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

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A R T I C L E I N F O

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A B S T R A C T

Nutrition policies recommend limiting the intake of added sugars. Information about added sugar content is not provided on packaged foods in Brazil, and even total sugar content information is often absent. This study aimed to (i) adapt a systematic methodology for estimating added sugar content in packaged foods when information on total and added sugar contents is not mandatory on labels, (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 were determined and presented by food categories. Validity was assessed using a US database containing values of added sugar as displayed on the product 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 subjective estimation. We found that 3,093 (64.4%) foods contained added sugar ingredients 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 for products with known added sugar values showed excellent agreement 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.

## 1. Introduction

For dietary purposes, sugars can be classified as intrinsic sugars, sugars from milk, and free / added sugars. Intrinsic sugars are found naturally within whole fruits, vegetables, and grains – such as the fructose in fruits. Milk sugars include lactose and galactose naturally found in dairy products. 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 (World Health Organization, 2015). Although no universally accepted definition for added sugars exists (Scapin, Fernandes & Proença, 2017), most of the 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 et al., 2017; Cumming & Stephen, 2007). The added sugar terminology used in this study has followed this definition. Examples of

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added sugars include saccharose, glucose syrup, and inverted sugar. The term total sugar includes all types of 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, obesity, and dental caries (Frantsve-Hawley, Bader, Welsh, & Wright, 2017; Scapin et al., 2017; Te Morenga, Howatson, Jones, & Mann, 2014; Moynihan & Kelly, 2014). World Health Organization (WHO) guidelines recommend that adults and children limit free sugars consumption to less than 10% of their total energy intake (50 g based on a 2,000 calories per day diet), or less than 5% for additional oral health benefits (WHO, 2015).

Added sugars are commonly included as ingredients in the formulation of packaged foods (Acton, Varderlee, Hobin, & Hammond, 2017; Probst, Dengate, Jacobs, Louie, & Dunford, 2017), and these foods have been recognised as primary sources of sugar intake (Azaïs-Braesco et al., 2017). The excessive use of added sugars in packaged foods has motivated discussions about the need for better reporting of the amount of added sugars on food labels (Scapin et al., 2021; 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 on labels (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, displayed on the back of the pack, includes the amount of both total and added sugars by 2021 (FDA, 2016).

Researchers often have difficulty monitoring added sugar content of packaged foods because it is not declared on the food labels of most countries and manufacturers do not make the information readily available. As a consequence, methodologies for estimating levels of added sugars have been developed and applied to foods. All these methodologies rely on the total sugar content being available in the Nutrition Information Panel (NIP) and used in the calculation (Bernstein, Schermel, Mills, & L'Abbe, 2016; Sluik, van Lee, Engelen, & Feskens, 2016; Louie et al., 2015). However, total sugar content is not mandated and therefore mostly absent from NIPs in countries such as Argentina, Brazil, Paraguay, Uruguay (Mercosur, 2003), and China (Ministry of Health of the People's Republic of China, 2011). Alternative methodologies are thus required for estimating the added sugar content of packaged foods in these countries.

While the total sugar content is required on food labels in many jurisdictions, guidelines recommend control of added and free sugar intake, not total 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). 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 when information on total sugar content is not mandatory on labels; (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 sugar content

To identify methodologies for estimating added or free sugar content in food, a search was performed of articles published in the Web of Science, Scopus, PubMed, and SciELO databases, and in reports from international health organisations. The search was conducted in August 2018, with no date restriction. The following search 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 the sugar content of foods were analysed, and those that fully described a methodological approach for determining sugar content (added or free) were included. Table 1 summarises the eight methodologies 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).

The identified methodologies had considerable differences due to variable degrees of subjectivity and adaptations reflecting the food composition characteristics of the countries where they were first applied. All the 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. Of the identified methodologies, the approach developed by Louie et al. (2015) and applied to an Australian database was selected for adaptation in the present study because it has verified reliability and does not rely on non-public linear programming for its application (Louie, Lei, & Rangan, 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 (see Supplementary File 1). Our adapted methodology used the same step-by-step logic, but was modified to account for the typical absence of information on total sugars. Two steps in the original methodology (steps 4 and 9) were 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 for packaged foods in 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 product's total sugar content when producers voluntarily make it available in the NIP. The methodology is organised in eight steps (steps 1–3 are objective and steps 4–8 are subjective), with estimation involving moving on to the next step when the criteria for the previous step are not met. 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 process showing the steps is presented in Fig. 1.

