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Prepackaged foods healthiness ranking index: developing front-of-pack labeling to facilitate the assessment and validation of healthiness rankings of prepackaged foods in China

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Abstract

Background The Medium and Long-Term Plan for the Prevention and Treatment of Chronic Diseases (2017–2025) in China has highlighted the importance of reducing fat, sodium, and sugar in foods. However, front-of-pack labeling, which enables consumers to assess the health levels of prepackaged foods, is lacking in China. In response to the Zhejiang Provincial Health Commission's request, we sought to develop a method for efficiently evaluating the health level of prepackaged foods.

Methods Through a comprehensive literature review, we established a systematic framework: the Prepackaged Foods Healthiness Ranking Index (PHRI). We determined specific threshold values and grading criteria and conducted two rounds of Delphi survey to refine the index. Using a measurement dataset, we aimed to determine the optimal limit values for assessing the health level of prepackaged foods in real-world settings.

Results After two rounds of Delphi surveys, the PHRI underwent multiple revisions until consensus among experts was reached. The final decision regarding the upper limit values set 30% Nutrient Reference Values as the limit for solid foods and 15% Nutrient Reference Values for liquid foods. The calculation of PHRI values was successfully implemented with the dataset, in accord with current nutrition awareness and real-world conditions.

Conclusions The PHRI provides a valuable tool for assessing the healthiness of prepackaged foods. This front-of-pack labeling system provides a convenient method for evaluating the nutritional quality of prepackaged foods. Ultimately, the PHRI has the potential to contribute to advancements in health policy, practice, and education in China.

Keywords FOPL, PHRI, Prepackaged food, Health rank, Delphi method

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Background

The global prevalence of non-communicable diseases is on the rise, and nutrition has been identified as a significant risk contributing factor to this trend [1]. Since the adoption of the Medium and Long-Term Plan for the Prevention and Treatment of Chronic Diseases (2017–2025) [2], Chinese society has placed an emphasis on reducing the consumption of fat, sodium, and sugar-rich foods, which are commonly known as high fat, salt, and sugar (HFSS) foods [3]. However, current consumption patterns of HFSS food in China are unfavorable, particularly with regard to prepackaged food [4]. Clear instructions for the appropriate intake of fat, salt, and sugar in prepackaged foods are urgently needed in China.

Currently, guidelines for prepackaged foods, such as the Dietary Guidelines for Chinese Residents 2022 [5] and GB28050-2011 General Principles of Nutrition Labelling for Prepackaged Foods [6], are widely implemented in China. Although China has not yet established a national standard for assessing the healthiness of prepackaged food [7], the applicable regulation is the proposed Norms for the Use of “Healthy Choice” Labelling for Prepackaged Foods [8]. However, these norms have not yet been implemented.

In other countries, methods for evaluating the healthiness of prepackaged goods are known as front-of-pack labeling (FOPL) systems [9]. Over 50 nations worldwide have implemented FOPL systems to enhance customer awareness of the nutritional value of the food they purchase [10–19]. The labeling format varies depending on the country [20]. There are three main categories of established FOPL methods: (1) Nutrient-specific labels [21]: These labels provide information regarding the amount of energy and other ingredients per serving, typically including saturated fat, sugar, and sodium (or salt). Some examples include the Multiple Traffic Lights (MTL) [22] and Guideline Daily Amounts (GDA) systems [23]. (2) Warning labels: A special form of FOPL that alerts consumers about the nutritional content of a product, such as foods that contain large amounts of added sugar [24, 25]. (3) Summary labels: These labels condense the various components of a food into a single value that indicates its level of healthiness. Examples include Nutri-Score [26] and star labels [27]. In summary, research on FOPL exhibits diversity and lacks uniformity [9], because systems vary on the basis of country-specific circumstances.

