars (fructose, glucose, sucrose, maltose, and lactose), and the results were expressed as mean ± standard deviation (Mean ± SD). At the same time, the minimum and maximum values were also calculated. A single-factor analysis of variance was used to compare the differences in sugar content between different categories. LSD-t test was used for pairwise comparisons between groups, and P<0.05 was considered statistically significant.

Ethical considerations

The research plan has been reviewed and approved by the Ethics Committee of the Beijing Center for Disease Control and Prevention (Approval No. BJCDC2024031).

Results

Basic information of research subjects

Among the 366 collected samples, there were significant differences in the proportion of samples from different categories. The milk tea category has the largest sample size, accounting for 29.80% (109/366), followed by specially formulated beverages at 26.80% (98/366) and fruit tea at 18.60% (68/366). From the distribution of sweetness indicators, the main categories were low sugar, with fruit tea accounting for 76.50% (52/68), milk tea accounting for 73.40% (80/109), and specially formulated beverages accounting for 69.40% (68/98) having a higher proportion of low sugar. It is worth noting that sugar-free products account for the highest proportion, 22.40% (13/58), in the coffee category, while all other beverage categories use standard sugar. The sample sizes of pure tea and carbonated beverages are relatively small, accounting for 4.40% (16/366) and 2.20% (8/366) of the total sample, respectively (Table 3).

Table 3: Distribution of characteristics of freshly made beverages in different categories n (%)

Category	Sample size	Sweetness label				The volume of one commercially available cup.		
		Sugar-free	Low sugar	Standard sugar	High sugar	≤300mL	300-500mL	>500mL
Milk tea category	109 (29.80)	0 (0.00)	80 (73.40)	21 (19.30)	8 (7.30)	0 (0.00)	86 (78.90)	23 (21.10)
Specially made beverages	98 (26.80)	1 (1.00)	68 (69.40)	19 (19.40)	10 (10.20)	0 (0.00)	74 (75.50)	24 (24.50)
Fruit tea category	68 (18.60)	0 (0.00)	52 (76.50)	15 (22.10)	1 (1.50)	1 (1.50)	44 (64.70)	23 (33.80)
Coffee category	58 (15.80)	13 (22.4)	24 (41.40)	21 (36.20)	0 (0.00)	0 (0.00)	58 (100.00)	0 (0.00)
Pure tea category	16(4.40)	1 (6.30)	11 (68.80)	4 (25.00)	0 (0.00)	1 (6.30)	6 (37.50)	9 (56.30)
Carbonated drinks	8(2.20)	1 (12.50)	0 (0.00)	7 (87.50)	0 (0.00)	3 (37.50)	5 (62.50)	0 (0.00)
Other beverages	9(2.50)	0 (0.00)	0 (0.00)	9 (100.00)	0 (0.00)	5 (55.60)	4 (44.40)	0 (0.00)

Table 4: Distribution characteristics of sugar content in commercially available freshly made beverages (g/100mL)

Carbohydrates	Number of detected samples	Detection rate (%)	Minimum value	Maximum value	Mean ± standard deviation
Fructose	265	72.4	0	10.58	1.64±1.78
Glucose	296	80.9	0	7.10	1.22±1.23
Sucrose	316	86.3	0	12.47	2.32±2.29
Malt dust	113	30.9	0	5.40	0.15±0.38
Lactose	172	47.0	0	5.86	0.64±1.05
Total sugar content	366	100.0	0	22.78	5.98±3.24

Table 5: Comparison of total sugar content in freshly made beverages of different categories (g/100ml)

Category	Sample size (Mean±SD)	Fructose (Mean±SD)	Glucose (Mean±SD)	Sucrose (Mean±SD)	Malt dust (Mean±SD)	Lactose (Mean±SD)	Total sugar content (Mean±SD)	95%CI (Total sugar content)
Milk tea category	109	1.15±1.25	0.84±0.70	2.00±1.90	0.30±0.21	0.86±0.94	5.15±2.25b	4.73-5.58
Specially made beverages	98	1.87±1.66	1.35±1.07	3.27±2.56	0.10±0.19	0.50±0.63	7.09±3.23a	6.44-7.74
Fruit tea category	68	3.07±2.19	2.38±1.55	1.73±2.08	0.04±0.14	0.05±0.19	7.27±3.60a	6.39-8.14
Coffee category	58	0.56±0.86	0.45±0.71	2.48±1.75	0.02±0.17	1.38±1.68	4.91±2.48b	4.25-5.56
Pure tea category	16	1.08±1.14	0.71±0.75	0.30±0.32	0.00±0.00	0.00±0.00	2.09±2.18c	0.93-3.25
Carbonated drinks	8	2.76±2.32	1.84±1.55	0.32±0.49	0.00±0.00	0.00±0.00	4.93±4.17b	1.44-8.41
Other beverages	9	1.41±2.48	0.95±1.59	4.67±4.28	1.09±1.90	1.03±2.04	9.15±4.15a	5.96-12.34