**Step 1.** *Assign 0 g of added sugars to foods without added sugar ingredients*. In this step, the ingredients are 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 voluntarily disclose this information, 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 sugar naturally found in milk, and instead should be assessed using the following steps. Exceptions are applied to dairy ingredients such as whey, milk protein concentrate, buttermilk, and cheese because they contain negligible amounts of naturally found sugars (Ohlsson et al., 2017). Fruit juices with minimal sugar content (e.g. lemon) are also not considered as

**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 |

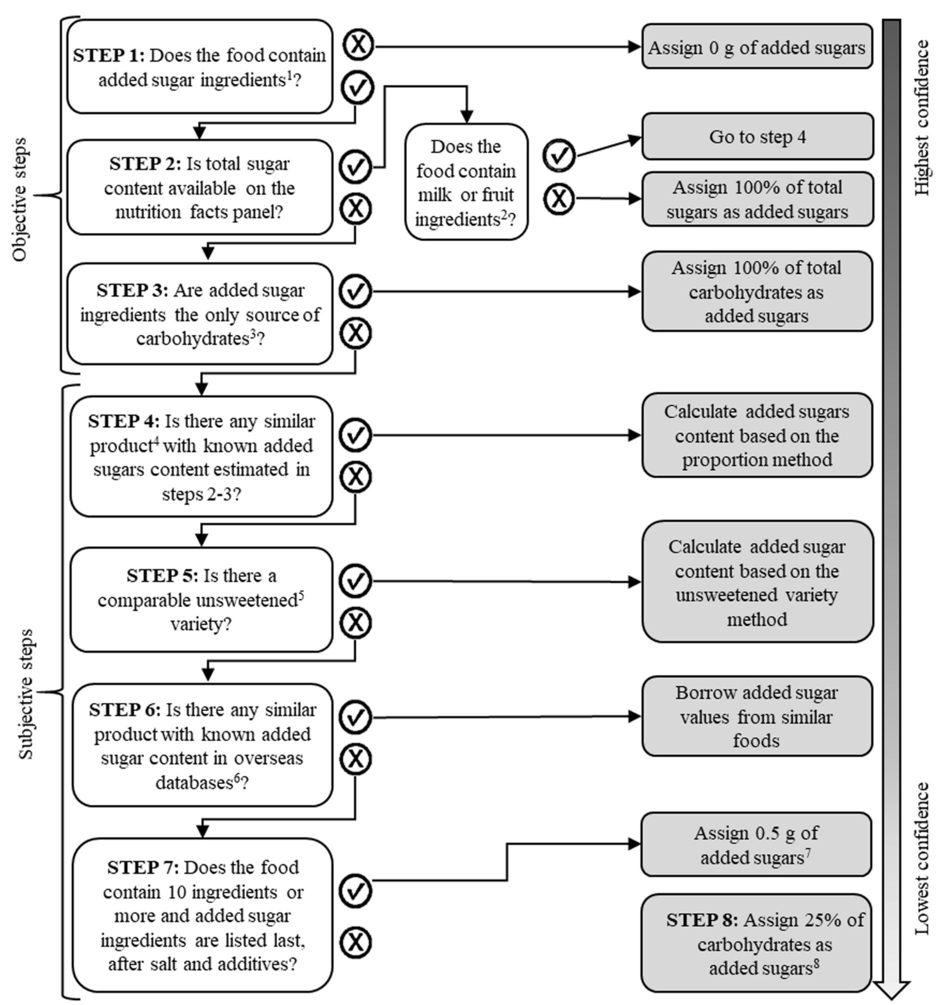


**Fig. 1.** Decision-making process for estimating added sugars in packaged foods.

**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).

sources of added sugars (United States Department of Agriculture, 2019). This step can be applied to some foods from the following food categories:

a) Regular soft drinks, sports drinks, flavoured water, and energy drinks;
b) Coffee and beverage mixes without milk (powdered or reconstituted in water);
c) Flan mix, dessert mix, and jelly;
d) Sauces;
e) Processed meats;
f) Sugars and syrups, toppings, candies, ice pops; and
g) 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 has no other carbohydrate (e.g. flour, starch, cereals, grains, roots, and vegetables) or naturally found sugar ingredients (milk, whole fruits, or 100% fruit juice), the total carbohydrate content is equal to the added sugar content. Vegetables containing less than 5% of carbohydrates on a wet basis are 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 can be applicable to most foods from the categories mentioned in step 2 when the total sugar content is not available.

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

$$\mathrm{ASt100g} = \left(\frac{\mathrm{ASs100g}}{\mathrm{CHOs100g}}\right) \times \mathrm{CHOt100g}$$

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 is 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 is particularly useful for dairy products; however, it is 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:

$$\mathrm{AS100g} = \left\{\frac{100 \times (\mathrm{CHOunsw100g} - \mathrm{CHOsw100g})}{(\mathrm{CHOunsw100g} - 100)}\right\}$$

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, other countries' food composition databases can be used, such as the database from the United States Department of Agriculture since it has information about added sugars (USDA, 2019).

