Title: Development and validity testing of the Canadian Food Scoring System (CFSS), a nutrient profile model based on the recommendations of Canada's food guide 2019

Running title: CFSS development and validity testing

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Abbreviations:

CCHS, Canadian Community Health Survey

CFG, Canada's food guide

CFG-FCS, Canada's Food Guide Food Classification System

CFSS, Canadian Food Scoring System

CDG, Canada's Dietary Guidelines for Health Professionals and Policymakers

CNF, Canadian Nutrient File

HEFI, Healthy Eating Food Index

FOPL, Front-of-pack labelling

TRA, Table of Reference Amounts for Food

ABSTRACT

Canada's food guide (CFG) 2019 provides dietary guidance for all Canadians; however, there is no tool available to help Canadians easily determine how individual foods align with CFG. Therefore, the objectives of this study were (1) to develop a nutrient profile model, Canadian Food Scoring System (CFSS), to rank the healthfulness of individual foods according to the recommendations of CFG; and (2) to assess its validity. The CFSS was developed based on CFG, leveraging existing Canadian labelling regulations to set quantitative criteria to the CFG recommendations. The CFSS included three main steps: (1) classifying foods into the CFG-based food categories and assigning points based on the alignment with the recommendations; (2) deducting points based on the levels of saturated fat, sugars, and sodium using thresholds from Canadian front-of-pack labelling regulations; and (3) calculating the final score from the first two steps to classify foods into one of five categories: "very poor", "poor", "fair", "good", or "excellent" choice. Convergent validity was assessed by examining the alignment of the CFSS with Health Canada's CFG-Food Classification System using a national food composition database and the Healthy Eating Food Index-2019 using nationally representative dietary intake survey data. The CFSS showed strong correlation with the CFG-Food Classification System (ρ=0.782, $p<0.001$) and moderate correlation with the Healthy Eating Food Index-2019 (r=0.636, $p<0.001$), indicating good convergent validity both at the food and dietary level. The newly developed CFSS can assess the alignment of individual foods with CFG, which can be used to help Canadians more easily make healthy food choices.

Keywords: food guide, nutrient profile model, food quality, healthy eating

INTRODUCTION

Diet is one of the top modifiable risk factors for poor health globally and in Canada (World Health Organization 2018). In 2016, Health Canada introduced the *Healthy Eating Strategy* to improve the dietary intakes and the food environments of Canadians, which included updates to Canada's food guide (CFG), the publication of front-of-pack labelling (FOPL) regulations, and a suite of additional nutrition-related policy actions (Health Canada 2016). CFG is Canada's most up-to-date, evidence-based national food-based dietary guidelines to promote healthy eating and overall nutritional well-being, and reduce the risk of nutrition-related non-communicable diseases for all Canadians over 2 years of age (Health Canada 2019a).

As CFG 2019 provides a broad overview of a healthy dietary eating pattern rather than prescribing specific number of servings of different food groups, additional tools and regulations have been developed to promote and support the application of CFG in practice. Shortly after the publication of CFG, Canada's Dietary Guidelines for Health Professionals and Policymakers (CDG) was published to provide more detailed dietary guidelines and their scientific rationale (Health Canada 2019b). Dietary and behavioural assessment tools have also been developed to measure the alignment of dietary intakes (i.e., The Healthy Eating Food Index [HEFI]-2019 (Brassard et al. 2022b)) and eating practices (i.e., Canadian Eating Practices Screener (Wallace et al. 2023)) with CFG recommendations. Most notably, the HEFI-2019 was designed to assess the adherence of diets to CFG using comprehensive total day dietary intake data (Brassard et al. 2022b) and it has been shown to predict cardiovascular disease risk (Brassard et al. 2022a). However, the application of CFG to assess the healthfulness of individual

foods remains poorly studied and explored, especially for food categories with similar foods containing varying nutrient levels (e.g., high levels of sodium and fiber, or low levels of sugars but high levels of saturated fat) and multiple combinations of ingredients, some of which may not align with the recommendations of CFG (e.g., combination of whole grains and high sugar levels, or beans and high salt levels).

Nutrient profile models are interpretive tools that use food components and/or nutrient thresholds to evaluate the overall healthfulness of foods (World Health Organization. 2010). Nutrient profile models can be used as a tool to underpin health promotion and non-communicable disease prevention-focused policies and regulations, including health claims and FOPL (Labonte et al. 2018; Sacks et al. 2011; Santos et al. 2021); and can also be used to translate food-based dietary guidelines (Drewnowski 2017; Food and Agriculture Organization of the United Nations [FAO] 2019).

Previously, a binary CFG nutrient profile model was developed to assess the alignment of foods with CFG 2019 to classify foods as ‘aligned’ or ‘not aligned’ with CFG (Mulligan et al. 2021). While a binary system can provide a direct answer to a specific question (i.e., ‘Does this food align with CFG?’), it is challenging to make more granular distinctions between individual foods. In contrast, a scoring system enables higher discriminatory ability by classifying foods into multiple categories, allowing for a more comprehensive evaluation and finer distinction among similar foods for consumers and other users of CFG. Since the development of the binary CFG nutrient profiling model (Mulligan et al. 2021), additional resources (e.g., HEFI-2019 (Brassard et al. 2022b)) and labelling regulations (e.g., FOPL regulations (Government of Canada

2022a)) have been published to evaluate adherence to CFG and further support its implementation, warranting a revision to the binary system.

As part of the HEFI-2019 development process, Health Canada developed the CFG-Food Classification System (CFG-FCS) to evaluate the alignment of foods in the Canadian Nutrient File (CNF), a national generic food composition database, with CFG (Health Canada 2022c, 2022d). However, the CFG-FCS was specifically designed, tested, and recommended for use with only generic foods in the CNF, largely for fresh produce. The CFG-FCS is also not applicable to all food categories (e.g., toddler foods, pre-packaged mixed meals, and soup mixes) (Health Canada 2022c), limiting its broader applicability as a nutrient profile model that could be easily applied to any food composition databases. Therefore, the objective of this study was to develop a graded nutrient profile model, Canadian Food Scoring System (CFSS), using the recommendations of CFG and test its validity against other established CFG-derived tools for assessing foods (i.e., CFG-FCS) and diets (i.e., HEFI-2019).

METHODS

Canadian Food Scoring System (CFSS) Development

The CFSS was developed using the recommendations of CFG (Health Canada 2019a) and CDG (Health Canada 2019b). CFG and CDG only provide qualitative recommendations without any serving sizes, specified number of servings per food group (Health Canada 2019a, 2019b), and does not define any terms (e.g., plant-based protein foods, ‘high in’ nutrients-of-concern); therefore, regulatory definitions of foods and terms used in CFG and CDG were drawn from current Canadian labelling

92 regulations (e.g., FOPL regulations (Government of Canada 2022b)) and standards
93 (e.g., Health Canada's Table of Reference Amounts for Food (TRA) (Health Canada
94 2022b)). To develop a nutrient profile model that could be easily applied to evaluate any
95 food or beverage product with the recommendations of CFG, ingredient information was
96 used to categorize and assign points to food and beverage products, then nutrient
97 information was used to identify products that are 'high in' nutrients-of-concern.
98 Ultimately, the CFSS classified a product to a specific category based on how well it
99 aligned with the recommendations of CFG and CDG, particularly Guideline 1 and
100 Guideline 2 of CDG, within the current Canadian regulatory context.