Note: Different lowercase letters indicate statistically significant differences between groups ($P<0.05$); $F=13.778$, $P<0.001$.

Table 6: Comparison of total sugar content in freshly made beverages with different sweetness labels

Sweetness label	Sample size(n, %)	Sugar content (g/100mL, Mean±SD)						Risk distribution of total sugar intake in one cup of freshly made beverage sold in the market (n, %)		
		Sample size	Fructose	Glucose	Sucrose	Malt dust	Lactose	≤25g	25g-50g	>50g
Sugar-free	16(4.40)	0.58±1.05	0.59±0.91	1.90±1.73	0.00±0.01	0.81±1.51	3.88±2.65	8 (50.00)	8 (50.00)	0 (0.00)
Low sugar	235(64.20)	1.66±1.74	1.23±1.22	2.23±2.12	0.14±0.20	0.52±0.79	5.76±3.04	93 (39.60)	119 (50.60)	23 (9.80)
Standard sugar	96(26.20)	1.88±1.97	1.35±1.30	2.28±2.51	0.22±0.66	0.80±1.38	6.53±3.71	28 (29.20)	57 (59.40)	11 (11.50)
high glucose	19(5.20)	1.16±1.42	1.02±1.12	4.06±2.91	0.19±0.24	1.30±1.24	7.72±2.10	1 (5.30)	14 (73.70)	4 (21.10)

Basic characteristics of sugar content in samples

Five types of sugars were detected in the 366 samples, with an average total sugar content of $5.98 \pm 3.24\text{g}/100\text{mL}$ and a maximum value of $22.78\text{g}/100\text{mL}$. The order of sugar content from high to low was: sucrose ($2.32 \pm 2.29\text{g}/100\text{mL}$, detection rate 86.3%), fructose ($1.64 \pm 1.78\text{g}/100\text{mL}$, detection rate 72.4%), glucose ($1.22 \pm 1.23\text{g}/100\text{mL}$, detection rate 80.9%), lactose ($0.64 \pm 1.05\text{g}/100\text{mL}$, detection rate 47.0%), and maltose ($0.15 \pm 0.38\text{g}/100\text{mL}$, detection rate 30.9%), (Table 4). The detection rate and content of sucrose are the highest, while the detection rate and content of maltose are the lowest.

Differences in sugar content among different beverage categories

The results of one-way ANOVA showed significant differences in total sugar content among different beverage categories ($F=13.778$, $P<0.001$). The total sugar content of other beverage categories is the highest ($9.15 \pm 4.15\text{ g}/100\text{mL}$), among which the sucrose content ($4.67 \pm 4.28\text{ g}/100\text{mL}$) is significantly higher than other categories, and it is also the only category with a high detection of maltose ($1.09 \pm 1.90\text{ g}/100\text{mL}$). The total sugar content of fruit tea ($7.27 \pm 3.60\text{ g}/100\text{mL}$) and specially formulated beverages ($7.09 \pm 3.23\text{ g}/100\text{mL}$) is second, with fruit tea beverages having significantly higher fructose ($3.07 \pm 2.19\text{ g}/100\text{mL}$) and glucose ($2.38 \pm 1.55\text{ g}/100\text{mL}$) content than other categories. Pure tea has the lowest total sugar content ($2.09 \pm 2.18\text{ g}/100\text{mL}$), mainly composed of sucrose ($0.30 \pm 0.32\text{ g}/100\text{mL}$), and no lactose or maltose was detected. The characteristic of milk tea drinks is that they have a relatively high lactose content ($0.86 \pm 0.94\text{ g}/100\text{mL}$), and the primary added sugar is sucrose ($2.00 \pm 1.90\text{ g}/100\text{mL}$). (Table 5)

The multiple comparison results showed that (1) the sugar content of unique drinks and fruit tea was significantly higher than that of milk tea ($P<0.001$); (2) The sugar content of pure tea was significantly lower than that of milk tea ($P=0.002$), specially formulated beverages ($P<0.001$), and fruit tea ($P<0.001$); (3) The sugar content of other beverages was significantly higher than that of milk tea ($P=0.002$) and coffee ($P=0.001$).