**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 can be used includesavoury 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 that assumes 50% of total sugars are added sugars (Louie et al., 2015), here it is assumed that 50% of carbohydrates are total sugars and that added sugars correspond to 25% of carbohydrates. The following equation is used to estimate added sugars in this step:

$$AS_{100g} = \frac{\mathrm{CHO100g}}{4}$$

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 sold in a major supermarket in Brazil in 2013. The supermarket belongs to one of the 10 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 in the application of the most subjective steps, such as which product should be used as comparator in step 4, 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 (50th), and quartiles (25th and 75th) 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 (TGI) global food composition database that contains nutritional information and lists of ingredients for packaged foods 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 TGI US database provides values of added sugars reported on labels for 68,675 products since the mandate for added sugars labelling in the US was gazetted in 2016 (grace period ends in 2021) (FDA, 2016). While the reported values cannot be assumed to be precise because of a degree of tolerated variation in reporting (FDA, 2020), they are assumed to be reliable due to the Food and Drug Administration being tasked with assessing compliance with labelling regulations (FDA, 2015).

For analysis, the TGI US database was divided into the minor food categories applied in the Brazilian database. The food category of baby foods and formulas was not included in the analysis because data were 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 adapted methodology to the TGI 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 labelling regulations (FDA, 2016). Estimated added sugar values were then compared against the TGI 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 0.76 and 0.9, and greater than 0.90 indicate 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 estimated added sugar values and the TGI US database (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 packaged products in a Brazilian 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 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.

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 the 930 products reported in the TGI US database and the added sugar values estimated by the proposed methodology. Although values from both sources showed excellent agreement (ICC = 0.98), the difference between estimated and TGI US values was significant (mean difference = $0.14 \pm 1.57$, $p = 0.007$). Fig. 2 shows a Bland–Altman plot of differences between the TGI US database and estimated added sugar values. Only 87 (1.8%) of the 930 products had a difference in the added sugar values estimated by the adapted methodology and the TGI US database values outside the limits of agreement of 95%. Additional analyses by the methodological steps also showed good agreement results for all steps (ICC > 0.88). Further details on the comparison of added sugar content between the two sources by step can be found in Table 5 and Fig. 3.

## 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 are not mandatory on labels. An additional contribution is the systematic calculation of 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 using information readily available on most food labels. The methodology showed good validity, and estimated values had an excellent agreement with values available on labels from the database used for validity analyses. 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 sugar labelling. The estimated added sugar contents of some products (1.8%) were outside the 95% limits of agreement on the Bland-Altman analysis. While a small overall mean is

**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, 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 |

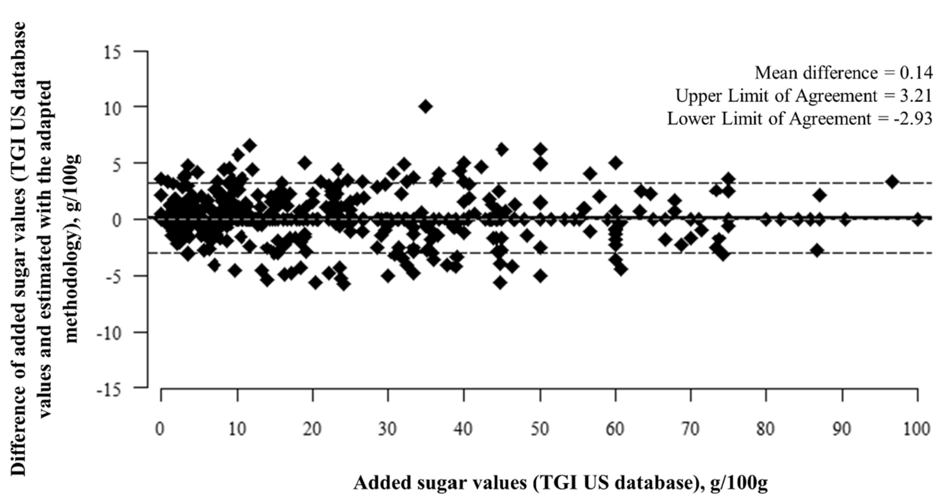


**Fig. 2.** Bland and Altman plot for the difference in added sugar values between The George Institute (TGI) US database (as declared on nutrition information panels) and the adapted methodology for 930 products. Solid black line: mean difference; black strip lines: 95% limits of agreement; grey strip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

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. In the case of Brazil, mandatory inclusion of total sugars should also be 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 restrictions on sugars in general (i.e., people with

**Table 5**
Agreement between added sugar values from The George Institute (TGI) US database and estimated added sugar values with the adapted methodology ($n$ = 930), presented by methodological step.

| Step | *N* | Mean ± SD | | Mean difference | Paired *t*-test *p*-value | ICC |
|---|---|---|---|---|---|---|
| | | **TGI US database value** | **Estimated value** | | | |
| 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.

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 are 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 a health halo effect applying to these products (Dallacker, Hertwig, & Mata, 2018).