In response to the widespread consumption of prepackaged foods in China, the Health Commission of Zhejiang Province organized an expert consulting group to formulate the “Regulation of the Management of Campus HFSS Foods” [28]. Previous studies have indicated that campus retail outlets show an insufficient capacity to classify the nutritional value of prepackaged foods [29]. Additionally, these businesses tend to either prohibit the sale of any snacks other than water and pure milk, or offer a wide variety of prepackaged foods that are clearly unhealthy. To facilitate the identification of HFSS products alongside healthier options among prepackaged foods in campus retail stores, it is essential to develop an index that assesses the health rankings of prepackaged foods.

Therefore, the primary aim of the current study was to develop the Prepackaged Foods Healthiness Ranking Index (PHRI), to serve as a fundamental tool for both campus retail store operators and relevant regulatory authorities. This index will evaluate the health states of prepackaged foods by quantitatively analyzing their fat, sugar, and sodium content, enabling individuals to make healthier food choices by minimizing their intake of salt, fat, and sugar. The secondary objective was to validate the ability of the PHRI to distinguish food groups with different levels of healthiness in the test dataset.

Methods

PHRI framework building

The primary aim of developing the PHRI was to provide a simplified scoring framework to scientifically evaluate the health status associated with the inclusion of fat, salt, and sugar in prepackaged foods, thereby providing consumers with a reliable reference standard to rank the healthiness of prepackaged foods. In China, the currently mandatory labeling of nutrients in the Nutrition Facts Table for prepackaged foods includes calories, protein, fat, carbohydrates, and sodium, and is expected to include sugar, saturated fat, and dietary fiber in the future. Therefore, we focused the proposed assessment on to providing nutrition information for prepackaged goods, including fat, sugar, and sodium, and excluding unpackaged foods, fresh foods, and alcoholic beverages. Importantly, the PHRI used a specific definition of sugar. According to the most recent version of the General Principles for Nutrition Labeling of Prepackaged Foods in China (exposure draft) [30], sugar content (the combined amount of glucose, fructose, sucrose, and maltose that can be measured and obtained from prepackaged foods) must be displayed on labeling. Therefore, the assessment of sugar in the PHRI is aligned with the new General Principles for Nutrition Labeling in China. The different definitions of sugar will be expanded upon in the “Discussion” section.

We conducted an extensive review of FOPL systems in individual countries, using the following inclusion criteria: (1) the FOPL system was operating as of June 2023; (2) in the development and implementation of the FOPL system, a well-defined threshold was used for high levels of fat, sugar, and sodium in prepackaged foods, specifically tailored for both solid and liquid food products. The exclusion criteria were as follows: in the process of developing the FOPL, there was no clear definition of upper limits of total fat, sugar, and sodium for prepackaged foods. For instance, the Healthy Choice Labeling system was not used as a reference because this type of FOPL does not typically define excessive thresholds for negative factors (e.g., fat, sugar, and sodium). The data source was drawn from the official websites of national standards related to FOPL systems, taking into account the cut-off values for solid and liquid fat, sugar, and sodium for FOPLs over 18 countries spanning Europe, North America, South America, Australia, and Asia. After removing the duplicated FOPLs, our analysis ultimately focused on FOPL systems that are employed in seven distinct countries/regions. The consolidated search outcomes are presented in Additional file 1.

Because the purpose of our study was to create an index for conveniently evaluating the healthiness of prepackaged foods, which requires a simple and straightforward method of presenting results, we decided to design the PHRI in the form of summary labels. Meanwhile, the PHRI needs to have a more general applicable threshold value and a simple calculation method to increase convenience in daily use. Therefore, we considered the type of calculation used in the MTL system to be a more appropriate reference.

After a comprehensive review of international literature and policies, we established thresholds for fat, sugar, and sodium indicators. The low limit values aligned with the Chinese standard GB28050-2011[6] for low-fat, low-sugar, and low-sodium requirements. Detailed indicators are as follows: the standard for low fat, low sugar, and low sodium were ≤ 3.0 g, ≤ 5.0 g, and ≤ 120 mg per 100 g of solid foods, respectively. For liquid foods, the standard for low fat, low sugar, and low sodium were ≤ 1.5 g, ≤ 5.0 g, and ≤ 120 mg per 100 ml.

