The adaptation, validation, and application of a methodology for estimating the added sugar content of packaged food products when total and added sugar label are not mandatory

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Abstract

Nutrition policies recommend limiting the intake of added sugar. Information about added sugar content is not provided on packaged foods, and even total sugar content is often absent in these products in Brazil. This study aimed to (i) adapt a systematic methodology for estimating added sugar content in packaged foods and non-alcoholic beverages when information on total and added sugar contents are not mandatory, (ii) apply the adapted methodology to a Brazilian food composition database to estimate the extent of added sugar content in the national food supply, and (iii) assess the validity of the adapted methodology. We developed an 8-step protocol to estimate added sugar content using information provided on food labels. These steps included objective and subjective estimation procedures. Mean, median, and quartiles of the added sugar content of 4,805 Brazilian foods and non-alcoholic beverages were determined and presented by food categories. Validity was assessed using a US database containing values of added sugars as displayed on the labels. Objective estimation of added sugar content could be conducted for 3,119 products (64.9%), with the remainder 1,686 (35.1%) being assessed using more subjective estimation. We found that 3,093 (64.4%) foods and non-alcoholic beverages contained added sugars and the overall estimated median added sugar content was 4.7 g (interquartile range 0 – 29.3) per 100 g or 100 ml. The validity testing on US data with known added sugar values showed an excellent correlation between estimated and reported added sugar values (ICC = 0.98). This new methodology is a useful approach for estimating the added sugar content of products in countries where both added and total sugar information are not mandated on food labels. The method can be used to monitor added sugar levels and support interventions aimed at limiting added sugar intake.

Keywords: food composition database; validity; food analysis; food labelling; free sugar; industrialized food.

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1. Introduction

For dietary purposes, sugars can be classified as intrinsic sugars and free / added sugars. Intrinsic sugars are found naturally within whole fruits, vegetables, dairy, and grains – such as the lactose in milk or the fructose in fruits. Free sugars include monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates (WHO, 2015). Although no universally accepted definition for added sugars exists (Scapin, Fernandes & Proença, 2016), most of food components included in the free sugars' definition are also considered added sugars (Food and Drug Administration, 2016). One of the main differences is that free sugars include all sugars naturally found in fruit juices while added sugars only include sugars added to these products (Bowman, 2017; Scapin, Fernandes & Proença, 2016; Cumming & Stephen, 2007). The added sugar terminology used in this study has followed this definition. Examples of added sugars include saccharose, glucose syrup, and inverted sugar. The term total sugar includes both intrinsic and free / added sugars (Food and Drug Administration, 2016; WHO, 2015).

Excessive consumption of added sugars is evidenced worldwide (Fisberg *et al.,* 2018; Azaïs-Braesco, Sluik, Maillot, Kok, & Moreno, 2017; Lei, Rangan, Flood, & Louie, 2016; Louie, Moshtaghian, Rangan, Flood, & Gill, 2016). It has been associated with adverse health conditions including non-communicable diseases such as diabetes, hypertension, and obesity (Frantsve-Hawley, Bader, Welsh, & Wright, 2017; Scapin, Fernandes, & Proença, 2017; Te Morenga, Howatson, Jones, & Mann, 2014). World Health Organization (WHO) guidelines recommend that adults and children limit free sugar consumption to less than 10% of their total energy intake (around 50 g based on a 2,000-a-day diet), or less than 5% for additional health benefits (WHO, 2015).

Added sugars are commonly included as ingredients in the formulation of processed and ultra-processed foods (Acton, Varderlee, Hobin, & Hammond, 2017; Probst, Dengate, Jacobs, Louie, & Dunford, 2017). Processed foods are simple products made by adding sugar, oil, and salt to raw foods, such as canned fruit, tinned fish preserved in oil, and sweetened milk. Ultra-processed foods are mostly formulated with ingredients for exclusive industrial use, and they are typically created by series of industrial techniques and processes. Examples of ultra-processed food include soft drink, cookies, and cakes (Monteiro, Cannon, Lawrence, Louzada, & Machado, 2019; Monteiro *et al.,* 2016). Processed and ultra-processed foods have been recognised as one of the primary sources of sugar intake (Azaïs-Braesco *et al.,* 2017), and their consumption is associated with adverse health outcomes, including overweight and cardio-metabolic risks (Elizabeth, Machado, Zinöcker, Baker, & Lawrence, 2020). The excessive use of added sugar in processed and ultra-processed foods has motivated discussions about the need for better reporting of the amount of added sugars on packaged food labels (Scapin *et al.,* 2020; Yeung & Louie, 2019). Countries such as the United States of America (USA), Australia, New Zealand, and members of the European Union follow the Codex Alimentarius recommendation on food labelling, which states that total sugar content should be presented in grams on the Nutrition Information Panel (NIP) on the back of the pack (WHO, 2012). Requirements for declaration of added sugars are now also being made in some countries. The USA, for example, requires that the nutrition facts panel, also displayed on the back of the pack, includes the amount of both total and added sugars by 2021 (FDA, 2016).

Since added sugar content is still not declared on the food labels of most countries, and because manufacturers do not make this information readily available, researchers can have difficulty monitoring the content of these sugars in packaged foods. As a consequence, methodologies for estimating levels of added

Table 1. Methodologies to estimate sugar content in foods, as identified in a literature search conducted in August 2018.

Reference	Country	Scope of application	Estimation level	Sugar type	Steps	Information used for sugars estimation	Validated or tested for reliability?	Particularities
Louie *et al.* (2015)	Australia	Foods and beverages	Food item	Added sugars	10	Ingredients list and total sugar content	Yes	-
Ng *et al.* (2015)	United States of America	Beverages	Food category	Added sugars	14	Ingredients list, total sugar content, and nutritional composition of each ingredient	Yes	Uses a linear programming method developed by the authors
Bernstein *et al.* (2016)	Canada	Foods and beverages	Food item	Free sugars	6	Ingredients list and total sugar content	No	Adapted from Louie *et al.* (2015)
Pan American Health Organisation (2016)	Latin America and the Caribbean	Foods and beverages	Food item	Free sugars	6	Total sugar content	No	Adapted from Louie *et al.* (2015)
Sluik *et al.* (2016)	Netherlands	Foods and beverages	Food category	Added sugars	Depends on the food category	Ingredients list and total sugar content	No	Uses a specific food categorisation
Kibblewhite *et al.* (2017)	New Zealand	Foods and beverages	Food item	Added, free, and intrinsic sugars	10	Ingredients list and total sugar content	No	Adapted from Louie *et al.* (2015)
Ruiz *et al.* (2017)	Spain	Foods and beverages	Food item	Free and intrinsic sugars	4	Ingredients list, ingredient proportion, and total sugar content	No	Steps are not clearly described
Amoutzopolous *et al.* (2018)	United Kingdom	Foods and beverages	Food item	Added and free sugars	5	Ingredients list, ingredient proportion, and total sugar content	No	Ingredient proportion must be known