According to the Brazilian Consumer Expenditure Survey (*Pesquisa de Orçamentos Familiares*) – a national survey of more than 30,000 individuals aged 10 + years, 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 the average consumption from a single person from the survey is 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 conditional recommendation of 5% of the energy intake (25 g based on a 2,000 calorie per day diet), as well as the strong recommendation of 10% of the energy intake (50 g based on a 2,000 calorie per 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 reactions and had only minor effects on their sensory perceptions of the product (Velázquez, Vidal, Varela, & Ares, 2020). Therefore, product reformulation has the potential to change the 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 of communicating the added sugar content of products on food labels, supporting people in their food choices (Alcantara, Ares, de Castro, & Deliza, 2020;

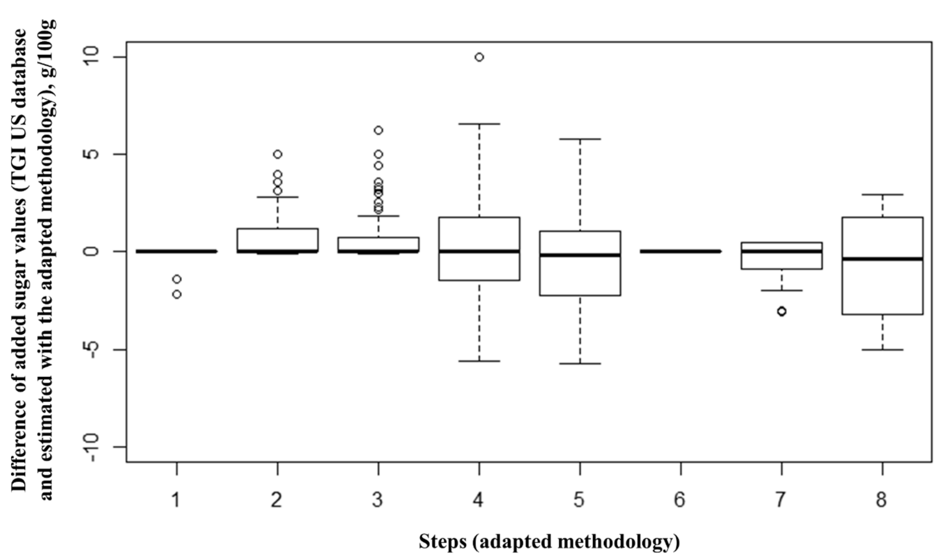


**Fig. 3.** Mean difference (solid lines) and standard deviation (dashed lines) between the The George Institute (TGI) US database's added sugar values and estimated added sugar values ($n$ = 930), presented by methodological step. Open circles represent outliers.

Scapin et al., 2021).

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 no other database with information about the use of added sugars in packaged foods sold in Brazil before 2018 has been identified, our data can serve as a baseline by which the effectiveness of this agreement, and the changes in the packaged 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 have been made, suggest a limited impact of voluntary arrangements on the sugar content of packaged foods. However, mandatory actions as the taxation of sugar-sweetened beverages seem to be effective to reduce the sugar content of these products (Scarborough et al., 2020). 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 governments, two main points can be raised. First, by estimating the added sugar content of packaged foods, it is possible to determine which categories of products should be targeted for food reformulation interventions. Second, an accessible way of estimating foods' added sugar content can contribute to sugar labelling discussions; the lack of effective methods of determining added sugars has been previously listed as a possible barrier to mandatory added sugars labelling (Pomeranz, 2012).

For the food industry, this methodology is likely to be useful for small manufacturers that cannot afford expensive laboratory analysis but want to estimate their products' added sugar contents. Finally, the methodology has the potential to assist health workers by providing a practical tool to estimate packaged foods' added sugar content to provide appropriate guidance to their patients.

### 4.2. Study limitations and future research

The current study has some limitations. As is the case for other methods of 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 overestimate the amount of added sugar by not considering some vegetables as carbohydrate sources. This compromise substantively increased the number 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 that 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 containing large numbers 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 found in different parts of the country. Future research could explore the foods available for sale in different regions and socioeconomic areas in Brazil.

## 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 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 foods containing added sugars, the median added sugar content was almost four times greater (18.2 g per 100 g or 100 ml) than from the overall data. The results can be used to monitor added sugar content in packaged foods and support public health interventions to reduce added sugar levels in target food categories.

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## CRediT authorship contribution statement

**Tailane Scapin:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Jimmy Chun Yu Louie:** Methodology, Writing - review & editing, Visualization. **Simone Pettigrew:** Supervision, Writing - review & editing. **Bruce Neal:** Conceptualization, Resources, Supervision, Writing - review & editing. **Vanessa Mello Rodrigues:** Methodology, Investigation, Writing - review & editing. **Ana Carolina Fernandes:** Methodology, Supervision, Writing - review & editing. **Greyce Luci Bernardo:** Investigation, Writing - review & editing. **Paula Lazzarin Uggioni:** Investigation, Writing - review & editing. **Rossana Pacheco da Costa Proença:** Conceptualization, Resources, Supervision, Writing - review & editing, Project administration.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2021.110329.