Multiple evaluation procedures exist worldwide to determine the upper limit value [31–35]. Key references include the Chinese Nutrient Reference Values (NRVs) [6], the World Health Organization's sugar intake guidelines [34], the Dietary Guidelines for Chinese Residents 2022, and the MTL system [36]. After meticulous consideration of source credibility and real-world applicability, we narrowed down our selection, which is detailed in the "Application of test datasets" section of the "Methods" section.

An increasing amount of research indicates that many artificial sweeteners are not beneficial for weight loss and are associated with a higher risk of chronic and cardiovascular diseases [37]. Thus, in the PHRI, if artificial sweeteners are present, products must present the following cautionary statement: "Artificial sweeteners are not beneficial for weight loss and may heighten your risk of developing various chronic diseases and cardiovascular issues."

Using the MTL system design, we calculated the PHRI for prepackaged foods using the following formula [38]:

PHRI = F + S + Na.

In the formula:

> PHRI represents the Prepackaged Foods Healthiness Rank Index value.
> F = fat content score of prepackaged foods.
> S = sugar content score of prepackaged foods.
> Na = sodium content score of prepackaged foods.

For each component, high content receives three points, medium content receives two points, and low content receives one point. The highest possible score is 9 and the lowest possible score is 3. A higher score indicates a lower health ranking for the prepackaged food.

On the basis of the score calculated from the above formula, PHRI health rank rating results are divided into four categories: HFSS foods, red light foods, yellow light foods, and green light foods. The classification method is determined by the measurement of the test dataset, the Delphi method, and expert discussion. The methodological framework for building PHRI is shown in Fig. 1.

Data collection and categorization

Between 2021 and 2023, members of our research group collected prepackaged food data in the field at 10 campus supermarkets and a large supermarket in Zhejiang Province, while supplementing the data provided by some campus food suppliers, which contained data for a total of 3019 foods, the dataset contained entries such as food name, net content, and nutrient content table. However, 753 products were excluded because of data has incorrect information or incomplete nutrition information ($n = 132$), duplicates ($n = 174$), missing values ($n = 320$), or food types that were not included in the evaluation ($n = 127$). The final dataset consisted of 2266 products, including 1560 solid foods and 706 liquid foods. The process of constructing the dataset is shown in Fig. 2.

The goods were categorized on the basis of a standardized food classification system created by the China State Administration of Market Supervision and Regulation. This system divides products into 32 primary food groups [39]. However, 13 types of food were excluded from the study, including tea, wine, and food additives, because they do not require food labeling.

Because the categories of dairy products and beverages have diverse nutritional compositions, a secondary classification was introduced to further divide these two groups into nine subcategories each. The study