101 **Figure 1** shows a flow diagram of the CFSS. All products were first divided into
102 two main categories, foods and beverages, as distinctions are consistently made
103 between these two product types in CFG. Foods, defined as solids and semi-solids,
104 were then further categorized as single- and multi-ingredient foods. Single-ingredient
105 foods were defined as foods with no additional ingredients (excluding antioxidants,
106 vitamins and minerals that are used to extend the shelf-life of intact foods) and that are
107 found in their natural state. Multi-ingredient foods were defined as foods with more than
108 one ingredient that may have undergone several processing or preparation steps,
109 altering them from their natural state and potentially contributing to excessive intakes of
110 nutrients-of-concern. Beverages were defined as liquids that are typically consumed by
111 drinking. Following this initial product categorization, there were three steps for scoring
112 products' alignment with the recommendations of CFG and CDG.

Step 1: CFG-based food categorization and point assignment

The first step was the categorization and assignment of points to products or ingredients of products according to the CFG-based food categories, which reflected Guideline 1 of CDG: "*Nutritious foods are the foundation for healthy eating* (Health Canada 2019b)." **Table 1** shows a summary of the CFG-based food categories with the associated CFG or CDG recommendations and definitions for each category. The CFG-based food categories and their respective point allocations were developed to categorize products or ingredients of products and assign points based on the alignment with the recommendations of CFG and CDG for each category.

Single-ingredient foods were divided into 5 main categories: Fruits & Vegetables, Whole grains, Protein foods, Fats & Oils, and Other Foods. Fruits & Vegetables consisted of all types of fruits and vegetables, including tropical fruits, fruits used as ingredients (e.g., lemon), dark green vegetables, and starchy vegetables. Whole grains consisted of grains that contain all three parts of the kernel – the bran, the endosperm, and the germ (Slavin 2004). Protein foods were divided into two categories: plant-based and animal-based protein foods. Plant-based protein foods included nuts, seeds, and legumes. Animal-based protein foods were further divided into 3 categories: (i) Lean meats (defined as any meat or poultry products that contain ≤10% total fat content and 'extra lean' ground meats defined as ≤10% total fat content (Canadian Food Inspection Agency 2019); (ii) Non-lean meats (any meat and poultry products that contain >10% total fat content); and (iii) Other animal-based protein foods without a 'lean' definition (e.g., eggs, fish, and other freshwater animals). Fats and oils were divided into two sub-categories based on their unsaturated fat content. Using the thresholds for the

unsaturated fat and blood cholesterol lowering health claim in Canada (Health Canada 2012), Fats and oils 'high in unsaturated fat' were defined as having >80% of unsaturated fat to total fat ratio, while fats and oils 'low in unsaturated fat' were defined as ≤80% of unsaturated fat to total fat. Other foods were defined as any foods that did not fit the criteria for the above 4 categories.

For multi-ingredient foods, their ingredients were similarly divided into five CFG-based food categories: Fruits & Vegetables, Whole grains, Protein (sub-divided into plant- vs. animal-based protein ingredients), Oils high in unsaturated fat, and Other ingredients. The first two ingredients were classified into their respective categories and assign the appropriate points based on the position of the ingredients in the Ingredient List. Since ingredients are listed in Canada based on their weight, using only the first two ingredients, which constitute the majority of the product (i.e., ≥60% of the food (Vergeer et al. 2020)), was deemed sufficient to estimate a product's alignment with the recommendations of CFG.

Beverages were divided into 3 main categories: Water, Protein beverages, and Other Beverages. Water was defined as any liquids without any added ingredients (excluding carbonation and natural flavour enhancers), and coffee and tea that do not have any additional nutritive properties. Protein beverages were divided into plant- vs. animal-based protein beverages. Plant-based protein beverages were defined as having ≥2.5 g of protein content per 100 mL of the beverage (Health Canada 2022d), and were further divided into two sub-categories: fortified and non-fortified. The minimum fortification thresholds of 125 mg of calcium and 0.85 µg of vitamin D per 100 mL of the beverage, as per the Interim Marketing Authorization for plant-based protein

beverages (Health Canada 2022a), were used to classify plant-based protein beverages. Animal-based protein beverages included dairy beverages (e.g., milk, drinkable yogurt, and kefir), and were divided into two sub-categories: lower fat (defined as ≤3.25% milk fat, consistent with the definition used in the CFG-FCS (Health Canada 2022d) and the HEFI-2019 (Brassard et al. 2022b)), and high fat (>3.25% milk fat). Other beverages consisted of all other non-alcoholic beverages, including fruit and vegetable juice, grain-based beverages, other plant-based beverages with insufficient protein content (i.e., <2.5 g of protein content per 100 mL of the beverage), and soda. Fruit and vegetable juice were included in the 'Other Beverages' category, as they are not considered part of the fruit and vegetable component category and are not listed as healthy beverages in CFG.

The points in the CFG-based food category system were determined through an iterative process to ensure that the results reflected the recommendations of CFG and CDG. The points ranged from 0 to 100, with higher points indicating more food components aligned with the recommendations of CFG. The points for single-ingredient foods and beverages were assigned to each food or beverage, while points for multi-ingredient foods were assigned to the first two ingredients and then summed for the overall point for the food. The maximum point for single-ingredient foods and beverages (i.e., 100) was higher than the maximum point for multi-ingredient foods (i.e., 90), as intact and less processed or prepared foods are recommended as a better choice according to CFG. For multi-ingredient foods, higher points were assigned to the first-listed ingredient than the second-listed ingredient, as the first-listed ingredient is the main ingredient of the food.

Step 2: Application of deduction proportion

The second step was determining the deduction proportion based on the levels of three nutrients-of-concern mentioned in CFG: saturated fat, sugars, and sodium. The second step essentially operationalized Guideline 2 of CDG: *"Processed or prepared foods and beverages that contribute to excess sodium, free sugars, or saturated fat undermine healthy eating and should not be consumed regularly (Health Canada 2019b)."* As Canada mandated FOPL regulations in 2022 to identify foods 'high in' saturated fat, total sugars, and/or sodium (Government of Canada 2022a), criteria for determining foods 'high in' nutrients-of-concern were derived from Canadian FOPL regulations. Although CFG recommends limiting consumption of free sugars, current Canadian labelling regulations mandate the declaration of total sugar levels on Nutrition Facts tables (Canadian Food Inspection Agency 2024) and FOPL regulations exempt products that would have high total sugar levels from naturally occurring sugars (e.g., fruits and starchy vegetables) (Government of Canada 2022a). Therefore, FOPL regulations were used as a proxy to identify foods 'high in' free sugars.