sugars have been developed and applied to foods. All these methodologies rely on the total sugar content being available in the NIP and used in the calculation (Bernstein, Schermel, Mills, & L'Abbe, 2016; Sluik, van Lee, Engelen, & Feskens, 2016; Louie *et al.,* 2015). However, the total sugar content is mostly absent from the NIP in countries such as Argentina, Brazil, Paraguay, Uruguay (Mercosur, 2003), and China (Ministry of Health of the People's Republic of China, 2011), where its declaration is not mandated on labels. Therefore, alternative methodologies for estimating added content of packaged foods are required.

While the total sugar content is required on food labels in many jurisdictions, guidelines recommend control of added and free sugar intake (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020; WHO, 2015; Ministry of Health of Brazil, 2014; Australian National Health and Medical Research Council, 2013), not total sugar intake. In this case, it is added and free sugar data that are of greatest importance to public health. Added sugars monitoring is important in Brazil because it is the world's second-largest producer and fourth-largest consumer of sugars (International Sugar Organization, 2018). Against this background, this study aims to (i) adapt a systematic methodology for estimating added sugar content in packaged foods and non-alcoholic beverages when information on total sugar content is not mandatory; (ii) apply the adapted methodology to a Brazilian food composition database to estimate the extent of added sugar content in the national food supply; and (iii) assess the validity of the adapted methodology.

2. Materials and methods

2.1. Identification and evaluation of methods for estimating added / free sugar content

A literature search of articles published in the Web of Science, Scopus, PubMed, and SciELO databases, and in reports from international health organisations, was performed to identify methodologies for estimating added or free sugar content in foods. This search was also performed to select one of the published methodologies to be further adapted and used to assess Brazilian food products. The literature search was conducted in August 2018, with no date restriction. The following strategy was used: ('sugar*') AND ('packaged food' OR 'pre-packaged food' OR 'industrialised food' OR 'processed food' OR 'packaged goods' OR 'label*' OR 'food composition'), limited to title, abstract, and keywords. Publications on sugar content of foods were analysed, and those that fully described a methodological approach for determining the sugar content (added or free) were included. Eight methodologies were identified (Amoutzopoulos *et al.,* 2018; Kibblewhite *et al.,* 2017; Ruiz *et al.,* 2017; Bernstein *et al.,* 2016; Pan-American Health Organization, 2016; Sluik *et al.,* 2016; Louie *et al.,* 2015; Ng *et al.,* 2015) and are summarised in **Table 1**.

The identified methodologies have considerable differences because their variable degrees of subjectivity and because they are adapted to the food composition reality of the country where they were first applied. All methodologies required information on total sugar content, which is not available on most food labels or in food composition tables from Brazil and other Latin American countries. These issues make it impossible to use the identified methodologies without adaptation. Among the identified methodologies in the literature search, the methodology developed by Louie *et al.* (2015), and used in an Australian database, was selected to be adapted in the present study because it is the only with verified reliability (Louie, Lei, & Rangan, 2016) without relying on a non-public linear programming for its application. The Louie method has been used and adapted previously by other researchers to provide accurate estimations for individual products (Kibblewhite *et al.,* 2017; Bernstein *et al.,* 2016; Pan-American Health Organization – PAHO, 2016).

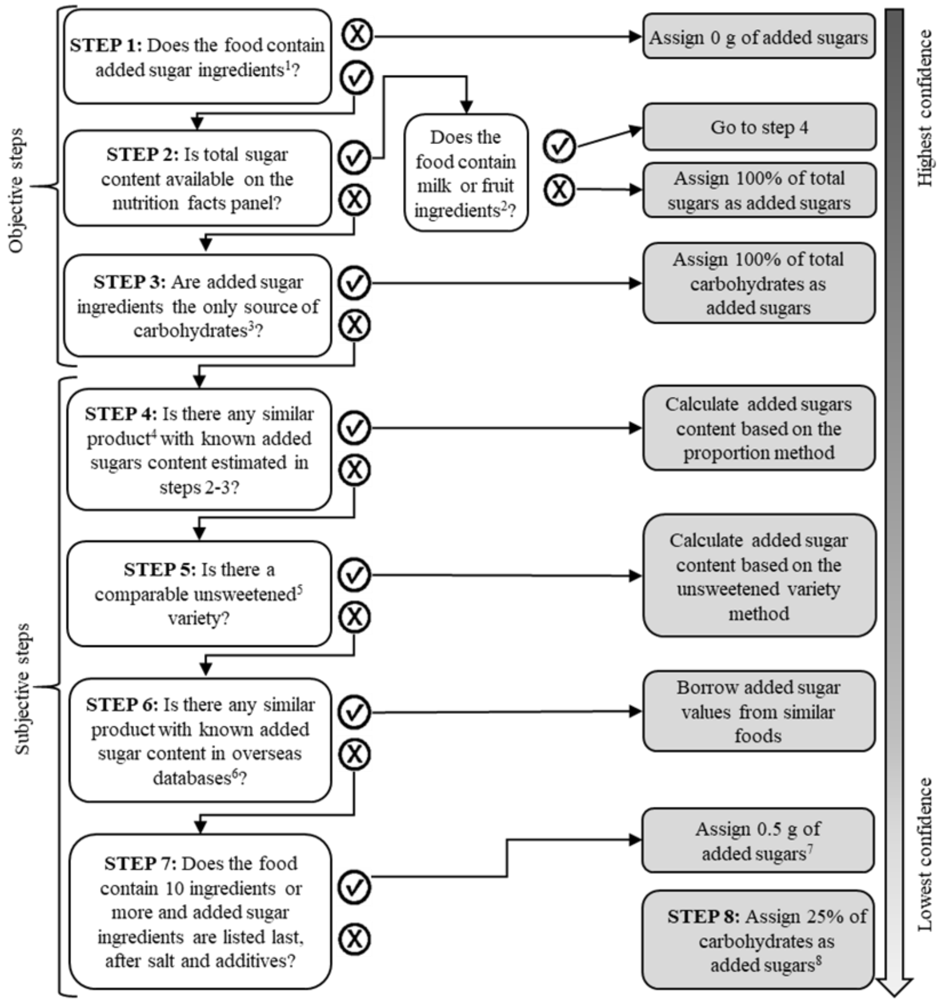
2.2. Adaptation of the methodology for estimating added sugar content in Brazilian packaged foods