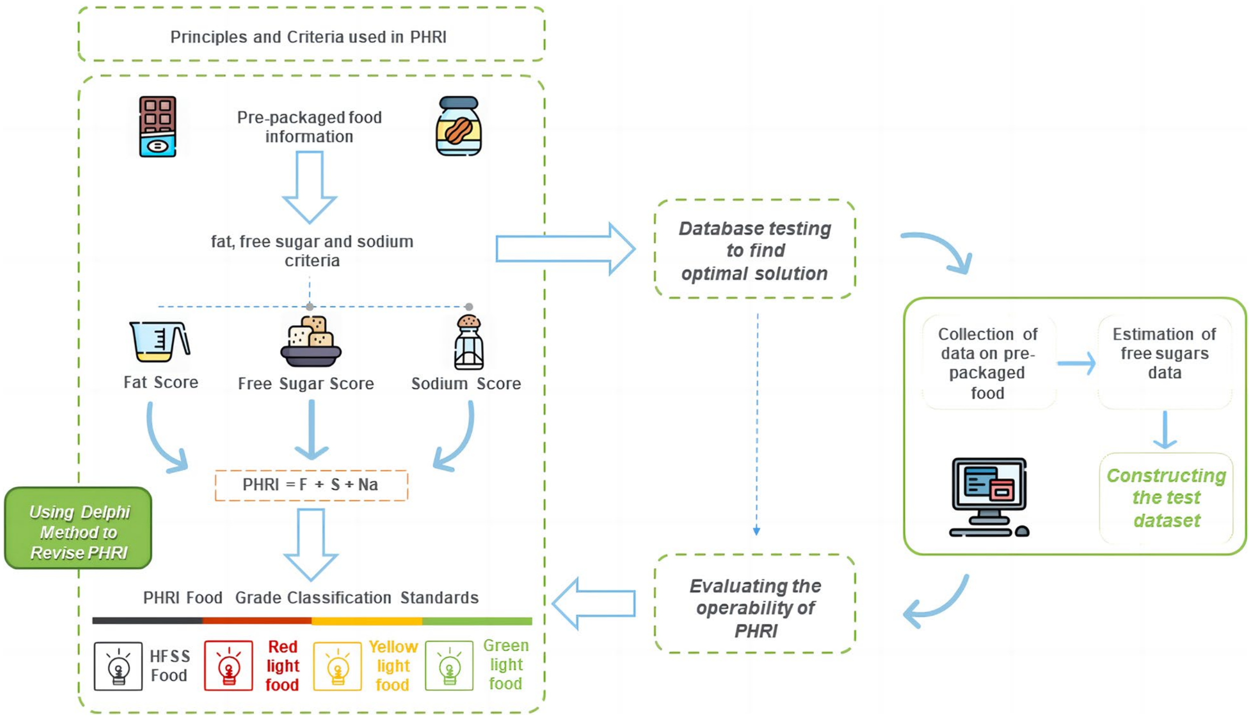

Fig. 1 The methodological framework for building PHRI

ultimately examined a total of 28 food groups, including biscuits, fried food and nut products, egg products, starch and starch products, condiments, soy products, convenience foods, bee products, pastries, canned food, frozen desserts, meat products, solid dairy products, vegetable products, potatoes and puffed food, aquatic products, fruit products, confectionery products, sterilized milk, fermented milk, prepared milk, packaged drinking water, tea beverages, protein beverages, fruit and vegetable juices and their beverages, carbonated beverages, other beverages, and solid beverages.

Obtaining precise statistics on sugar in prepackaged food is challenging in China. Currently, the General Regulations for Prepackaged foods in China do not require compulsory labeling of sugar. To enhance the precision of data on sugar, the researchers determined the sugar content of prepackaged foods by estimating the ratio of sugar to carbohydrates in each product group. The final dataset used to evaluate sugar was the carbohydrate data on the food package multiplied by the sugar ratio.

Application of test datasets

Variation in the three indicators' low limit values is limited in China because they are based on authorized provisions. Nevertheless, it is crucial to assess the scientific validity of the three indicators through datasets to establish appropriate upper limit values. To determine the most appropriate values for the indicators, four possible upper limit values were selected.

The four options are shown in Table 1. The reference ranges listed below refer to the Chinese NRVs. The first method involves utilizing the upper limit value range specified by the MTL system. The second method incorporates a reference range of 25% for solids and 12.5% for liquids. The third method applies a reference range of 30% for solids and 15% for liquids. Finally, the fourth method employs the recommended range values from the Dietary Guidelines for Chinese Residents 2022.

The four options mentioned in the "PHRI framework building" section were separately measured in the dataset to obtain the proportion of food for each of the four classes under each plan. After discussion among the research group, the most appropriate option was selected, taking into account factors such as whether the option significantly differentiated between foods of different health classes in the test data set and whether the criteria for evaluating HFSS foods would be too stringent or too lenient if the option was applied in the real world. Because this judgment was based on nutrition-related experience, there was an element of empiricism.