## References

Alcantara, M. d., Ares, G., de Castro, I. P. L., & Deliza, R. (2020). Gain vs. loss-framing for reducing sugar consumption: Insights from a choice experiment with six product categories. Food Research International, 136, 109458. https://doi.org/10.1016/j.foodres.2020.109458.

Acton, R. B., Vanderlee, L., Hobin, E. P., & Hammond, D. (2017). Added sugar in the packaged foods and beverages available at a major Canadian retailer in 2015: A descriptive analysis. *Canadian Medical Association Journal, 5*(1), E1–E6. https://doi.org/10.9778/cmajo.20160076.

Amoutzopoulos, B., Steer, T., Roberts, C., Cole, D., Collins, D., Yu, D., … Page, P. (2018). A disaggregation methodology to estimate intake of added sugars and free sugars: An illustration from the UK national diet and nutrition survey. *Nutrients, 10*(9). https://doi.org/10.3390/nu10091177.

Azaïs-Braesco, V., Sluik, D., Maillot, M., Kok, F., & Moreno, L. A. (2017). A review of total & added sugar intakes and dietary sources in Europe. *Nutrition Journal, 16*(1), 6. https://doi.org/10.1186/s12937-016-0225-2.

Australian National Health and Medical Research Council. (2013). *Eat for Health: Australian Dietary Guidelines*. Canberra, Australia: National Health and Medical Research Council.

Bernstein, J. T., Schermel, A., Mills, C. M., & L'Abbe, M. R. (2016). Total and free sugar content of Canadian pre-packaged foods and beverages. *Nutrients, 8*(9). https://doi.org/10.3390/nu8090582.

Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet, 1*(8476), 307–310.

Borjes, L. C., Cavalli, S. B., & Proença, R. P. C. (2010). Proposta de classificação de vegetais considerando características nutricionais, sensoriais e de técnicas de preparação. *Journal of Nutrition, 23*(4), 645–654. https://doi.org/10.1590/S1415-52732010000400014.

Bowman, S. A. (2017). Added sugars: Definition and estimation in the USDA food patterns equivalents databases. *Journal of Food Composition and Analysis, 64*, 64–67. https://doi.org/10.1016/j.jfca.2017.07.013.

Cummings, J. H., & Stephen, A. M. (2007). Carbohydrate terminology and classification. *European Journal of Clinical Nutrition, 61*(1), S5–S18. https://doi.org/10.1038/sj.ejcn.1602936.

Dallacker, M., Hertwig, R., & Mata, J. (2018). Parents' considerable underestimation of sugar and their child's risk of overweight. *International Journal of Obesity, 42*(5), 1097–1100. https://doi.org/10.1038/s41366-018-0021-5.

Dunford, E., & Neal, B. (2017). FoodSwitch and use of crowdsourcing to inform nutrient databases. *Journal of Food Composition and Analysis, 64*(1), 13–17. https://doi.org/10.1016/j.jfca.2017.07.022.

Fisberg, M., Kovalskys, I., Gomez, G., Rigotti, A., Sanabria, L. Y. C., Garcia, M. C. Y., … Previdelli, A. N. (2018). Total and added sugar intake: Assessment in eight Latin American countries. *Nutrients, 10*(4). https://doi.org/10.3390/nu10040389.

Food and Drug Administration. FDA. (2015). Guidance for industry: Nutrition labeling manual-a guide for developing and using data bases. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-guide-developing-and-using-data-bases-nutrition-labeling. Accessed 28 January 2021.

Food and Drug Administration. FDA. (2016) Changes to the Nutrition Facts Label. United States Department of Health and Human Services. https://www.fda.gov/food/food-labeling-nutrition/changes-nutrition-facts-label. Accessed 28 September 2020.

Food and Drug Administration. FDA. (2020). Food labeling: Revision of the nutrition and supplement facts labels: Guidance for industry. United States Department of Health and Human Services. https://www.fda.gov/media/134505/download. Accessed 15 February 2021.

Food and Organization of the United Nations. FAO. (2019). International network of food data systems (INFOODS). Latin American food composition tables.http://www.fao.org/infoods/infoods/tables-and-databases/en/. Accessed 28 September 2020.

Frantsve-Hawley, J., Bader, J. D., Welsh, J. A., & Wright, J. T. (2017). A systematic review of the association between consumption of sugar-containing beverages and excess weight gain among children under age 12. *Journal of Public Health Dentistry, 77*(Suppl 1), 43–66. https://doi.org/10.1111/jphd.12222.