Characteristics and risk assessment of freshly made beverages with different sweetness labels

The results of one-way ANOVA showed significant differences in total sugar content among freshly made beverages with different sweetness indicators ($F=5.574$, $P=0.001$). The high-sugar group has the highest total sugar content, followed by the standard sugar group and the low-sugar group, while the sugar-free group has the lowest. Multiple comparison results showed that the total sugar content of the sugar-free group was significantly lower than the other three groups ($P<0.05$), with differences of 1.88, 2.65, and 3.84 $\text{g}/100\text{mL}$ compared to the low sugar group, standard sugar group, and high sugar group, respectively. The total sugar content of the low-sugar group was significantly higher than that of the sugar-free group ($P=0.022$) and significantly lower than that of the standard sugar group ($P=0.046$) and the high sugar group ($P=0.010$). There was no statistically significant difference in total sugar content between the standard sugar group and the high sugar group ($P=0.137$). From Table 6, it can be seen that as sweetness increases, the total sugar content of one cup of freshly made beverages on the market also shows an upward trend. There are no samples with a total sugar content exceeding 50g in sugar-free beverages. In high-sugar beverages, more than half of the samples have a total sugar content between 25g and 50g, and nearly one-fifth of the samples have a total sugar content exceeding 50g.

According to the risk assessment based on the volume of commercially available freshly made beverages, the highest high-risk proportion was 21.10% (4/19) in high-sugar products. At the same time, there were no high-risk samples in sugar-free products. It is worth noting that even among products labelled as low sugar, 9.80% (23/235) still belong to the high-risk category.

Comprehensive risk assessment of freshly made beverages

Impact of capacity on risk distribution

At a standard capacity of 300mL, 81.1% (297/366) of beverages belong to the low-risk category ($\leq 25\text{g}$), 17.8% (65/366) belong to the medium-risk category (25-50g), and only 1.1% (4/366) belong to the high-risk category ($>50\text{g}$). When the capacity increased to

Table 7: Risk classification distribution of sugar content in beverages with different capacities n (%)

Capacity	Low risk (≤ 25 g)	Medium risk (25-50g)	High risk (> 50 g)
300mL	297(81.1)	65(17.8)	4(1.1)
500mL	137(37.4)	198(54.1)	31(8.5)

Table 8: Risk distribution of sugar content in one commercially available beverage

category	Sample size	Total sugar content (g)	risk distribution n(%)		
			Low risk(≤ 25 g)	Medium risk(25-50g)	high risk(> 50 g)
Milk tea category	109	27.22 \pm 13.44	47 (43.10)	56 (51.40)	6 (5.50)
Specially made beverages	98	36.78 \pm 16.85	18 (18.40)	61 (62.20)	19 (19.40)
Fruit tea category	68	37.91 \pm 20.36	15 (22.10)	43 (63.20)	10 (14.70)
Coffee category	58	22.46 \pm 11.53	29 (50.00)	28 (48.30)	1 (1.70)
Pure tea category	16	11.95 \pm 13.04	14 (87.50)	2 (12.50)	0 (0.00)
Carbonated drinks	8	21.22 \pm 17.84	3 (37.50)	5 (62.50)	0 (0.00)
Other beverages	9	36.41 \pm 23.86	4 (44.40)	3 (33.30)	2 (22.20)

500mL, the proportion of low-risk drinks decreased to 37.4% (137/366), while the proportion of medium-risk and high-risk drinks increased to 54.1% (198/366) and 8.5% (31/366), respectively. As the capacity increases from 300mL to 500mL, the proportion of risk and high-risk in beverages increases significantly (Table 7).

Risk assessment of sugar content in one commercially available beverage

According to the volume of a commercially available beverage, specially formulated beverages have the highest risk level, with a high-risk sample proportion of 19.40% (19.98) and a high total sugar content (36.78 \pm 16.85 g). The fruit and tea category are second, with a high-risk sample proportion of 14.70% (10.68). In contrast, the risk of milk tea is relatively low, with only 5.50% (6.109) belonging to the high-risk category, but it has the largest sample size and the widest impact range. The low-risk proportion of pure tea beverages is the highest, at 87.50% (14.16) (Table 8).