To assess the ability of the PHRI to distinguish the nutritional quality of prepackaged foods, the index was applied to the test dataset in this study. Initially, the

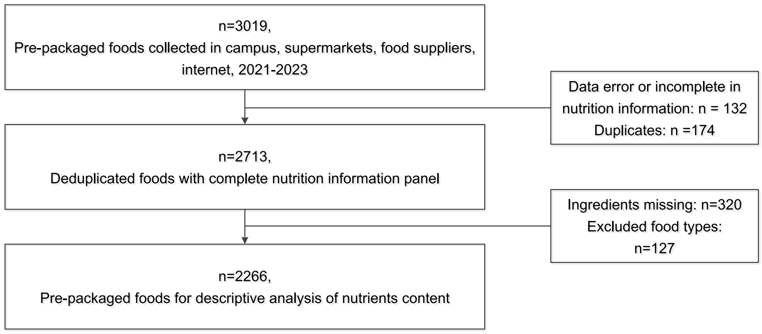

Fig. 2 Flowchart for dataset construction

proportion of each type of prepackaged food in each of the four grades was assessed. Subsequently, the distribution of the four grades across different food categories was evaluated. Drawing from the two aforementioned results, a comprehensive assessment was conducted to determine the relative nutritional values of different food categories. This conclusion was then juxtaposed against common nutritional knowledge to ultimately assess the practicality of PHRI and its effectiveness for identifying prepackaged foods within each healthy food category level.

Revising the PHRI using the Delphi method

To enhance the scientific rigor and practicality of the PHRI, we used the Delphi method to revise the measure. Two rounds of the Delphi method [40] were conducted to reach consensus on the indicators in this study. This technique was used because it has previously been demonstrated to be an effective method for developing indicators in the field of nutrition [41–43].

According to the requirements of the Delphi method, this study required inviting at least 15 experts to participate in the expert correspondence. The criteria for selecting the experts were as follows: (1) currently engaged in student nutrition research, or have 3 or more years of work experience in the field of nutrition; (2) the invited experts needed to come from more than three provinces in China; (3) a strong interest in the study and willingness to actively participate in the study.

In accordance with the requirements of the Delphi method, we assembled a panel of 15 specialists from six different regions, representing four distinct domains: nutrition, student nutrition, health behavior promotion, as well as food supervision and management. Subsequently, we conducted two rounds of Delphi surveys with this panel. The Delphi questionnaire is shown in Additional file 2. The questionnaire encompassed three primary components: experts' agreement rating on the reasonableness of the upper and low cut-off values; experts' opinion on the reasonableness of the four grades classification; and experts' views on the frequency of intake for various PHRI grades.

The data were analyzed using Excel and SPSS 26.0. Fifteen questionnaires were sent in each round of expert consultation, with an effective recovery rate of 100% in the first round and 93.3% in the second round. The experts proposed revisions in both rounds. The coefficients for expert judgment (Ca), knowledge (Cs), and authority (Cr) were all above 0.7 in both rounds, indicating familiarity with the issues [40]. Kendall's W coefficient increased from 0.14 to 0.39 between rounds, showing improved convergence of expert opinions. The chi-square test p value for Kendall's W coefficient in both rounds was <0.05, indicating highly significant results. The PHRI underwent revisions on the basis of feedback

Table 1 Upper limit value options

Upper limit	Solid food			Liquid food		
	Fat (g/100 g)	Sugar (g/100 g)	Sodium (mg/100 g)	Fat (g/100 g)	Sugar (g/100 g)	Sodium (mg/100 g)
Approach 1	17.5	22.5	600	8.8	11.3	300
Approach 2	15	12.5	500	7.5	6.3	250
Approach 3	18	15	600	9	7.5	300
Approach 4	20	25	800	10	11.5	400

from the experts. The data, results, and revisions are detailed in Additional file 3.