Goldfein, K. R., & Slavin, J. L. (2015). *Why sugar is added to food: food science, 101*(14(5)), 644–656. https://doi.org/10.1111/1541-4337.12151.

Gortmaker, S. L., Swinburn, B. A., Levy, D., Carter, R., Mabry, P. L., Finegood, D. T., … Moodie, M. L. (2011). Changing the future of obesity: Science, policy, and action. *Lancet, 378*(9793), 838–847. https://doi.org/10.1016/S0140-6736(11)60815-5.

Hashem, K. M., He, F. J., Jenner, K. H., & MacGregor, G. A. (2016). Cross-sectional survey of the amount of free sugars and calories in carbonated sugar-sweetened beverages on sale in the UK. *British Medical Journal, 6*(11), Article e010874. https://doi.org/10.1136/bmjopen-2015-010874.

Instituto Brasileiro de Geografia e Estatística. IBGE. (2011). Pesquisa de Orçamentos Familiares, 2008-2009. Análise do Consumo Alimentar Pessoal no Brasil. [Brazilian Budgets Survey, 2008-2009. Analysis of individual food intake in Brazil]. https://biblioteca.ibge.gov.br/visualizacao/livros/liv50063.pdf. Accessed 28 September 2020.

International Sugar Organization. (2018). About sugar: the sugar market. The George Institute for Global Health. https://www.isosugar.org/sugarsector/sugar. Accessed 28 September 2020.

Jin, C., Lin, L., Li, C., Peng, Y., MacGregor, G. A., He, F., & Wang, H. (2019). The sugar and energy in non-carbonated sugar-sweetened beverages: A cross-sectional study. *BMC Public Health, 19*(1), 1141. https://doi.org/10.1186/s12889-019-7486-6.

Kibblewhite, R., Nettleton, A., McLean, R., Haszard, J., Fleming, E., Kruimer, D., & Te Morenga, L. (2017). Estimating free and added sugar intakes in New Zealand. *Nutrients, 9*(12), 1292. https://doi.org/10.3390/2Fnu9121292.

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155–163.

Lei, L., Rangan, A., Flood, V. M., & Louie, J. C. (2016). Dietary intake and food sources of added sugar in the Australian population. *British Journal of Nutrition, 115*(5), 868–877. https://doi.org/10.1017/s0007114515005255.

Louie, J. C., Moshtaghian, H., Boylan, S., Flood, V. M., Rangan, A. M., Barclay, A. W., … Gill, T. P. (2015). A systematic methodology to estimate added sugar content of foods. *European Journal of Clinical Nutrition, 69*(2), 154–161. https://doi.org/10.1038/ejcn.2014.256.

Louie, J. C., Moshtaghian, H., Rangan, A. M., Flood, V. M., & Gill, T. P. (2016). Intake and sources of added sugars among Australian children and adolescents. *European Journal of Clinical Nutrition, 55*(8), 2347–2355. https://doi.org/10.1007/s00394-015-1041-8.

Louie, J. C. Y., Lei, L., & Rangan, A. M. (2016). Reliability of a systematic methodology to estimate added sugar content of foods when applied to a recent Australian food composition database. *Journal of Food Composition and Analysis, 46*, 36–42. https://doi.org/10.1016/j.jfca.2015.11.002.

Louzada, M. L. C., Martins, A. P., Canella, D. S., Baraldi, L. G., Levy, R. B., Claro, R. M., … Monteiro, C. A. (2015). Ultra-processed foods and the nutritional dietary profile in Brazil. *Revista de Saúde Pública, 49*, 38. https://doi.org/10.1590/S0034-8910.2015049006132.

Luo, X., Arcot, J., Gill, T., Louie, J. C. Y., & Rangan, A. (2019). A review of food reformulation of baked products to reduce added sugar intake. *Trends in Food Science & Technology, 86*, 412–425. https://doi.org/10.1016/j.tifs.2019.02.051.

Mercosur. (2003). Resolución GMC n° 46/03. Reglamento técnico Mercosur sobre el rotulado nutricional de alimentos envasados (Resolution – GMC n. 46/03: Mercosur technical regulation on the nutritional labeling of packaged foods). Montevidéu, Uruguay. http://www.anmat.gov.ar/Legislacion/r_gmc_46-06.pdf. Acessed 28 May 2020. Acessed 29 September 2020.

Ministry of Health of Brazil. (2018). Termo de compromisso que firmam entre si a união, por intermédio do Ministério da Saúde, Agência Nacional de Vigilância Sanitária (ANVISA), Associação Brasileira das Indústrias da Alimentação (ABIA), Associação Brasileira das Indústrias de Refrigerantes e de Bebidas não Alcoólicas (ABIR), Associação Brasileira das Indústrias de Biscoitos, Massas Alimentícias e Pães & Bolos Industrializados (ABIMAPI) e Associação Brasileira de Laticínios (viva lácteos) para o estabelecimento de metas nacionais para a redução do teor de açúcares em alimentos industrializados no Brasil [Term of commitment signed by the Ministry of Health and Brazilian Food Industry Association to set national targets for reducing sugar content in processed foods in Brazil]. Brasília, DF: Minstério da Saúde. https://www.abia.org.br/vsn/tmp_2.aspx?id=386. Accessed 28 September 2020.