The Louie methodology consists of 10 steps, of which steps 1–6 are classified as objective and steps 7–10 as subjective (**Supplementary File 1**). Our adapted methodology used the same step-by-step logic but was modified to account for the absence of information on total sugars, as well as for the availability of a relevant food database in Brazil. Two steps in the original methodology (steps 4 and 9) are calculations based on standard recipes from the Australian food composition database using proportion data for each ingredient in the recipe. Since there is no similar database with the proportion of each ingredient from the packaged foods for Brazil, these two steps were not used in our adaptation.

Our proposed methodology requires the ingredients list and the carbohydrate content of food products. Additionally, one of the steps uses the total sugar content of the products when it is available in the NIP even not being mandated. The methodology was organised in eight subsequent steps (steps 1–3 were objective and steps 4–8 were subjective), and it is a decision process that if a food does not meet the criterion in a step one has to move on to the next step. Working examples are provided in Supplementary File 1. Our methodology was planned, discussed, and tested by three dietitians with expertise in food labelling analysis (TS, VMR, ACF). The researcher who developed the original methodology (JCYL) also contributed to the adaptation. Steps 1–8 are described below, and a decision-making diagram showing the steps is presented in **Figure 1**.

Step 1. Assign 0 g of added sugars to foods without added sugar ingredients. In this step, the ingredients were systematically searched for ingredients representing added sugars. Added sugar terms used in Brazilian packaged foods are shown in **Table 2**.

Step 2. Assign 100% of total sugars as added sugars if the food does not contain milk, whole fruits, or 100% fruit juices (except from fruits naturally low in sugar). Although it is not mandatory to include total sugars on the NIP in Brazil, some manufacturers disclose this information voluntarily, making it possible to apply this step in those instances. Foods containing significant amounts of fruits, 100% fruit juice, and milk should not be estimated in this step as they contain intrinsic sugar, and instead should be assessed using following steps. Exceptions are applied to dairy ingredients such as whey, milk protein concentrate, buttermilk,



Grey box indicates decision endpoints. [1]Added sugar ingredients include sugars, syrups, honey, fruit juice concentrate, mono and disaccharides, among others. [2]Fruits (whole, 100% juice or pulp) with naturally minimal intrinsic sugar content (e.g. lemon) are not included. This step applies mainly to sugar-sweetened soft drinks, sports drinks, flavoured water, energy drinks, coffee and dairy free beverages, flan mix, dessert mix, jelly powder, sauces, processed meat, sugar, syrups, toppings, candies, water-based ice pop, and dairy-free chocolates. [3]If the food does not contain non-sugar carbohydrate ingredients (e.g. flour, starch, cereals, grains, roots, and vegetables), milk, whole fruits, or 100% fruit juice, the added sugar content is considered to be equal to the carbohydrate content. Vegetables containing less than 5% (wet basis) carbohydrate (e.g. cucumber, capsicum, cabbage, onion, and others) are not considered carbohydrate ingredients. [4]Similar foods should meet the following criteria: i) belong to the same food category, ii) have similar flavour (e.g. strawberry; raspberry), iii) ideally belong to the same brand, iv) contain similar ingredients (at least the first three ingredients should be the same), and v) added sugar ingredients appear in a similar position in the ingredients list. [5]Unsweetened varieties should meet the same criteria, excepting those related to sugar ingredients. [6]Overseas databases should be searched according to similar food criteria. [7]Foods included here are savoury ready-to-eat dishes, such as frozen burgers and lasagne. [8]It is assumed that 50% of carbohydrates are total sugars and that 50% of total sugars are added sugars (25% of carbohydrates).

Figure 1. Decision-making diagram for estimating added sugars in packaged foods and non-alcoholic beverages.

and cheese because they contain negligible amounts of intrinsic sugars (Ohlsson *et al.,* 2017). Fruit juices with minimal sugar content (e.g. lemon) are also not considered as sources of added sugars (United States Department of Agriculture, 2019). This step was applied to some foods from the following food categories:

- Regular soft drinks, sports drinks, flavoured water, and energy drinks;
- Coffee and beverage mixes without milk (powdered or reconstituted in water);
- Flan mix, dessert mix, and jelly;
- Sauces;
- Processed meats;
- Sugars and syrups, toppings, candies, ice pops; and
- Dairy-free chocolate.

Step 3. Assign 100% of total carbohydrates as added sugars if the food does not contain milk, whole fruits, 100% fruit juice, or non-sugar carbohydrate sources. Sugars are a subset of carbohydrates. Therefore, if a food item had no other carbohydrate (e.g. flour, starch, cereals, grains, roots, and vegetables) or intrinsic sugar ingredients (milk, whole fruits, or 100% fruit juice), the total carbohydrate content was equal to the added sugar content. Vegetables containing less than 5% of carbohydrates on a wet basis were not considered as carbohydrate sources here (e.g. cucumber, chilly, cabbage, onion, olive, chard, turnip, coriander, parsley, and chive) (Borjes, Cavalli, & Proença, 2010). This step was applicable to most foods from the categories mentioned in step 2 when the total sugar content was not presented.

Step 4. Use borrowed values from similar products from steps 2 and 3. Similar food products should i) belong to the same food category, ii) have similar flavour (e.g. strawberry, raspberry), iii) ideally belong to the same brand, iv) contain similar ingredients: at least the first three ingredients should be the same, as they are listed in descending order by weight, and v) present added sugar ingredients in a similar position in the ingredients list. In this

Table 2. Added sugar terms commonly found in packaged foods sold in Brazil.