Results

Determination of criteria using the dataset

The health rank of the prepackaged foods in the test dataset was assessed using four approaches. The results of applying each approach to the dataset are presented in Table 2.

The analysis presented in Table 2 shows the distribution of HFSS foods within solid foods under four approaches, with percentages of 0.45%, 1.92%, 0.58%, and 0.00%. When applying approach 1, using cut-off values of the MTL, the percentages of the four categories for solid foods were 0.45%, 40.13%, 44.81%, and 14.61%, while the percentages of the four categories for liquid foods were 2.12%, 8.64%, 59.63%, and 29.60%. The proportions for approach 2, with a maximum restriction of 25% NRV, were 1.92%, 45.64%, 38.97%, and 13.46% for solid foods and 2.41%, 16.86%, 51.13%, and 29.60% for liquid foods, when the upper limit was set at 12.5% NRV. While employing approach 3, the percentages of solid foods, with the upper limit value set at 30% of the NRV, were 0.58%, 41.28%, 43.97%, and 14.17%. Similarly, the percentages of liquid foods, with the upper limit value set at 15% of the NRV, were 2.12%, 15.86%, 52.41%, and 29.60%. Under approach 4, the solid foods accounted for 0.00%, 32.31%, 52.63%, and 15.06%, while the liquid foods accounted for 0.99%, 9.63%, 59.77%, and 29.60%, respectively. The dietary proportions described in this article are in line with the recommended ranges provided by the Dietary Guidelines for Chinese Residents.

The outcomes of approaches 1–4 are presented in Fig. 3. The first row of graphs represents the rank distribution of solid foods and the second row represents the rank distribution of liquid foods. Each graph is arranged horizontally from left to right, categorizing foods into HF foods, red light foods, yellow light foods, and green light foods.

After detailed evaluation and comparison of the four options, we finally chose approach 3. The specific decision-making process was as follows.

Although approach 2 was able to effectively screen out a high proportion of HFSS foods, it was a relatively stringent criterion, which could cause operational inconvenience in practical applications.

Approach 4, which was based on the Dietary Guidelines for Chinese Residents (2022), was more lenient, resulting in a low proportion of HFSS foods, and was unable to effectively restrict the entry of less healthy foods into the market. Thus, on the basis of the analysis of solid foods, we preferred approach 1 or approach 3.

For liquid foods, when approach 1 or approach 4 was adopted as an HFSS indicator, its differentiation ability in food classification was relatively weak and not as significant as that of approach 2 and approach 3.

Taking into account the differences in nutrient composition and intake between solid foods and liquid foods, as well as maintaining the consistency and operability of the evaluation scheme, we finally decided to adopt approach 3, with 30% NRV as the upper limit value criterion for solid foods and 15% NRV as the upper limit value criterion for liquid foods.

Methodology for calculating PHRI values

The construction of the PHRI calculation system was achieved by establishing the classification criteria for the PHRI index. The calculation was divided into three distinct steps.

The first step was to determine the boundary ranges for prepackaged foods on the basis of their fat, sugar, and sodium content. Depending on whether the prepackaged food was solid or liquid food, the corresponding judgment criteria were selected. The specific cut-off values are presented in Fig. 4.