Ministry of Health of Brazil (2014). Secretariat of Health Care. Primary Health Care Department. Dietary Guidelines for the Brazilian population / Ministry of Health of Brazil, Secretariat of Health Care, Primary Health Care Department; Brasília. https://www.paho.org/hq/dmdocuments/2015/dietary-guides-brazil-eng.pdf. Accessed 28 January 2021.

Ministry of Health of the People's Republic of China. (2011). National Standards of People's Republic of China, National Food Safety Standard: standard for nutrition labelling of prepackaged foods. https://extranet.who.int/nutrition/gina/sites/default/files/CHN%202011%20Standard%20for%20Nutrition%20Labelling%20of%20Prepackaged%20Foods%20-%20Unofficial%20Translation.pdf. Accessed 28 September 2020.

Moynihan, P. J., & Kelly, S. A. (2014). Effect on caries of restricting sugars intake: Systematic review to inform WHO guidelines. *Journal of Dental Research., 93*(1), 8–18. https://doi.org/10.1177/0022034513508954.

Ng, S. W., Bricker, G., Li, K.-P., Yoon, E. F., Kang, J., & Westrich, B. (2015). Estimating added sugars in US consumer packaged goods: An application to beverages in 2007–08. *Journal of Food Composition and Analysis, 43*, 7–17. https://doi.org/10.1016/j.jfca.2015.04.004.

Ohlsson, J. A., Johansson, M., Hansson, H., Abrahamson, A., Byberg, L., Smedman, A., … Lundh, Å. (2017). Lactose, glucose and galactose content in milk, fermented milk and lactose-free milk products. *International Dairy Journal, 73*, 151–154. https://doi.org/10.1016/j.idairyj.2017.06.004.

Oliveira, D., Reis, F., Deliza, R., Rosenthal, A., Giménez, A., & Ares, G. (2016). Difference thresholds for added sugar in chocolate-flavoured milk: Recommendations for gradual sugar reduction. *Food Research International, 89*, 448–453. https://doi.org/10.1016/j.foodres.2016.08.019.

Pan American Health Organization. PAHO. (2016). Nutrient Profile Model. Washington, DC: PAHO. https://iris.paho.org/handle/10665.2/18621. Accessed 20 September 2020.

Pfinder, M., Heise, T. L., Hilton Boon, M., Pega, F., Fenton, C., Griebler, U., . . . Lhachimi, S. K. (2020). Taxation of unprocessed sugar or sugar-added foods for reducing their consumption and preventing obesity or other adverse health outcomes. Cochrane Database of Systematic Reviews, (4). https://doi.org/10.1002/14651858.CD012333.

Pomeranz, J. L. (2012). The bittersweet truth about sugar labeling regulations: They are achievable and overdue. *American Journal of Public Health, 102*(7), e14–e20.

Popkin, B. M., & Hawkes, C. (2016). Sweetening of the global diet, particularly beverages: Patterns, trends, and policy responses. *The Lancet Diabetes & Endocrinology, 4*(2), 174–186. https://doi.org/10.1016/S2213-8587(15)00419-2.

Probst, Y. C., Dengate, A., Jacobs, J., Louie, J. C. Y., & Dunford, E. K. (2017). The major types of added sugars and non-nutritive sweeteners in a sample of Australian packaged foods. *Public Health Nutrition, 20*(18), 3228–3233. https://doi.org/10.1017/s136898001700218x.

Public Health England. (2018). Sugar reduction and wider reformulation programme: report on progress towards the first 5% reduction and next steps. London: Public Health London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/709008/Sugar_reduction_progress_report.pdf. Accessed 28 September 2020.

Ruiz, E., Rodriguez, P., Valero, T., Avila, J. M., Aranceta-Bartrina, J., Gil, A., … Varela-Moreiras, G. (2017). Dietary intake of individual (free and intrinsic) sugars and food sources in the Spanish population: Findings from the ANIBES study. *Nutrients, 9*(3). https://doi.org/10.3390/nu9030275.

Scapin, T., Fernandes, A. C., dos Anjos, A., & Proença, R. P. C. (2018). Use of added sugars in packaged foods sold in Brazil. *Public Health Nutrition, 21*(18), 3328–3334. https://doi.org/10.1017/S1368980018002148.