Briefly, Canadian FOPL regulations mandate that pre-packaged foods meeting and/or exceeding thresholds for three nutrients-of-concern (saturated fat, total sugars, and sodium) display a 'high in' nutrition symbol on the front of the food package. Foods may be exempted from displaying a nutrition symbol regardless of their nutrient levels, if it meets one of three criteria: (i) foods that have shown to have recognized health protection benefits (e.g., fruits and vegetables, unflavoured milk, fats high in unsaturated fat content, cheese high in calcium); (ii) foods that are exempted from carrying a Nutrition Facts table (e.g., single ingredient meats, foods sold in very small

packages); and (iii) foods that are known sources of the target nutrients (e.g., table sugar, honey, salt, butter). There are six thresholds as a percent daily value per reference amount for each nutrient-of-concern (shown in **Table S1**), depending on the age groups (1 to <4-year-old -year-old children; and children ≥4 years of age and adults) and reference amounts (foods with a small reference amount ≤30 g or 30 mL; foods with a reference amount >30 g or 30 mL; main dishes with a reference amount >170 g for 1 to <4-year-old children; and main dishes with a reference amount >200 g for children ≥4 years of age and adults). The deduction proportion system was developed based on the number of FOPL thresholds for nutrients-of-concern a product would meet and/or exceed (i.e., would display a 'high in' nutrition symbol); a greater deduction proportion was applied for an increasing number of 'high in' nutrients-of-concern (i.e., 50% deduction for foods meeting and/or exceeding 1 nutrient; 65% for 2 nutrients, and 80% for all 3 nutrients). Similar to the point system for Step 1, the point system for Step 2 was determined through an iterative process using examples provided in CFG and CDG to ensure foods were categorized foods consistently, as recommended by both CFG and CDG, while ensuring they would not conflict with existing labelling regulations.

Step 3: Final score calculation

In the third step, the final CFSS score was calculated using the Step 1 CFG-based food category points and applying the Step 2 FOPL deduction proportion, as shown in *Equation 1*.

$$Final\ score = \frac{[(Base\ point\ of\ 100 + Step\ 1\ point) \times Step\ 2\ deduction]}{2} \qquad (Equation\ 1)$$

The base point of 100 was assigned to all foods, as foods may have other benefits beyond their energy and nutritive properties; and CFG recognizes the benefits of enjoying food and recommends "*enjoying your food is part of healthy eating*" (Health Canada 2019a). The scoring system was converted to a maximum score of 100 by dividing the aggregated score by 2, resulting in a possible final CFSS score ranging from 10-100 points with a higher score indicating better alignment with CFG. A five-level CFSS category system was established based on the final score, with a range of 20 points for each category, except for the "excellent" category. All food and beverage products were categorized into one of five CFSS categories: "very poor (CFSS score range: 10-29)," "poor (30-49)," "fair (50-69)," "good (70-89)," and "excellent (90-100)" choice. To be classified as an "excellent" choice, a food or beverage product needed to achieve the final CFSS score between 90 and 100 to ensure that only those products that most closely adhere to the CFG's highest standards are recognized as "excellent" choices.

Table 2 shows examples of how the CFSS can be applied to foods.

Food Level Validity Testing

Food Composition Data – Canadian Nutrient File (CNF)

The generic food composition database, Canadian Nutrient File (CNF) 2015, was used to assess the discriminant and the convergent validity of the CFSS. The CNF 2015 is a database of foods commonly consumed by Canadians (n=6,904), including fresh and pre-packaged foods available on the Canadian market and homemade recipes, with data available for up to 152 nutrients (Health Canada 2015b). The nutrient

information is derived from the United States Department of Agriculture National Nutrient Database for Standard Reference with modifications for Canadian levels of fortification and regulatory standards, as necessary; Canadian-specific foods; and other Canadian commodity data from some brand name foods (Health Canada 2015b). The nutrient composition in the CNF foods reflects the average nutrient composition of foods derived from brands of similar products or varieties of foods from various producers (Health Canada 2015b). All products were categorized into Health Canada's TRA categories, representing the amount of food typically consumed in one sitting, which serves as the basis for determining serving sizes in the Nutrition Facts table (Health Canada 2022b). Health Canada's TRA categories consist of 24 major and 188 minor categories. To apply the CFSS to generic foods in the CNF, first and second ingredients of foods were estimated based on the food descriptions provided in the CNF by two experienced dietitians/nutrition research assistants. Out of 6,904 foods in the CNF database, homemade recipes (e.g., homemade lasagna; n=3,169) and miscellaneous products (e.g., alcoholic beverages, nutritional supplements; n=59) were excluded from the analysis, resulting in a final analytic sample size of 3,676 foods and beverage products.

Food Level – CFSS Component Assessment

To ensure that the CFSS captured the recommendations of CFG in a balanced manner, the association between the final CFSS scores and the points from each step were evaluated using Pearson's correlations. We hypothesized that there would be

strong and similar correlations ($r \geq 0.60$) between the final CFSS scores and scores from each CFSS step, as the two CFSS steps are the only contributors to the final score.

Food Level – Discriminant Validity

Discriminant validity evaluates a nutrient profile model's ability to differentiate the quality of different foods that are expected to be different (e.g., fresh vegetables vs. salty chips; regular chips vs. less salty chips) as it should discriminate the food quality between and within food categories (Santos et al. 2021; Scarborough and Rayner 2014). Therefore, the median and the interquartile range (IQR) of the CFSS scores for foods and the proportion of foods categorized according to the CFSS categories were assessed by TRA categories. We hypothesized that TRA categories less aligned with CFG (e.g., Desserts, Dessert Toppings) would have lower median CFSS scores while TRA food categories more aligned with CFG (e.g., Legumes, Vegetables) would have higher scores.

Food Level – Convergent Validity

Convergent validity refers to how well a nutrient profile model correlates with another nutrient profile model that shares similar objectives (Poon et al. 2018; Santos et al. 2021). Health Canada's CFG-FCS, which assesses the alignment of generic foods in the CNF according to CFG (Health Canada 2022d), was used to examine the convergent validity of the CFSS. According to the CFG-FCS, Tier 1 represents products encouraged by CFG (i.e., "most aligned"); Tier 3 represents products that should not be

consumed regularly (i.e., “least aligned”); and Tier 2 represents products that do not meet requirements for Tier 1 or Tier 3 (i.e., “somewhat aligned”) (Health Canada 2022d). The CFG-FCS excludes foods for infants and toddlers (n=99), foods with missing information for classification (n=21) and other miscellaneous foods (n=309), resulting in a sample size of 3,247 generic food and beverage products available in the CNF for analysis. The agreement between the CFSS and the CFG-FCS scores was assessed using Spearman’s rho (ρ). Poor agreement was defined as no to low correlation ($\rho<0.40$), while good agreement was defined as moderate to strong correlation ($\rho\geq0.40$) (Myers et al. 2010).

Diet Level Validity Testing

Although nutrient profile models are applied to individual foods rather than diets, healthier changes at the food level have been shown to have the potential to improve overall diet quality (Scarborough et al. 2007). Therefore, we evaluated how well the CFSS can characterize diet quality with respect to CFG by converting the food-based CFG into a dietary index system and comparing it to Health Canada’s established diet quality assessment tool, the HEFI-2019.