Type of added sugar	Common terms for added sugar ingredients
Sugars	Sugar, vanilla sugar, caramelised sugar, crystal sugar, invert crystal sugar, demerara sugar, invert sugar, liquid sugar, invert liquid sugar, brown sugar, invert brown sugar, refined sugar, sucrose, dextrose, corn dextrose, glucose, corn glucose, glucose powder, fructose, lactose
Honey and sugarcane products	Honey, royal jelly, molasses, sugarcane syrup
Syrups	Sugar syrup, high-fructose syrup, caramel syrup, glucose syrup, glucose-fructose syrup, guaraná syrup, corn syrup, corn syrup with high-fructose content, high-fructose corn syrup, glucose syrup solids
Sweet spreads and jams	Sweet spreads and fruit jams
Fruit juices concentrated, pulps, and dried fruits	Fruit juice concentrates, fruit pulps, fruit sauces, dried and/or dehydrated fruits
Maltodextrin	Maltodextrin, corn starch maltodextrin, potato maltodextrin, corn maltodextrin
Others	Sweetened condensed milk and marshmallow

Source: Adapted from Scapin, Fernandes, dos Anjos, & Proença, 2018.

situation, the proportion of added sugars to total carbohydrates was calculated using values borrowed from similar food. Added sugar content of the target food (AS_{t100g}) was then estimated as follows:

$$AS_{t100g} = \left(\frac{AS_{s100g}}{CHO_{s100g}}\right) \times CHO_{t100g}$$

where AS_{s100g} is the added sugar content per 100 g estimated for the similar food, CHO_{s100g} is the carbohydrate content per 100 g of the similar food, and CHO_{t100g} is the carbohydrate content per 100 g of the target food.

Step 5. Calculation based on comparison with unsweetened variety. Added sugars can be estimated by comparing the carbohydrate content of sweetened and unsweetened versions of products. This step was limited to foods whose compositions differ mainly in the absence/presence of sugars or in the use of low-calorie sweeteners. The criteria for comparability of products are the same as for step 4, except for criterion five (v), which relates to the ordering of the ingredients list for added sugar ingredients. This step was particularly useful for dairy products; however, it was unhelpful for foods rich in carbohydrate sources in which sugars are replaced by flour or cereals in addition to low -calorie sweeteners (e.g. regular vs diet biscuits and cakes). The formula to estimate added sugar content per 100 g (AS_{100g}) for step 5 is:

$$AS_{100g} = \left\{\frac{100 \times (CHO_{unsw100g} - CHO_{sw100g})}{(CHO_{unsw100g} - 100)}\right\}$$

where $CHO_{unsw100g}$ is the carbohydrate content per 100 g of the unsweetened product, and CHO_{sw100g} is the carbohydrate content per 100 g of the sweetened product.

Step 6. Use borrowed values from similar products from overseas food composition databases. Brazil and other Latin American countries do not have food composition databases with information on sugar content (Food and Agriculture Organization, 2019). Therefore, for this step, we borrowed information from other countries' food composition databases, particularly the database from the United States Department of Agriculture since it has information about added sugars (USDA, 2019).

In cases where it was not possible to estimate added sugar content using the previous steps, one of the following steps was used.

Step 7. Assign an added sugar content of 0.5 g if the product contains 10 or more ingredients and added sugar ingredients are listed last (after salt and food additives). In these circumstances, added sugar content is likely minute. Foods for which this step was used included mostly savoury ready-to-eat dishes, such as frozen lasagnes and burgers.

Step 8. Assign 25% of total carbohydrates as added sugars if the product has fewer than 10 ingredients or added sugar ingredients are listed before salt and food additives. Foods with very high or very low amounts of added sugars would likely have been estimated using an earlier step. Following the original methodology (Louie *et al.,* 2015), which considers that 50% of total sugars are added sugars, here it was assumed that 50% of carbohydrates are total sugars and that added sugars correspond to 25% of carbohydrates. The following equation was used to estimate added sugars in this step:

$$AS_{100g} = \frac{CHO_{100g}}{4}$$

where CHO_{100g} is the carbohydrate content per 100 g.

2.3. Application of the adapted methodology to a Brazilian food packaged composition database

The adapted methodology was applied to food items within a Brazilian packaged food composition database. The database comprises information on product name and type, nutrition information facts, serving size, and ingredients for 4,805 packaged foods and non-alcoholic beverages sold in a major supermarket in Brazil in 2013. The supermarket belongs to one of the ten largest Brazilian chain stores, with most of the products sold being well-known food and beverage brands and representing products sold in other large supermarket chain stores throughout the country. Details of data collection are described elsewhere (Scapin *et al.,* 2018). The food items were classified into seven major groups and further divided into 32 minor categories according to their nutritional composition, based on a Mercosur resolution (Mercosur, 2003). One author of the present study (TS) estimated the added sugar content of all food items in the database using the proposed adapted 8-step methodology. Uncertainty was resolved through discussion with two other authors (ACF, VMR) until consensus was reached. All three researchers have a nutrition background and expertise in food label research.

Added sugar content was expressed as g per 100 g or 100 ml. Mean, minimum, maximum, standard deviation (SD), median (50^{th}) and quartiles (25^{th} and 75^{th}) were determined and reported by minor food category. All statistical analyses were performed using Microsoft Excel 2016 (Redmond, WA, USA) and *R* software version 3.6.2 (*R* Foundation for Statistical Computing, Vienna, Austria).

2.4. Validity testing of the adapted methodology

To evaluate the validity of the adapted methodology, we performed an agreement test comparing known added sugar values from a US food composition database against added sugar values estimated for the same products using our adapted methodology. The US data are from The George Institute's global food composition database that contains nutritional information and lists of ingredients for packaged foods and non-alcoholic beverages collected via supermarket surveys and using the FoodSwitch application (The George Institute for Global Health, 2017). Further details about FoodSwitch data collection can be found elsewhere (Dunford & Neal, 2017). The US database provides values of added sugars for 68,675 products reported on labels by manufactures since the mandate for added sugars labelling in the US was gazetted in 2016 (grace period ends in 2021) (FDA, 2016). Data from FoodSwitch relies on the accuracy of nutritional values reported on product labels, and so may not always be 100% representative of what is actually in the foods (Dunford & Neal, 2017). However, the nutritional information displayed on labels can be considered reliable since FDA assigns the manufacturers the responsibility for assuring the validity of a product label's stated nutrient values. Also, it is FDA responsibility to determine compliance of the reported information with labelling regulations (FDA, 2018).