The second step involved assigning values to the three indicators on the basis of their ranges. Value one was assigned within the low limit range, value two was assigned within the medium limit range, and value three was assigned outside the upper limit range. The sum of the indicators was calculated, providing the specific PHRI value. PHRI has a maximum score of 3 for each individual nutrient, with a total maximum score of 9. A higher score indicated that the food was

Table 2 Proportion of food in each grade using various approaches

Upper limit	Solid food ($n=1560$)				Liquid food ($n=706$)			
	HFSS food	Red light	Yellow light	Green light	HFSS food	Red light	Yellow light	Green light
Approach 1	0.45%	40.13%	44.81%	14.61%	2.12%	8.64%	59.63%	29.60%
Approach 2	1.92%	45.64%	38.97%	13.46%	2.41%	16.86%	51.13%	29.60%
Approach 3	0.58%	41.28%	43.97%	14.17%	2.12%	15.86%	52.41%	29.60%
Approach 4	0.00%	32.31%	52.63%	15.06%	0.99%	9.63%	59.77%	29.60%

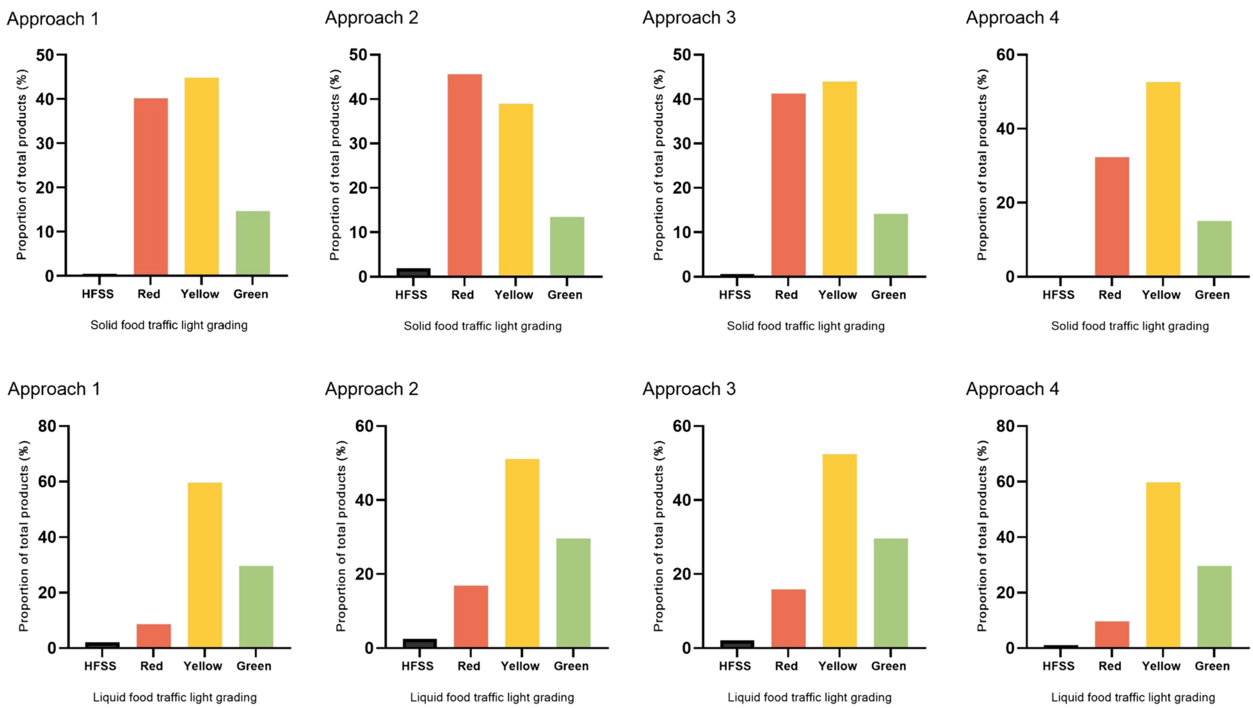

Fig. 3 Grade distribution of solid and liquid foods

less healthy; a lower score indicated that the food was healthier.

The third step was to judge the health level of the prepackaged food on the basis of PHRI scores. The criteria for this evaluation were detailed in Table 3.

The descriptions for each of the four class levels were as follows:

HFSS foods: these foods should not be on campus and intake is not recommended.

Red light foods: restricted consumption, intake should not exceed once per week.