Dietary Intake Data – Canadian Community Health Survey 2015

The Canadian Community Health Survey (CCHS)-Nutrition 2015 Public Use Microdata File (Statistics Canada 2019) was used for this analysis. The CCHS-Nutrition is a nationally representative cross-sectional survey conducted in 2015, which includes a general health questionnaire and a 24-hour dietary recall survey data from over

20,000 Canadians (Health Canada 2017). The CCHS-Nutrition 2015 includes data from individuals over 1 year of age living in private dwellings in the Canadian provinces, and excludes data from full-time members of the Canadian Forces or those who live in the Territories, on reserves and other Indigenous settlements, in some remote areas, or institutions (e.g., prisons or care facilities) (Health Canada 2017). The first day dietary recall data from adults (≥19 y) was used for the analysis. Data from respondents <19-year-olds (n=6,568), underweight (body mass index [BMI] <18.5 kg/m^2; n=230), lactating (n=183), or did not report any food consumption (n=11) were excluded from the analysis, resulting in a final sample size of 13,495. Detailed characteristics of the respondents used in the analysis can be found elsewhere (Lee et al. 2023a).

Conversion to a Dietary Index System

To compare the CFSS against a validated CFG dietary index system (i.e., HEFI-2019), the CFSS scoring system was converted into a dietary index system. The final CFSS score for each food was converted into a scale of 0-100 (from 10-100) to standardize the dietary index score (*Equation 2*). The adjusted CFSS scores for each food and beverage product were summed for each participant, weighted by the proportion of the reference amount (as per Health Canada's TRA (Health Canada 2022b)) contributed by each food to get an individual dietary index system (*Equation 3)*. Contrary to previous dietary index systems using energy adjustment to develop dietary index scores (Lee et al. 2023b; Paper et al. 2023), the individual CFSS food scores were adjusted for the reference amounts, as the HEFI-2019 (Brassard et al. 2022b) and FOPL (Government of Canada 2022a) both use the reference amounts for foods in TRA.

$$\textbf{\textit{Adjusted CFSS score}} = \frac{CFSS\ score - 10}{90} \times 100 \qquad \textit{(Equation 2)}$$

$$\textbf{\textit{CFSS dietary index score}} = \frac{\sum_{i=1}^{n}(Adjusted\ CFSS\ scorei) \times RAi}{\sum_{i=1}^{n} RAi} \qquad \textit{(Equation 3)}$$

where CFSS score is the assigned score based on the CFSS scoring system for each individual food or beverage consumed, and RA_i is the reference amount for that food or beverage product (as per Health Canada's TRA (Health Canada 2022b)).

Healthy Eating Food Index (HEFI)– 2019

The HEFI-2019 is a dietary index system developed to assess the alignment of daily total diets with CFG (Brassard et al. 2022b). The HEFI-2019 uses 10 components related to key recommendations in CFG (i.e., Vegetables and fruits, Whole-grain foods, Grain foods ratio, Protein foods, Plant-based protein foods, Beverages, Fatty acids ratio, Saturated fats, Free sugars, and Sodium) to measure the dietary adherence to CFG (Brassard et al. 2022b). The HEFI-2019 scores range from 0 to 80, which was converted to be on a scale of 0 ("least aligned") – 100 ("most aligned") to standardize it to the CFSS dietary index system.

Diet Level – Convergent Validity

Since the HEFI-2019 is a composite measure of overall dietary alignment with CFG, good agreement between the CFSS dietary index system and the HEFI-2019 would show the validity of the CFSS for quantifying the recommendations of CFG, as previously shown (Fulgoni et al. 2009). Therefore, the HEFI-2019 was used as the reference standard and weighted Pearson's correlation coefficients were used to assess the agreement between the CFSS dietary index system and the HEFI-2019. Poor

agreement was defined as low to negligible correlation ($r<0.40$), while good agreement was defined as moderate to strong correlation ($r\geq0.40$) (Schober et al. 2018). To further evaluate the agreement between pairs of dietary index scores, total scores from each dietary index system were divided into quintiles, and the agreement of the sample falling into quintile categories for pairs of dietary indices was examined using weighted κ statistic (95 % CI), as follows: 0.01–0.20 'slight'; 0.21–0.40 'fair'; 0.41–0.60 'moderate'; 0.61–0.80 'substantial'; and 0.81–0.99 'near perfect' (Viera and Garrett 2005). The level of agreement between the CFSS dietary index system and the HEFI-2019 was quantified using the proportions of concordant pairs (defined as samples falling into a given quintile group in one dietary index system also falling into the same or ±1 quintile group in the other dietary index system) and discordant pairs (defined as samples falling into a given quintile group in one dietary index system but falling into ±2 quintile groups or greater in the other dietary index system) (Liese et al. 2015). We hypothesized good agreement between the CFSS and the HEFI-2019 using Pearson's correlations, and moderate agreement using κ statistic due to mathematically different approaches taken to compute these dietary index scores.

All statistical analyses for this study were performed using SAS, and a p-value <0.05 was considered significant.

RESULTS

Food Level Validity Testing

Food Level – CFSS Component Testing

There was a strong correlation between the final CFSS scores and points from Step 1 ($r=0.849$, $p<0.001$) and Step 2 ($r=0.851$, $p<0.001$), demonstrating strong and similar strengths that each step has on the final CFSS score.

Food Level – Discriminant Validity

Figure 2 shows the proportion of food and beverage products from the CNF classified according to the CFSS by TRA major category. Overall, 32.7% of products (n=1,202/3,676) were classified as an "excellent" choice, 24.1% (n=885/3,676) as "good", 13.9% (n=510/3,676) as "fair", 9.3% (n=342/3,676) as "poor", and 20.0% (n=737/3,676) as "very poor". Food categories with a high proportion (≥80%) of products classified as an "excellent" or "very good" choice were: Eggs & Substitutes; Nuts & Seeds; Vegetables; Legumes; Fish, Seafood & Substitutes; and Potatoes. Food categories with a high proportion of (≥80%) a "poor" or "very poor" choice were: Soups; Combination Dishes; Dessert Toppings & Fillings; and Desserts.

Figure S1 shows a box and whisker plot with median, IQR, and percentiles of the CFSS scores for food and beverage products overall and by TRA major category. Overall, the median CFSS score was 85 [IQR: 43, 93]. Food categories with the highest median CFSS scores were Vegetables (100 [100, 100]; n=385), Potatoes (100 [85,

100]; n=27), and Miscellaneous (100 [50, 100]; n=80), while food categories with the lowest median CFSS scores were Combination Dishes (25 [18, 26]; n=13), Desserts (25 [18, 26]; n=70), Dessert Toppings & Fillings (25 [25, 25]; n=8), Soups (25 [25, 28]; n=194), and Sugars & Sweets (25 [25, 50]; n=102).

Figure 2 and **Figure S1** showed a wide variability within and between food categories, demonstrating good discriminant validity of the CFSS.