For analysis, the US database was divided into the minor categories applied to the Brazilian database. The food category of baby foods and formulas was not included in the analysis because data was not available. A random sample of 30 products from each of 31 remaining minor categories (total of 930 products) was selected using a randomisation formula in Excel®. The lead researcher applied the steps of the adapted methodology to the US database with the added sugar values removed. To test all steps of our adapted methodology, we also removed at random, 90% of total sugar values but retained 10% to be in line with Brazilian food labelling patterns. We did not consider maltodextrin as an added sugar in our analyses to be consistent with US food

Table 3. Number and proportion (%) of products with added sugar estimated at each step (n = 4,805)

Step*	*n* (%)	Description
1	1,712 (35.6%)	Food products without AS ingredients (AS = 0 g)
2	483 (10.1%)	Total sugar content is available on NIP and product contains no milk, whole fruit, or 100% fruit juice ingredients (AS = total sugars)
3	924 (19.2%)	AS ingredients are the only source of carbohydrates (AS = total carbohydrates)
4	1,058 (22.0%)	Borrowed values from similar products in the database (AS = AS content of similar product)
5	176 (3.7%)	Comparison with an unsweetened version (AS = difference in total carbohydrate contents)
6	326 (6.8%)	Borrowed values from an overseas database (AS = AS content from similar product)
7	96 (2.0%)	Assumption of low contents (AS = 0.5 g/100 g or 100 ml)
8	30 (0.6%)	Final assumption (AS = 25% of total carbohydrates)
TOTAL	4,805 (100%)	–

*Steps 1, 2, and 3 are objective, and steps 4, 5, 6, 7, and 8 are subjective. NFP, nutrition information panel; AS, added sugars.

labelling regulations (FDA, 2016). Estimated added sugar values were then compared against US database values using paired sample Wilcoxon test and Intraclass Correlation Coefficient (ICC). ICC estimates and their 95% confident intervals were calculated based on a mean-rating (k = 2), absolute-agreement, 2-way mixed-effects model. Values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 are indicative of poor, moderate, good, and excellent reliability, respectively (Koo & Li, 2016). A Bland–Altman plot was also constructed to assess the level of agreement between the two sets of values (Bland & Altman, 1986). All statistical analyses were performed using Microsoft Excel 2016 (Redmond, WA, USA) and *R* software version 3.6.2 (*R* Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1 Estimation of the added sugar content of a Brazilian food packaged database

Of the 4,805 food products assessed, 64.4% (n = 3,093) had at least one type of added sugar in their ingredient lists. Total sugar content was declared in 11.1% (n = 532) of products. Objective steps 1–3 were used to estimate the added sugar content of 3,119 products (64.9%) and subjective steps 4–8 were used to estimate the added sugar content of a further 1,686 products (35.1%), as shown in **Table 3**.

The estimated median added sugar content of all foods was 4.7 g per 100 g or 100 ml (IQR 0–29.3). Analyses restricted to only those foods that contained added sugars in their ingredient list (n = 3,121) identified an estimated median added sugar content of 18.2 g per 100 g or 100 ml (IQR 5.2–48.0).

Table 4 shows the estimated added sugar content of food products, stratified by food category. Twenty-three of the 32 food categories had more than 50% of products with added sugars listed in their ingredients. Candies, sugars and syrups, coffee mixes and powdered drinks, dessert mixes, jams, chocolates, and cakes had the highest median added sugar content.

3.2 Validity of the adapted methodology

Comparisons were made between the added sugar content of 930 products reported in the US database and added sugar values estimated by the proposed methodology. There was a significant difference between estimated and US database added sugar values (mean difference = 0.14 ± 1.57, p = 0.007), although values from both sources also showed an excellent correlation (ICC = 0.98). **Figure 2** shows a Bland–Altman plot of differences between estimated and Us database added sugar values. Eighty-seven (1.8%) of the 930 products had a difference in the added sugar values estimated by the adapted methodology and the US database values outside the limits of agreement of 95%. Additional analyses by the methodological steps also showed good correlation results for all steps (r > 0.75). Further details on the comparison of added sugar content between the two sources by step can be found in **Table 5** and **Figure 3**.

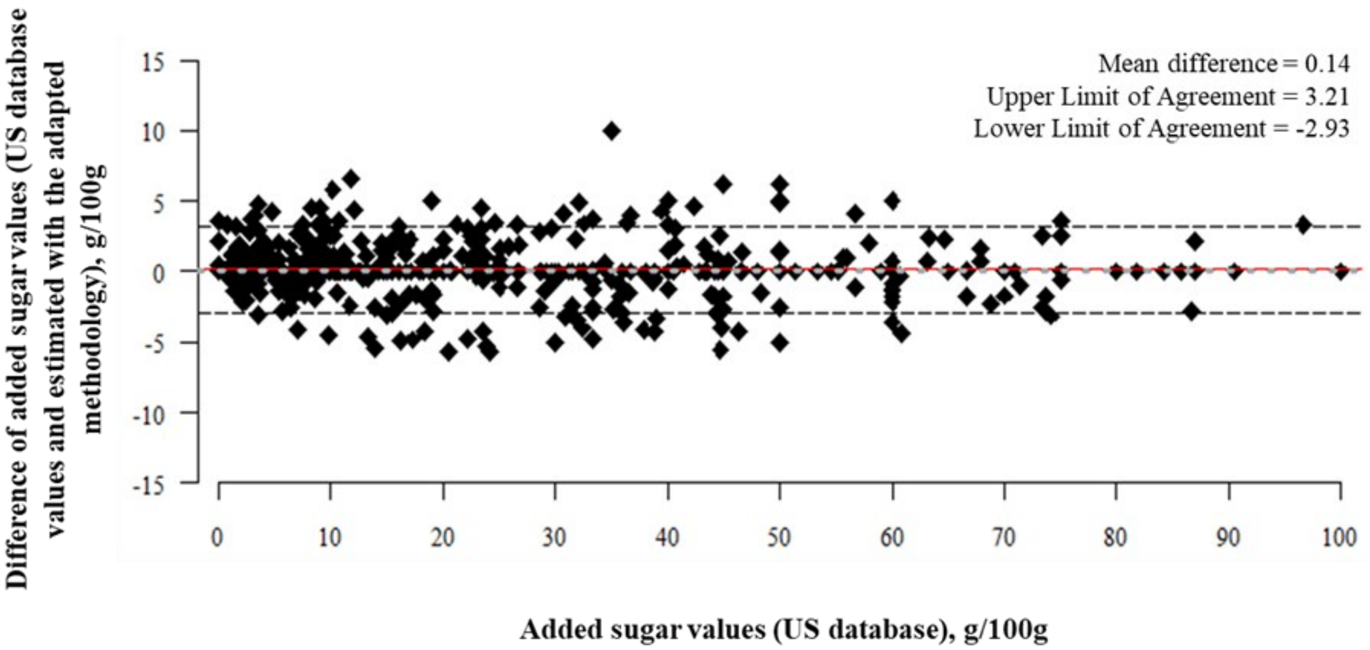


Figure 2. Bland and Altman plot for the difference in added sugar values between the US database (as declared on the nutrition information panels) and the adapted methodology for 930 products. Solid red line: mean difference; black strip lines: 95% limits of agreement; grey strip line: fit line.