Analysis of high risk carbohydrates

This study focuses on analyzing the distribution characteristics of sucrose and fructose, two sugars that have a significant impact on health. The

detection rate of sucrose is the highest, at 86.3% (316.366), with an average content of 2.32 \pm 2.29 g/100mL and a maximum detection value of 12.47 g/100mL. The detection rate of fructose was 72.4% (265.366), with an average content of 1.64 \pm 1.78 g/100mL and a maximum detection value of 10.58 g/100mL. From the perspective of freshly made beverage categories, specially formulated beverages have the highest sucrose content (16.44 \pm 12.40 g), while fruit tea has the highest fructose content (16.08 \pm 11.87 g) (Table 5).

Discussion

This study used high-performance liquid chromatography to analyze the sugar content of 366 commercially available freshly made beverages, revealing the impact of different categories, sweetness labelling, and capacity on sugar content and health risks. The results show that the proportion of sugar-free products in coffee beverages is the highest at 22.40% (13.58), significantly higher than other categories, indicating that sugar-free coffee can be a healthy alternative to sugary drinks and help reduce sugar intake. Sugar-free coffee not only avoids the risk of high sugar intake but may also bring additional health benefits through its physiological functions, such as antioxidant and

anti-inflammatory effects, such as reducing the risk of neurodegenerative diseases and hypertension¹⁸. Therefore, promoting the consumption of sugar-free coffee can help reduce sugar intake and improve overall health. It is recommended that the public be encouraged to choose healthy beverages, such as sugar-free coffee, through policy intervention and health education in order to reduce the health risks associated with high-sugar diets¹⁸. In addition, the volume of commercially available freshly made beverages is generally large, especially with very few samples below 300mL, which directly increases the sugar intake for single consumption and increases the risk of sugar intake for consumers. Although many beverage categories are mainly low sugar, with fruit tea accounting for 76.50% (52.68), milk tea accounting for 73.40% (80.109), and speciality drinks accounting for 69.40% (68.98), the actual total amount of sugar consumed by consumers is still relatively high due to the large volume of a single cup. For example, in milk tea and unique drinks, the proportion of samples with a volume of 300-500mL is 78.90% and 75.50%, respectively, while in fruit tea, 64.70% of the sample volume is also between 300-500mL. Even if it is a low-sugar drink, large volume intake will lead to an increase in sugar intake, and long-term drinking may increase the risk of chronic diseases such as obesity and diabetes¹⁹. To reduce the risk of sugar intake, it is recommended that consumers not only pay attention to the sweetness label when choosing freshly made beverages but also pay attention to the volume of the beverage. At the same time, food regulatory authorities should strengthen the supervision of the volume and sugar content of freshly made beverages and promote the industry to develop in a healthier direction. For example, measures such as implementing taxes on sugary drinks, restricting marketing and sales, etc., can be taken to reduce the consumption of high-sugar drinks^{19,20}.

The detection results of five types of sugars (fructose, glucose, sucrose, maltose, and lactose) in 366 freshly made beverages showed an average total sugar content of 5.98 ± 3.24 g/100mL, with sucrose content (2.32 ± 2.29 g/100mL) and detection rate (86.3%) significantly higher than other sugars, indicating that sucrose is the most essential added sugar in freshly made beverages. Souza and Santos found that sucrose has high sweetness, low cost, and is easy to process, making it a widely used sweetener

in the food industry. In contrast, the detection rate (30.9%) and content (0.15 ± 0.38 g/100mL) of maltose are the lowest. Studies have shown that maltose is less commonly used in food processing and has lower sweetness, which can only be detected in specific products²¹. Sucrose, as the primary added sugar in freshly made beverages, reflects the current dependence of the food industry on high sweetness and low-cost sweeteners due to its high content and high detection rate. This dependence may pose a potential threat to public health, especially in the context of excessive sugar intake and increased risk of chronic diseases²². Future research should further explore the feasibility of reducing the use of sucrose and developing healthier alternative sweeteners to reduce the negative impact of freshly made beverages on health.