Food Level – Convergent Validity

Figure S2 shows the overall proportion of products presented by the CFSS categories and the CFG-FCS tiers and **Figure 3** shows the proportion of products in the CFSS categories presented by the CFG-FCS tiers. Overall, 36.9% (n=1,199/3,247) of products were classified as Tier 1 (“most aligned” with CFG), 20.7% (n=673/3,247) as Tier 2 (“somewhat aligned” with CFG), and 42.3% (n=1,375/3,247) as Tier 3 (“least aligned” with CFG). There was a strong correlation between the CFSS and the CFG-FCS (ρ=0.782, $p<0.001$), indicating good alignment between the two systems.

Among products in CFG-FCS Tier 1, 98.1% (n=1,176/1,199) were rated as an “excellent” or “good” choice and 1.9% (n=23/1,199) were rated as a “fair” choice. Among foods in CFG-FCS Tier 2, 71.3% (n=480/673) were rated as an “excellent” or “good” choice, 21.1% (n=142/673) were rated as a “fair” choice, and 7.6% (n=51/673) of were rated as a “poor” or “very poor” choice. Among products in CFG-FCS Tier 3 (“least aligned” with CFG), 21.4% (n=294/1,375) were rated as an “excellent” or “good” choice, 19.2% (n=264/1,375) were rated as a “fair” choice, and 59.4% (n=817/1,375) were rated as a “poor” or “very poor” choice. Although there were no products in CFG-FCS Tier 1

rated as a “poor” or “very poor” choice according to the CFSS, some foods in the CFG-FCS Tier 3 were rated as a “good” or “excellent” choice. These products included oil-roasted nuts, trail mix, poultry and seafood with skin, and fortified, slightly sweetened soy beverages (i.e., total sugar levels below FOPL thresholds).

Diet Level – Convergent Validity

The mean±SD dietary index scores for Canadians as evaluated by the CFSS dietary index system and the HEFI-2019 were 55.9±8.5 and 54.4±14.7 (out of 100), respectively. **Table S2** shows the agreement between quintile combinations of the CFSS dietary index system and the HEFI-2019. The CFSS dietary index system showed moderate agreement with the HEFI-2019 ($r=0.636$, $p<0.001$; and $\kappa=0.46$ [0.45, 0.47]) with 17.9% of the total sample identified as discordant pairs (i.e., samples falling into a given quintile group in one dietary index system, but falling into ±2 quintile groups or greater in the other dietary index system), indicating the CFSS’ ability to characterize diet quality aligned with the recommendations of CFG.

DISCUSSION

We developed the CFSS, a graded nutrient profile model that ranks individual product’s alignment with the recommendations of CFG in the context of existing Canadian labelling regulations, and tested its validity at both the food and dietary level. The CFSS showed good discriminatory ability to differentiate the healthfulness of food and beverage products between and within food categories. The CFSS also showed good convergent validity both at the food and dietary level with good agreement with the

449 CFG-FCS and the HEFI-2019, respectively, tools developed by or with Health Canada
450 to assess food and dietary alignment with CFG.

451 The CFSS showed good discriminatory ability between and within food categories
452 and good convergent validity, highlighting its potential as an effective nutrient profile
453 model that can differentiate the healthfulness of foods beyond those found in the CNF.
454 Consistent with other established nutrient profile models (e.g., Food Standard
455 Australia/New Zealand Nutrient Profiling Scoring Criterion), a wide range of CFSS
456 scores was seen in the food categories (e.g., Bakery Products, Beverages, Cereals and
457 Grains, and Dairy Products) with significant heterogeneity in the nutritional quality of
458 pre-packaged products (Poon et al. 2018)). Despite using an alternative approach to
459 translate the recommendations of CFG, the CFSS showed good agreement with the
460 CFG-FCS, demonstrating its ability to well capture the recommendations of CFG.
461 Considering the CFG-FCS was only designed for use with the CNF, which does not
462 capture the nutritional variability of pre-packaged food and beverage products in the
463 Canadian food supply, our findings support that the CFSS, with its 5-level categorization
464 system, showed promising results as a versatile nutrient profile model for branded foods.
465 The CFSS can also be used to support a diverse range of CFG users, including
466 researchers, health professionals, public health officials, and the general public.

467 Although we saw good agreement between the CFSS and the CFG-FCS, there
468 were some differences between the two systems, despite both systems having the
469 same underlying aim of evaluating the alignment of foods with CFG. In particular, about
470 20% of food and beverage products classified as “least aligned” under the CFG-FCS
471 were identified as a “good” or “excellent” choice using the CFSS. A closer look into the

discrepancies revealed that some processed or prepared foods that may have multiple ingredients (e.g., oil-roasted nuts, trail mixes) or food components naturally high in nutrients-of-concern (e.g., skin on poultry or seafood) may not be appropriately captured using the CFG-FCS. For example, some categories, such as snack foods, condiments, and processed meats can only be classified as Tier 2 or Tier 3 in the CFG-FCS, regardless of their food components that may align with CFG (e.g., fruits and vegetables, plant-based protein, and whole grains). However, recognizing the rapidly evolving food supply and the constant introduction of novel food and beverage products that may align with the recommendations of CFG to a varying degree, the CFSS leveraged existing regulatory definitions to be able to make finer distinctions on the healthfulness of products within food categories. Interestingly, the CFG-FCS showed more leniency towards some food categories compared to the CFSS. For instance, the CFG-FCS treats 100% whole grain foods, foods with whole grains and whole wheat as the first ingredient equally, with an opportunity to be categorized as Tier 1 (Health Canada 2022d). However, following the CFG recommendation on the grains category to "*Choose whole grain foods*" (Health Canada 2019a), the CFSS allocated points only to single and multi-ingredient foods that have whole grains in the first two ingredients. Part of the discrepancies are related to the qualitative nature of terms used in CFG and CDG, which do not provide clear definitions on criteria for the terms used (e.g., whole grain foods). CFG is an important public health policy tool that sets guidance for other public health programs and initiatives (e.g., school food program and guidelines for meals served in long-term care homes), and therefore, having the recommendations of CFG clearly operationalized and detailed for wide applicability is needed. Meanwhile, the

CFSS, with its good alignment with the CFG-FCS shows great potential for its broader use, including its application to different food composition databases and the development of consumer-friendly tools; however, it does not provide guidance on amounts of these foods.

Interestingly, despite over 40% of infant and toddler foods for children under the age of 4 being classified as a “poor” or “very poor” choice using the CFSS, the CFG-FCS excluded these foods in their categorization. This is an important and unfortunate gap, as similar to our findings, based on proposed FOPL regulations, about 45% of infant and toddler foods in the Canadian pre-packaged food supply in 2017, would have to display a front-of-pack ‘high in’ nutrition symbol for meeting and/or exceeding one or more of the nutrients-of-concern, unless reformulated, with nearly all those products (97%, n=100/103) meeting and/or exceeding thresholds for total sugars (Mulligan et al. 2022). Limiting free and added sugar intakes for children, particularly for those under the age of 2, are critical in establishing healthy eating behaviours and health outcomes later in life (Health Canada 2015a; World Health Organization 2015). The exclusion of these foods in the CFG-FCS underscores one of its main limitations, demonstrating the need for the CFSS to evaluate the healthfulness of a wide range of foods.