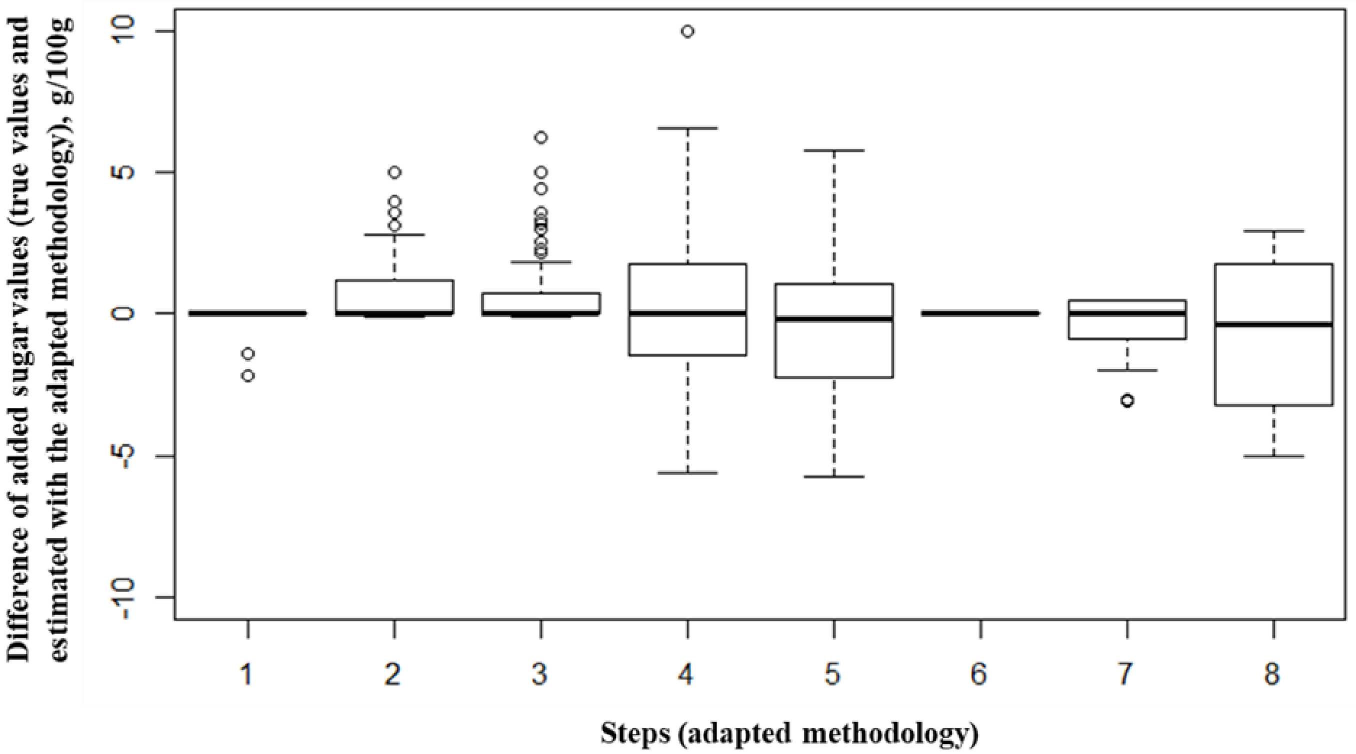


Figure 3. Mean difference (solid lines) and standard deviation (dashed lines) between the US database added sugar values and estimated added sugar values (*n* = 930), presented by methodological step. Open circles represent outliers.

4. Discussion

To the best of our knowledge, this is the first study to propose a systematic methodology for estimating the added sugar content of packaged foods and beverages when data for total sugar is not mandatory on labels. Additionally, no further studies have systematically calculated the added sugar content in a large sample of Brazilian packaged products. The proposed approach is based on a previous study (Louie *et al.,* 2015), with adaptations made to extend its applicability to food items sold in countries such as Brazil, where food labelling laws do not require reporting of total sugars.

The proposed methodology is a valid, multi-step, low-cost approach to estimating added sugar levels in packaged foods and non-alcoholic beverages using information readily available on most food labels. The methodology showed good validity, and estimated values had an excellent correlation with values available on labels from the database used for validation. These results could be achieved because of the small number of products evaluated, allowing a detailed product-by-product evaluation by a researcher with expertise on sugars. The estimated added sugar contents of some products (1.8%) were outside the 95% limits of agreement on the Bland-Altman analysis, accounting for the difference between the overall mean added sugar values estimated by the adapted methodology and the values available on labels. While a small overall mean is interesting from a broad public health perspective, high quality individual product data are important for decision making around food choice and for government and industry action. Given that, we support the mandatory inclusion of added sugar content on the NIP. In the case of Brazil, mandatory inclusion of total sugars should be also implemented since our results showed that only 532 (11.1%) of the assessed products presented this information in the NIP, reflecting its voluntary nature in the country. Information relating to total sugar content can be useful for people with dietetic restriction on sugars in general (i.e. people with diabetes).

Our results showed that 64.4% of packaged foods sold in Brazil contained added sugars, similar to the observed results for packaged foods sold in other countries (Zupanic *et al.,* 2018; Acton *et al.,* 2017; Probst *et al.,* 2017). Median added sugar content was 4.7 g/100 g, which is higher than that observed for free sugar estimation on packaged foods in Canada (Bernstein *et al.,* 2016) and Slovenia (Zupanic *et al.,* 2018), although the results are similar when compared at food category levels. These differences may be due to the higher number of products evaluated in those studies, with a greater number of minimally processed foods, which could result in lower median free sugar values. In addition, data in this study were collected from a single supermarket in an urban area of Brazil, which may have introduced inclusion bias.