There are significant differences in the total sugar content of different types of beverages. The total sugar content of other beverages is the highest (9.15 ± 4.15 g/100mL), followed by fruit tea (7.27 ± 3.60 g/100mL) and specially formulated beverages (7.09 ± 3.23 g/100mL). The high sugar content of these categories may be related to the syrup, juice, or other sweeteners added during the production process. A review also mentioned that the high sugar content in sugary drinks mainly comes from added sucrose, high fructose corn syrup, or juice concentrates²¹. In contrast, pure tea has the lowest total sugar content (2.09 ± 2.18 g/100mL), mainly due to its simple composition, usually containing only a small amount of sucrose or no sugar. This result is consistent with a study on pre-packaged sugary beverages in supermarkets, which indicated that pure tea beverages have simple ingredients and low sugar content²³. It is worth noting that milk tea drinks have a relatively high lactose content (0.86 ± 0.94 g/100mL), which is related to the commonly used dairy products in milk tea, such as milk and creamer. Although the total sugar content of milk tea (5.15 ± 2.25 g/100mL) is lower than that of fruit tea and speciality drinks, its sample size is the largest (109), and its consumer group is broad, so its health risks cannot be ignored. Milk tea beverages may have adverse effects on consumers' metabolic health due to their high sugar and high fat content^{23,24}. Sugar content of speciality drinks and fruit tea was significantly higher than that of milk tea ($P < 0.001$).

In comparison, the sugar content of other drinks was significantly higher than that of milk tea

and coffee ($P < 0.05$). This is related to a study on the complex formula and high-sugar raw materials used in freshly made milk tea²⁴. In addition, the sugar content of pure tea is significantly lower than that of milk tea, specially formulated drinks, and fruit tea ($P < 0.001$), and pure tea drinks can be chosen to reduce sugar intake²⁵.

Through one-way analysis of variance and multiple comparisons, it was found that there were significant differences in the total sugar content of freshly made beverages with different sweetness indicators, and the total sugar content showed an upward trend with increasing sweetness. The total sugar content of the sugar-free group was significantly lower than that of the low sugar group, standard sugar group, and high sugar group, indicating that the sugar-free label reflects the lower sugar content to some extent. However, there are still some samples with total sugar content close to or exceeding the recommended daily intake (25g), and even 21.10% (4.19) of the samples in the high sugar group have total sugar content exceeding 50g. Although consumers of freshly made beverages also have health awareness and mostly choose low sugar 64.20% (235.366) or sugar-free 4.40% (16.366) freshly made beverages, the actual sugar content of these beverages is still relatively high. After drinking one cup of such beverages, half of the intake exceeds 25g, and 23 (9.80) low-sugar freshly made beverages have a sugar content of over 50g per cup. Therefore, it is recommended that relevant departments strengthen the supervision of sugar content in freshly made beverages, improve labelling standards, and help consumers make healthier choices.

According to the World Health Organization's recommended sugar intake, the risk distribution of sugar content in beverages with two different capacities of 300mL and 500mL was found to significantly increase with the increase of capacity, especially in the proportion of medium and high-risk categories. Multiple studies have shown that an increase in the intake of sugary drinks is associated with an increased risk of various diseases^{6,26-29}. This finding suggests that public health policies should strengthen regulation of high-capacity sugary drinks, such as limiting the sale of high-sugar drinks through tiered tax policies³⁰. At the same time, consumers should also increase their awareness of the relationship between beverage

capacity and sugar content and choose small-capacity beverages to reduce health risks.

The results on the sugar content and related health risks in one commercially available freshly made beverage showed that, except for specially formulated beverages, which had the highest proportion of high-risk samples, fruit and tea products followed closely, with the highest fructose content (16.08 ± 11.87 g). Although it is commonly believed that fruit tea contains fruits and is considered healthier, excessive sugar addition actually outweighs these health benefits. In contrast, the proportion of high-risk samples for milk tea products is lower, which may be due to their lower fructose content (5.79 ± 6.21 g). However, due to the large sample size and widespread consumption of milk tea, its impact on public health remains significant, especially among young people who frequently consume these beverages. Pure tea is the safest choice, with 87.50% of the samples classified as low-risk, reflecting its minimal added sugar content, which is in line with the recommended dietary guidelines for reducing sugar intake³⁰. These results emphasize the need for stricter regulation of sugar content in commercially available beverages, especially speciality drinks and fruit teas, which pose the highest health risks.

Fructose and lactose have a significant impact on health among common added sugars, so this study focuses on these two types of sugars³¹⁻³³. The detection rates of sucrose and fructose in freshly made beverages were higher than other sugars, at 86.3% and 72.4%, respectively. The highest detection value of fructose was 10.58g/100mL, and the highest detection value of sucrose was 12.47g/100mL. At this sugar content level, even drinking one cup of the smallest commercially available freshly made beverage would exceed the intake of 25g. The high detection rate and content of sucrose and fructose reflect their universality in modern beverages. Future research should further explore alternative sugar additives to reduce their long-term effects on health.