Despite the inherent mathematical differences in comparing a food-based nutrient profile model (i.e., CFSS) with a diet-based dietary index system (i.e., HEFI-2019), moderate agreement was observed between the CFSS and the HEFI-2019. Our findings corroborate a large body of research supporting the use of evidence-based, validated nutrient profile models as a tool to shape food and nutrition standards, guidelines, and policies, to improve diets, and ultimately, population health (Labonte et

al. 2018; Sacks et al. 2011; Santos et al. 2021; Scarborough and Rayner 2014; World Health Organization. 2010). Previous studies have shown nutrient profile models designed to promoting health (e.g., Nutri-score from France and Ofcom from the UK) have positive associations with risk of cardiovascular diseases (Adriouch et al. 2017; Adriouch et al. 2020), cancer (Deschasaux et al. 2018; Donnenfeld et al. 2015), and overweight and obesity (Julia et al. 2015). Food-level nutrient profile models provide additional advantages as interpretive tools, where they can be easily translated and applied as public health tools (e.g., as front-of-pack labels/symbols; underpin food and nutrition policies and programs) (Labonte et al. 2018; Sacks et al. 2011; Scarborough and Rayner 2014). In the absence of a 'gold standard' nutrient profile model, we successfully leveraged publicly available data (i.e., CCHS) and a validated dietary assessment tool (i.e., HEFI-2019) to examine the convergent validity of the CFSS at the dietary level, further highlighting the potential of the CFSS to promote healthy eating among Canadians.

Although we conducted extensive validation testing to examine the ability of the newly developed CFSS to quantitatively capture the recommendations of CFG using established labelling regulations and standards, there are a few limitations to note. First, the CFSS was developed and tested using the CNF, a generic food composition database, with an estimated ingredient list to validate the model against Health Canada's published tool (i.e., CFG-FCS). The high proportion of fresh, unpackaged products in the CNF contributed to the high overall CFSS scores, which may not necessarily reflect the current food supply, particularly the pre-packaged food supply, as the CNF does not capture the nutritional variability of pre-packaged food and beverage

541 products. In fact, earlier research from our group found that each packaged product in
542 the CNF represents about nine different unique products available in the pre-packaged
543 food supply (Bernstein et al. 2023). Applying the CFSS to a branded food composition
544 database with ingredient information is needed to better characterize the quality of the
545 pre-packaged food supply. Second, we leveraged labelling regulations and standards to
546 interpret subjective terms used in CFG and CDG. However, regulations and standards
547 may change and evolve over time with emerging scientific evidence and stakeholder
548 input, requiring regular updates. For example, Canada uses a protein rating system
549 based on the protein efficiency ratio and protein digestibility corrected amino acid
550 scores (temporarily permitted since 2020) to assess protein quality (Health Canada
551 2023b). However, due to the lack of available protein rating information for foods,
552 protein content was used to identify dairy alternatives (e.g., ≥2.5 g of protein content per
553 100 mL of the beverage) as per the CFG-FCS (Health Canada 2022d). Regular updates
554 to the CFSS will be needed to ensure the CFSS remains consistent with labelling
555 regulations and standards.

556 In conclusion, we successfully developed the CFSS, a nutrient profile model, that
557 assesses food and beverage products' alignment with the recommendations of CFG
558 2019, the most up-to-date national dietary guidelines for Canadians. The CFSS showed
559 good discriminatory ability to differentiate the healthfulness of products within and
560 between food categories, and well captured individual products' alignment with the
561 recommendations of CFG. The CFSS can be used to easily translate dietary
562 recommendations of CFG onto individual food and beverage products to support a

563 variety of CFG users, including policymakers, researchers, health professionals, and the
564 public.

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Data Availability Statement:

The Canadian Nutrient File (CNF) dataset is available online from Health Canada: https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/nutrient-data/canadian-nutrient-file-about-us.html. The Canadian Community Health Survey

(CCHS)-Nutrition 2015 Public Use Microdata File is available from Statistics Canada: https://www150.statcan.gc.ca/n1/en/catalogue/82M0024X2018001.

Supplementary Material:

Table S1. Nutrient thresholds which would determine the display of a 'high in' nutrition symbol according to Canadian front-of-pack labelling regulations.

Table S2. Agreement between quintile combinations of the Canadian Food Scoring System (CFSS) dietary index system and the Healthy Eating Food Index (HEFI-2019).

Figure S1. Box and whisker plot of the Canadian Food Scoring System (CFSS) scores of generic food and beverage products overall and by Table of Reference Amounts for Food (TRA) category.

Figure S2. Proportion of food and beverage products classified using the Canadian Food Scoring System (CFSS) and the Canada's Food Guide-Food Classification System (CFG-FCS).

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Table 1. Descriptions and the point system of the Canada's food guide-based food categories used in the Canadian Food Scoring System.

CFG-based Food Categories	CFG or CDG Recommendations	Definition	TRA categories*	Points
Single-ingredient foods				
Fruits & Vegetables	"Have plenty of vegetables and fruits."	All types of fruits and vegetables.	J (excluding J.11 and J.12), P, Q, V (excluding V.7)	100
Whole grains	"Choose whole grain foods."	Grains that contain all three parts of the kernel (bran, endosperm, and germ) (Slavin 2004).	C	100
Protein foods	"Eat protein foods."			
Plant-based protein foods	"Among protein foods, consume plant-based more often." "Protein foods include legumes, nuts, seeds, […]"	Include legumes, nuts, and seeds.	K and O	100
Animal-based protein foods				
Lean meats	"Protein foods include […] poultry, lean red meat including wild game, […]."	Any meat or poultry products that contain ≤10% total fat (including ground meat, which is defined as 'extra lean' (Canadian Food Inspection Agency 2019).	L	85
Non-lean meats		Meat and poultry products that contain >10% total fat.	L	75
Other animal-based protein foods	"Protein foods include […] fish, shellfish, eggs, […]."	All eggs, fish, and other freshwater animals.	D (excluding D.6, D.9, D.11, D.12, D.13), G, I	85

CFG-based Food Categories	CFG or CDG Recommendations	Definition	TRA categories*	Points
Fats & Oils			H	
High in unsaturated fat	"Foods that contain mostly unsaturated fat should replace foods that contain mostly saturated fat."	Fats and oils with >80% unsaturated fat to total fat ratio as per the thresholds used for unsaturated fat and blood cholesterol lowering claim (Health Canada 2012).		50
Low in unsaturated fat		Fats and oils with ≤80% unsaturated fat to total fat ratio.		0
Other foods		All other foods not meeting any of the single-ingredient food categories listed above.	A, E, F, M, N, R, S, T, U, W	0
Multi-ingredient foods				
Fruit & vegetable ingredients	"Have plenty of vegetables and fruits."	Ingredients identified as single-ingredient fruit and vegetables foods in TRA categories J, P, Q, and V. Concentrated sources of fruits were excluded as they are functional substitutes for sweetening agents (Health Canada 2023a).		70; 20†
Whole grain ingredients	"Choose whole grain foods."	Ingredients identified as single-ingredient whole grain foods in TRA category C.		70; 20†
Protein ingredients	"Eat protein foods."			
Plant-based protein ingredients		Ingredients identified as single ingredient plant-based protein foods in TRA categories K and O		70; 20†
Animal-based protein ingredients		Ingredients identified as single-ingredient animal-based protein foods in TRA categories D, G, I, and L; 'lean' assessment could not be applied as the total fat content may differ based on other ingredients.		50; 10†
Oils high in unsaturated fat	"Foods that contain mostly unsaturated fat should replace foods that contain mostly saturated fat."	Ingredients identified as single ingredient oils high in unsaturated fat (i.e., unsaturated fat to total fat ratio >80%) in TRA category H.		30; 0†
Other ingredients		All other ingredients not meeting any of the multi-ingredient food categories listed above.		0; 0†