As expected, the food categories with the highest levels of added sugars in our dataset were those comprising sweet foods, such as cakes, desserts, cereal bars, sugars, and syrups. However, foods often not associated with sweetness (e.g. salty crackers, pickled vegetables, and processed meats) were also found to contain added sugars. This may be at least partially due to sugars being added to foods not only as sweeteners but also as preservatives, acidity regulators, and colourings (Goldfein & Slavin, 2015).

The estimated high levels of added sugars in sweetened drinks are in line with previous research (Jin *et al.,* 2019; Vin *et al.,* 2019; Hashem, He, Jenner, & MacGregor, 2016), and is consistent with sugary drinks being a main target of public interventions aimed at reducing sugar intake, such as taxation (Pfinder *et al.,* 2020). Our results showed that dairy drinks and yoghurts also had high levels of added sugars. This finding is important because consumers often underestimate the sugar content of dairy products, probably because of the health halo effect around these products (Dallacker, Hertwig, & Mata, 2018).

According to the Brazilian Consumer Expenditure Survey (Pesquisa de Orçamentos Familiares) – a national survey with more than 30,000 individuals over 10 years old, the average daily consumption of soft drinks, juices/nectars, and dairy drinks is 94.7, 145.0, and 19.9 ml, respectively (Instituto Brasileiro de Geografia e Estatística, 2011). If we calculate the sum of added sugars from these products using estimates from our database, then a single individual can consume more than 22 g/day of added sugars from these sweetened beverages alone. Moreover, considering that Brazilian adults ingest about 15.4 g/day of sugars by adding table sugar to coffee and tea (Louzada *et al.,* 2015), it can be concluded that their intake of added sugars from beverages alone surpasses the WHO free sugar recommendation of 5% of the energy intake (around 25 g based on a 2,000-a-day diet), as well as the more liberal recommendation of 10% of the energy intake (around 50 g based on a 2,000-a-day diet) (WHO, 2015).

Our results show that added sugar levels can differ greatly among food products within the same category, demonstrating that products with lower added sugar content can survive in the market and highlighting the potential for product reformulation to lower sugar content. For instance, an experimental study found that a 6.7% reduction in added sugar content in chocolate-flavoured milk was imperceptible to adult consumers (Oliveira *et al.,* 2016). Similarly, an added sugars reduction of 40% in milk desserts did not have a significant effect on children's hedonic reaction and had only minor effects on their sensory perception of the product (Velázquez, Vidal, Varela, & Ares, 2020). Therefore, product reformulation has the potential to change dietary intake of critical nutrients (Spiteri & Soler, 2018; Yeung *et al.,* 2017), and has been suggested as another way to decrease the disease burden associated with excess added sugar intake (Gortmaker *et al.,* 2011). At the same time, the food industry should adopt better ways to communicate the added sugar content of its products on the food labels, supporting people on their food choices (Alcantara, Ares, de Castro, & Deliza, 2020; Scapin *et al.,* 2020).

Table 4. Mean, minimum, maximum, standard deviation (SD), and quartile values of estimated added sugar content (g/100 g or g/100 ml) in 4,805 Brazilian packaged foods and non-alcoholic beverages, stratified by food category.

Food groups and categories	*n*	*n* (%) of products with added sugar ingredients	Added sugar content (g/100 g or g/100 ml)					
			Mean (SD)	Min	25th	50th (Median)	75th	Max
Bakery goods, bread, cereals, and related products								
Processed grains	208	10 (4.8)	0.8 (3.9)	0.0	0.0	0.0	0.0	25.0
Cereal bars	77	77 (100.0)	34.7 (18.3)	1.4	24.3	30.9	41.6	77.8
Breakfast cereals	63	58 (92.1)	20.8 (13.9)	0.0	4.5	21.7	33.3	40.0
Breads	101	68 (67.3)	3.8 (3.9)	0.0	0.0	3.4	5.8	23.3
Salty crackers	206	142 (68.9)	3.8 (4.3)	0.0	0.0	2.0	5.7	21.7
Cakes	205	197 (96.1)	33.6 (15.2)	0.0	24.4	31.6	41.7	70.3
Pastas	233	46 (19.7)	0.8 (1.7)	0.0	0.0	0.0	0.0	4.9
Baby foods and formulas	79	43 (54.4)	21.3 (23.7)	0.0	0.0	14.2	52.5	60.0
Vegetables and nuts								
Minimally processed vegetables	238	0 (0.0)	0.0 (0.0)	0.0	0.0	0.0	0.0	0.0
Pickled vegetables	148	35 (23.6)	1.9 (4.7)	0.0	0.0	0.0	0.0	38.0
Packaged nuts	73	26 (35.6)	3.5 (5.3)	0.0	0.0	0.0	6.7	15.1
Fruits and juices								
Fruit juices	199	169 (84.9)	10.1 (5.8)	0.0	5.5	11.3	13.5	28.3
Canned fruits	51	26 (51.0)	17.8 (22.4)	0.0	0.0	9.6	31.7	73.9
Milk and dairy products								
Dairy drinks, fermented milk, and yogurt	155	130 (83.9)	7.6 (4.7)	0.0	3.1	9.2	10.8	18.2
Dairy dessert mixes	82	61 (75.3)	30.4 (24.4)	0.0	2.9	34.9	47.2	85.0
Cheese	103	11 (10.7)	1.1 (3.4)	0.0	0.0	0.0	0.0	12.9
Sweetened products								
Sugars and syrups	97	97 (100.0)	82.2 (17.0)	26.0	75.0	80.0	100.0	100.0
Chocolates	244	240 (98.4)	52.8 (16.3)	0.0	44.4	55.4	60.8	93.8
Coffee mixes and powdered drinks	122	121 (99.2)	71.1 (19.3)	0.0	69.3	75.0	81.7	94.0
Popsicles and ice creams	102	102 (100.0)	22.6 (5.9)	5.7	20.1	21.9	23.9	39.3
Candies	134	113 (84.3)	69.5 (35.0)	0.0	55.0	85.0	95.0	100.0
Jams	159	151 (95.0)	52.2 (22.4)	0.0	40.0	60.0	67.8	90.0
Soft drinks	218	173 (79.4)	5.4 (4.5)	0.0	0.5	5.0	10.0	15.0
Biscuits	314	307 (97.8%)	29.5 (14.5)	0.0	20.8	29.4	38.0	75.0
Non-dairy dessert mixes	106	92 (86.8)	46.1 (27.7)	0.0	21.4	51.7	70.4	95.7
Processed meat and seafood								
Canned seafood	35	6 (17.1)	0.3 (0.8)	0.0	0.0	0.0	0.0	3.2
Processed meat	233	109 (46.8)	1.0 (1.7)	0.0	0.0	0.0	1.1	11.8
Pastes, sausages, and salami	222	176 (79.3)	2.0 (2.3)	0.0	0.5	1.7	2.8	15.0
Gravies, sauces, ready-made seasonings, oils, and ready-to-eat dishes								
Seasonings	56	25 (44.6)	5.2 (7.5)	0.0	0.0	0.0	8.5	28.0
Gravies and sauces	194	144 (74.2)	5.3 (5.7)	0.0	0.0	5.10	6.10	47.5
Oils and creams	88	0 (0.0)	0.0 (0.0)	0.0	0.0	0.0	0.0	0.0
Ready-to-eat dishes	260	138 (53.1)	1.4 (3.6)	0.0	0.0	0.5	0.5	30.8
TOTAL	4,805	3,093 (64.4)	18.4 (26.0)	0.0	0.0	4.7	29.3	100.0