This study also has some limitations. Firstly, the sample is unevenly distributed among brands, with some brands having smaller sample sizes, which may affect the representativeness of the results. Secondly, the detection method failed to distinguish between natural sugars and added sugars and did not consider the impact of seasonal changes.

In addition, the risk assessment only considered the sugar content factor and did not cover influencing factors such as consumption frequency. Future research can expand sample size and coverage, delve into consumer drinking behaviour and frequency, explore the development of low-sugar formulas, and evaluate the impact of different sweetness levels on consumer acceptance.

In this study, a total of 366 freshly-made beverages with high sales volumes in Beijing were collected, and high-performance liquid chromatography (HPLC), a method renowned for its high sensitivity and accuracy, was employed to determine their sugar content. The obtained results can offer data-driven support to policymakers. By analyzing the sugar content distribution in these beverages, policymakers can formulate more scientific regulations regarding sugary beverages, aiming to regulate the market, guide the production and marketing of beverage enterprises, and ultimately promote public health at a population level. For clinicians, these findings provide valuable reference information. They can leverage the detailed data on sugar content in different types of freshly-made beverages to offer more targeted dietary advice to patients. This enables patients to make more informed choices about their beverage consumption, helping to prevent diseases associated with excessive sugar intake, such as obesity, type 2 diabetes, and dental caries. Overall, this study bridges the gap between scientific research, policy-making, and clinical practice, demonstrating significant practical value.

Future research recommendations: (1) Expand sample size and geographic coverage to improve the representativeness of research results; (2) Conduct longitudinal research to evaluate the impact of seasonal changes on sugar content; (3) Conduct in-depth research on consumers' drinking behaviour and frequency; (4) Explore the development and consumer acceptance of low sugar formulas; (5) Evaluate the impact of different sweetness levels on taste and sales; (6) Conduct risk assessment research for special populations such as adolescents and pregnant women.

Conclusion

This comprehensive analysis of 366 freshly made beverages revealed significant differences in sugar content across different beverage categories,

sweetness labels, and portions. Research has found that: (1) Coffee beverages have the highest proportion of sugar-free products (22.40%), while other beverages have the highest total sugar content (9.15 ± 4.15 grams/100 millilitres). (2) Sucrose is the primary added sugar, with the highest detection rate (86.3%) and content (2.32 ± 2.29 g/100mL). (3) Although low-sugar options are commonly found in fruit tea (76.50%), milk tea (73.40%), and speciality drinks (69.40%), the total sugar intake per cup is still relatively high due to the generally large capacity of one freshly made beverage available on the market. (4) 50% of low-sugar label beverages exceed the recommended daily sugar intake (25 grams), with 9.80% of beverages containing more than 50 grams of sugar per serving.

These findings highlight the urgent need for stricter regulation of the portion size and sugar content of freshly made beverages, especially for speciality drinks and fruit teas that pose the highest risk to health. Future public health interventions should focus on promoting sugar-free alternatives, implementing portion limits, and improving sweet labelling standards to help consumers make healthier choices and reduce the risk of sugar-related chronic diseases.

Acknowledgements

We would like to thank all participants.

Funding

This study were funded by the Capital's Funds for Health Improvement and Research, CFH (2024-2G-3019) and the Talent Development Plan for High-level Public Health Technical Personnel Project in Beijing (2022-1-003)

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of the Beijing Center for Disease Prevention and Control (protocol code: BJCDC2024031, date of approval: 14 September 2024).

Informed consent statement

Informed consent was obtained from all subjects involved in the study. Written informed consent has

been obtained from the patient(s) to publish this paper.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author(s).

Conflicts of interest

The authors declare no conflicts of interest.

Patents author contributions

Conceptualization, L.H. and J.D.; methodology, W.L.; validation, L.H. and W.L.; formal analysis, L.H. and W.L. and S.L.; investigation, Y.L., S.L., W.L. and J.Z.; resources, Y.Z., J.L. and X.L.; data curation, L.H. and W.L.; writing—original draft preparation, L.H. and W.L.; writing—review and editing, L.H. and W.L.; visualization, W.L.; supervision, Y.Z., L.M. and R.C.; project administration, L.M. and S.F.; funding acquisition, L.H. All authors have read and agreed to the published version of the manuscript.

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