Scapin, T., Fernandes, A. C., Curioni, Pettigrew, S., Neal, B., Coyle, D. H., …Proença, R. P. (2021). Influence of sugar label formats on consumer understanding and amount of sugar in food choices: a systematic review and meta-analyses'. Nutrition Reviews, nuaa108. https://doi.org/10.1093/nutrit/nuaa108.

Scapin, T., Fernandes, A. C., & Proença, R. P. C. (2017). Added sugars: Definitions, classifications, metabolism and health implications. *Journal of Nutrition, 30*, 663–677. https://doi.org/10.1590/1678-98652017000500011.

Scarborough, P., Adhikari, V., Harrington, R. A., Elhussein, A., Briggs, A., Rayner, M., … White, M. (2020). Impact of the announcement and implementation of the UK Soft Drinks Industry Levy on sugar content, price, product size and number of available soft drinks in the UK, 2015–19: A controlled interrupted time series analysis. *PLoS Medicine, 17*(2), Article e1003025. https://doi.org/10.1371/journal.pmed.1003025.

Sluik, D., van Lee, L., Engelen, A. I., & Feskens, E. J. (2016). Total, free, and added sugar consumption and adherence to guidelines: The Dutch National Food Consumption Survey 2007–2010. *Nutrients, 8*(2), 70. https://doi.org/10.3390/nu8020070.

Spiteri, M., & Soler, L. G. (2018). Food reformulation and nutritional quality of food consumption: An analysis based on households panel data in France. *European Journal of Clinical Nutrition, 72*(2), 228–235. https://doi.org/10.1038/s41430-017-0044-3.

Te Morenga, L. A., Howatson, A. J., Jones, R. M., & Mann, J. (2014). Dietary sugars and cardiometabolic risk: Systematic review and meta-analyses of randomised controlled trials of the effects on blood pressure and lipids. *American Journal of Clinical Nutrition, 100*(1), 65–79. https://doi.org/10.3945/ajcn.113.081521.

The George Institute for Global Health. (2017). FoodSwitch. https://www.georgeinstitute.org/projects/foodswitch. Accessed 28 September 2020.

U.S. Department of Agriculture and U.S. Department of Health and Human Services (2020). Dietary Guidelines for Americans, 2020-2025. 9th Edition. Washington, D.C. https://www.dietaryguidelines.gov/sites/default/files/2020-12/Dietary_Guidelines_for_Americans_2020-2025.pdf. Accessed 28 January 2021.

U.S. Department of Agriculture. USDA. (2019). Agricultural Research Service. FoodData Central, 2019. https://fdc.nal.usda.gov/index.html. Accessed 20 September 2020.

Velázquez, A. L., Vidal, L., Varela, P., & Ares, G. (2020). Cross-modal interactions as a strategy for sugar reduction in products targeted at children: Case study with vanilla milk desserts. *Food Research International, 130*, Article 108920. https://doi.org/10.1016/j.foodres.2019.108920.

Vin, K., Beziat, J., Seper, K., Wolf, A., Sidor, A., Chereches, R., … Ménard, C. (2019). Nutritional composition of the food supply: A comparison of soft drinks and breakfast cereals between three European countries based on labels. *European Journal of Clinical Nutrition, 74*, 17–27. https://doi.org/10.1038/s41430-019-0442-9.

World Health Organization. WHO. (2012). Food and Agricultural Organization of the United Nations. Codex Alimentarius: Guidelines on Nutrition Labelling. Rome: FAO. http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXG%2B2-1985%252FCXG_002e.pdf. Accessed 20 September 2020.

World Health Organization. WHO. (2015). Guideline: Sugars intake for adults and children. Geneva: WHO. https://www.who.int/publications/i/item/9789241549028. Accessed 20 September 2020.

Yeung, C. H. C., Gohil, P., Rangan, A. M., Flood, V. M., Arcot, J., Gill, T. P., & Louie, J. C. Y. (2017). Modelling of the impact of universal added sugar reduction through food reformulation. *Scientific Reports, 7*(1), 17392. https://doi.org/10.1038/s41598-017-17417-8.

Yeung, C. H. C., & Louie, J. C. Y. (2019). Methodology for the assessment of added/free sugar intake in epidemiological studies. *Current Opinion in Clinical Nutrition & Metabolic Care, 22*(4), 271–277. https://doi.org/10.1097/mco.0000000000000567.

Zupanic, N., Miklavec, K., Kusar, A., Zmitek, K., Fidler Mis, N., & Pravst, I. (2018). Total and free sugar content of pre-packaged foods and non-alcoholic beverages in Slovenia. *Nutrients, 10*(2). https://doi.org/10.3390/nu10020151.

Zupanic, N., Hribar, M., Fidler Mis, N., & Pravst, I. (2019). Free sugar content in pre-packaged products: Does voluntary product reformulation work in practice? *Nutrients, 11*(11). https://doi.org/10.3390/nu11112577.