CFG-based Food Categories	CFG or CDG Recommendations	Definition	TRA categories*	Points
Beverages				
Water	"Make water your drink of choice."	Water, including carbonated and naturally flavoured water (with no nutritional properties), and coffee and tea.	B	100
Protein beverages	"Protein foods include […] unsweetened fortified soy beverage, lower fat milk, lower fat kefir, […]."		D.6, D.9, D.10, D.11, D.12, D.13	
Plant-based protein beverages		Beverages made up of plant-based protein foods with ≥2.5 g protein /100 mL of the beverage as per the CFG-FCS (Health Canada 2022d)		
Fortified plant-based protein beverages		Plant-based beverages with fortified calcium (≥125 mg/100 mL) and vitamin D (≥0.85 µg/100 mL) according to the Interim Marketing Authorization for plant-based beverages (Health Canada 2022a).		100
Unfortified plant-based protein beverages		Plant-based beverages with below minimum fortification levels for calcium (<125 mg/100 mL) and vitamin D (<0.85 µg/100 mL) according to the Interim Marketing Authorization for plant-based beverages (Health Canada 2022a).		75
Animal-based protein beverages				
Lower fat animal-based protein beverages		Milk and any other animal-derived milk beverages with ≤3.25% milk fat, consistent with the CFG-FCS (Health Canada 2022d) and HEFI-2019 (Brassard et al. 2022b).		100
High fat animal-based protein beverages		Milk and any other animal-derived milk beverages with >3.25% fat were included.		75

CFG-based Food Categories	CFG or CDG Recommendations	Definition	TRA categories*	Points
Other beverages		All other beverages not meeting any of the beverage categories listed above were included – e.g., fruit and vegetable juice, grain-based beverages, other plant-based beverages with insufficient protein content, and soda.	B (excluding B.2), J.11, J.12, V.7	0

*Detailed description and examples of Table of Reference Amounts for Food (TRA) categories can be found elsewhere (Health Canada 2022b).
†Points for multi-ingredient foods were assigned based on the position of the ingredients on the ingredient list, which are ordered by weight (1st position as the main ingredient; 2nd position as the next ingredient). The main ingredient listed in the 1st position was allocated a higher point than the next ingredient listed in the 2nd position. Abbreviations: CFG-FCS, Canada's Food Guide-Food Classification System; CFG, Canada's food guide; CFSS, Canadian Food Scoring System; CDG, Canada's Dietary Guidelines; HEFI-2019, Healthy Eating Food Index-2019; TRA, Table of Reference Amounts for Food.

Table 2. Examples of applying the Canadian Food Scoring System (CFSS) to different food and beverage products.

Food/Beverage Product	**Navy beans, dried**	**Ground beef, medium**	**Baked beans in molasses, canned**	**Vegetarian chili, canned**	**Soy milk, chocolate flavoured, fortified**
Product Type	Single-ingredient food	Single-ingredient food	Multi-ingredient food	Multi-ingredient food	Beverage
Ingredients*	Navy beans	Beef	Navy beans, sugars…	Tomatoes, kidney beans…	Soy, water,…
Step 1					
Food Categorization	Plant-based protein	Non-lean meats			
Ingredient Categorization			1st: Plant-based protein 2nd: Other	1st: Vegetables 2nd: Plant-based protein	
Beverage Categorization					Fortified plant-based protein
CFG Categorization Points	100	75	70 + 0 = 70	70 + 20 = 90	100
Step 2					
FOPL Categorization	< Thresholds	Exempted from FOPL	Nutrition symbol for Sugars, Sodium	Nutrition symbol for Sodium	Nutrition symbol for Sugars
Point Deduction Proportion	0%	0%	65%	50%	50%
Step 3					
Final Score Calculation†	[(100+100)*(1-0)]/2	[(100+75)*(1-0)]/2	[(100+70)*(1-0.65)]/2	[(100+90)*(1-0.5)]/2	[(100+100)*(1-0.5)]/2
Final Score (Range: 10-100)	100	87.5	29.75	47.5	50
Final Category	Excellent	Good	Very Poor	Poor	Fair

*Ingredients of foods were estimated based on the food descriptions provided in the Canadian Nutrient File by two experienced dietitians/nutrition research assistants. †Final score was calculated using *Equation 1:* Final score = [(Base point of 100 + Step 1 point) x (Step 2 deduction)]/2. Abbreviations: CFG, Canada's food guide; FOPL, front-of-pack labelling

FIGURE LEGEND

Figure 1. Flow diagram of the Canadian Food Scoring System (CFSS). There were three main steps. In Step 1, all food and beverage products or ingredients of products were categorized according to the Canada's food guide (CFG)-based food categories and assigned points, which were developed based on the recommendations of CFG for each category. In Step 2, the deduction proportion was determined and applied based on the level of saturated fat, total sugars, and sodium using the exemption criteria and thresholds set in Canadian front-of-pack labeling (FOPL) regulations (Government of Canada 2022a). Health Canada's 'high in' nutrition symbol image was retrieved from Government of Canada (2022a). In Step 3, the final score was calculated by combining the points from Steps 1 and 2 resulting in a score ranging from 10 to 100. A higher score indicated better alignment with the recommendations of CFG. The final score was used to categorize all products into one of five categories: "very poor", "poor", "fair", "good", and "excellent" choice. Abbreviations: CFG, Canada's food guide; CFSS, Canadian Food Scoring System; FOPL, front-of-pack labelling.

Figure 2. Proportion of products classified according to the Canadian Food Scoring System (CFSS), overall and by Table of Reference Amounts for Food (TRA) category. n=3,676. Proportions are presented overall and by Table of Reference Amounts for Food (TRA) major category (Health Canada 2022b). Homemade recipes and miscellaneous products (e.g., alcoholic beverages, nutritional supplements) were removed from the analysis. Abbreviations: CFSS, Canadian Food Scoring System; TRA, Table of Reference Amounts for Food.

Figure 3. Proportion of products classified using the Canadian Food Scoring System (CFSS) categories presented by the Canada's Food Guide-Food Classification System (CFG-FCS) tiers. n=3,247. Infant and toddler foods, foods with missing information for classification, and other miscellaneous products (n=429) were excluded from the analysis. The CFSS and the CFG-FCS showed good agreement (ρ=0.782, $p<0.001$). Abbreviations: CFG-FCS, Canada's Food Guide-Food Classification System; CFSS, Canadian Food Scoring System.