In 2018, the Brazilian Ministry of Health and the food industry sector signed a voluntary agreement to reduce the use of sugars in some types of packaged foods by 2022 (Ministry of Health of Brazil, 2018). Since we have not identified other database with information about the use of added sugar in packaged foods sold in Brazil before 2018, our data can serve as a baseline by which the effectiveness of this agreement, and the changes in the industrialised food market, can be evaluated. Data from Slovenia (Zupanic, Hribar, Fidler Mis, & Pravst, 2019) and the United Kingdom (Public Health England, 2018), where similar voluntary agreements were made, suggest a limited impact of voluntary arrangements on the sugar content of packaged foods. Objective independent monitoring will be key to evaluating the effects of this strategy in Brazil and can also be used to evaluate the extent to which non-sugar sweeteners (NNS) are used as sugar substitutes (Luo, Arcot, Gill, Louie, & Rangan, 2019; Popkin & Hawkes, 2016).

4.1 Practical implications

The proposed methodology has several practical implications. For the governmental area, two main points can be raised. First, by estimating the added sugar content of packaged food it is possible to determine which category of products should be targeted for food reformulation interventions. Second, an accessible way to estimate the added sugar content of foods can contribute to sugar labelling discussions. The lack of methods to determine added sugar has been previously listed as a possible barrier to mandatory added sugar labelling (Pomeranz, 2012).

For the industry, this methodology is handy for small manufactures that cannot afford expensive laboratory analysis but want to estimate their products' added sugar content. Finally, the methodology contributes to health workers by providing a practical tool to estimate the added sugar content of packaged foods and, thereby, assist patients. This is especially useful for practitioners who provide healthcare for people who need restricted sugar consumption.

4.2 Study limitations and future research

The current study has some limitations. As in other methods for estimating the sugar content of food products (Yeung & Louie, 2019; Bernstein *et al.,* 2016; Sluik *et al.,* 2016; Louie *et al.,* 2015), subjective analyses might have introduced errors, although the methodology had good validity overall. Step 3 might have overestimated the amount of added sugars by not considering some vegetables as carbohydrate sources. This compromise substantively increased the numbers of food items for which the added sugar content could be estimated based on objective information, and we believe that because these vegetables have less than 5% of the carbohydrate content in their wet form, the impact was likely minimal. Furthermore, validity analyses for step 3 showed good agreement results. In addition, the arbitrary step 8 was used for very few items (n = 30). It is also of note that this method is a time-consuming approach which requires a detailed product-by-product evaluation made by an expert researcher to provide accurate estimates. Future research could investigate ways to digitally automate the estimation process, allowing the standardisation of the methodology and its application in databases with a greater number of products.

Finally, foods items were sampled in 2013 from a single supermarket of an urban area in southern Brazil, and the results may be different for products reformulated after 2013 or sourced from low-income or rural areas of the country. However, this supermarket is part of a large supermarket chain with stores in several Brazilians states. Thus, our database comprised food items and food brands that can be found in different parts of the country. Future research could explore the foods available for sale in different regions and socioeconomic areas in Brazil.

Table 5. Comparison and correlation between US database added sugar values and estimated added sugar values (*n* = 930), presented by methodological step.

Step	*n*	Mean ± SD US database value	Mean ± SD Estimated value	Mean difference	Paired t-test *p*-value	ICC
1	357	0.01 ± 0.14	0.00	-0.01	0.38**	0.99
2	60	30.5 ± 24.6	31.3 ± 24.4	0.78	<0.01	0.99
3	113	40.6 ± 38.5	41.2 ± 38.5	0.65	<0.01	0.99
4	233	31.4 ± 20.3	31.6 ± 20.1	0.23	0.15	0.92
5	53	11.0 ± 6.13	10.5 ± 5.15	-0.58	0.21**	0.88
6*	78	21.5 ± 15.4	21.5±15.4	N/A	N/A	1
7	32	0.84 ± 1.0	0.5 ± 0.0	-0.34	0.70	0.99
8	4	13.4 ± 13.6	12.7 ± 10.5	-0.71	0.87**	0.96
Overall	930	17.3 ± 24.4	17.4 ± 24.5	-0.14	0.06	0.98

SD, standard deviation; ICC, Intraclass Correlation Coefficient; CI, Confidence Interval for ICC; N/A not applicable as the values are constant. *Estimated values are the same from the US database values since they were borrowed from the US database. **Wilcoxon test.

5. Conclusions

The comprehensive methodology for estimating added sugar content proposed in this study showed excellent validity and can be useful for Brazil and other countries where total sugars labelling is not mandatory. Our results showed that about two-thirds of packaged foods and non-alcoholic beverages sold in Brazil contain added sugar ingredients, with a median added sugar content of 4.7 g per 100 g or 100 ml. Amongst the two-thirds of foods containing added sugars, the median added sugar content was almost four times greater at 18.2 g per 100 g or 100 ml. The results can be used to monitor added sugar content in packaged foods and support public health interventions to reduce added sugars levels in target food categories.

Conflict of interest

The authors declare that they have no conflict of interest.

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