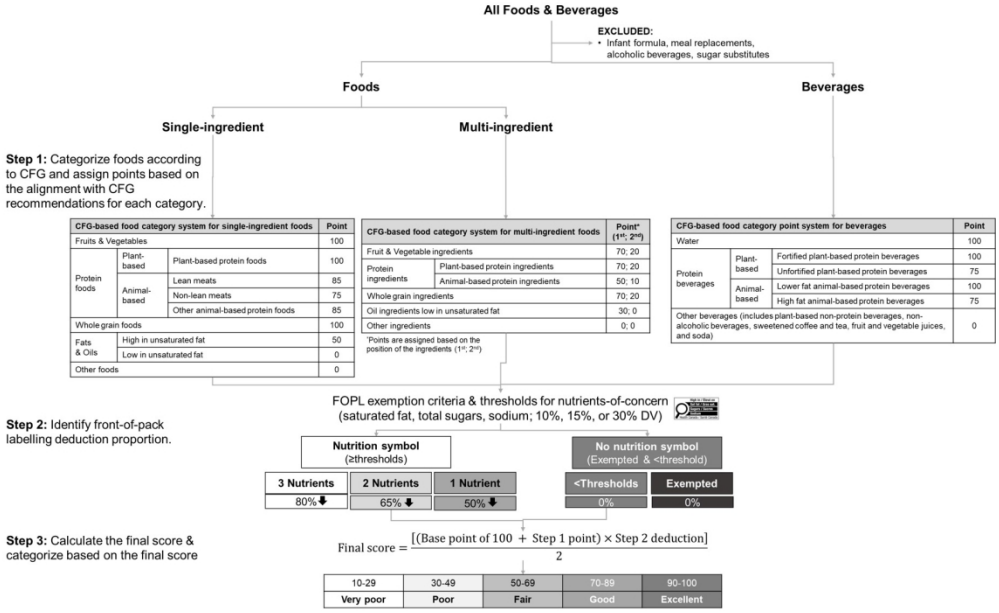

Figure 1. Flow diagram of the Canadian Food Scoring System (CFSS).

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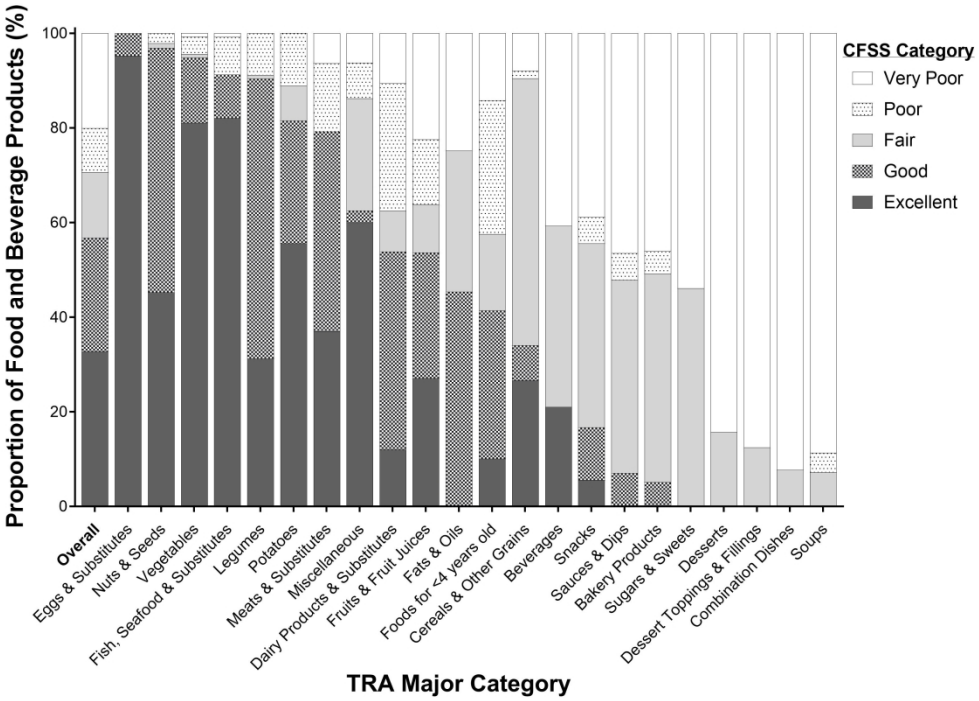

Figure 2. Proportion of products classified according to the Canadian Food Scoring System (CFSS), overall and by Table of Reference Amounts for Food (TRA) category.

270x194mm (300 x 300 DPI)

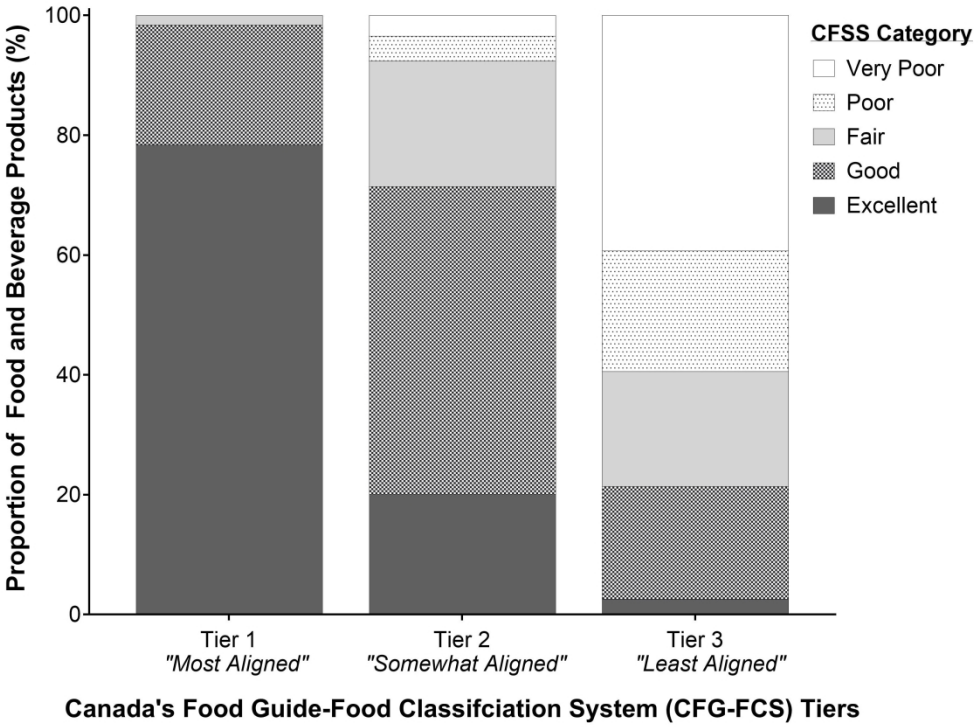

Figure 3. Proportion of products classified using the Canadian Food Scoring System (CFSS) categories presented by the Canada's Food Guide-Food Classification System (CFG-FCS) tiers.

252x192mm (300 x 300 DPI)