Yellow light foods: moderate consumption, intake should not exceed three times per week.

Green light foods: recommended to be consumed on a weekly basis as needed.

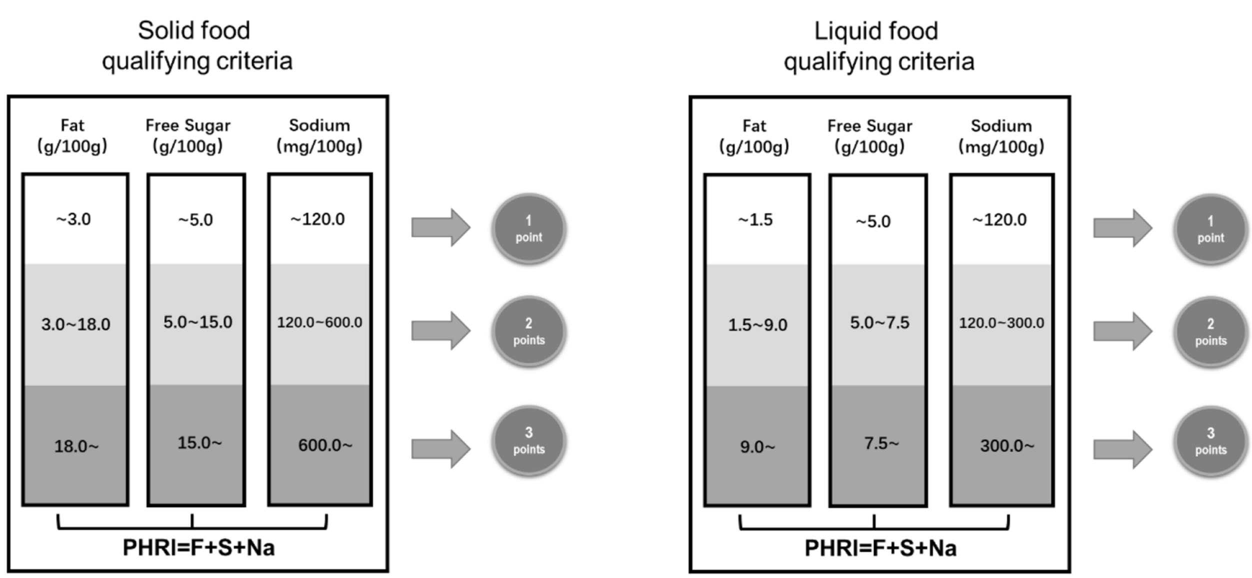

Fig. 4 PHRI qualifying criteria

Table 3 Judgment criteria

Food type	HFSS food	Red light food	Yellow light food	Green light food
Solid food	9	8, 7	6, 5	4, 3
Liquid food	9	8, 7, 6	5, 4	3

Ability of PHRI to classify food healthiness quality

To validate the PHRI, we applied it to the test dataset. Table S1, Additional file 4 presents the categories of the foods in the test dataset along with their nutrient information. The table shows the average fat, carbohydrate, sugar obtained after estimation, and sodium in each type of solid and liquid food included in the dataset. The mean fat content of all products was 8.76 g/100 g, the carbohydrate content and sugar content were calculated to be different, the mean sugar content was 11.95 g/100 g, and the mean sodium content was 455.54 mg/100 g.

Figure 5 and Table S2, Additional file 4 present the distribution of the four PHRI classes across various food types, along with the proportion of each class within each food category. The test dataset consisted of a total of 25 different types of HFSS food. Among these, biscuits accounted for seven types, while beverages accounted for 15 types. Figure 5 reveals that the red light foods, which account for 60.0% or more, consisted of biscuits (64.6%), fried food and nut goods (63.8%), pastries (84.3%), solid dairy products (80.0%), and prepared milk (60.8%). The foods that received green light ratings of 60.0% or higher were as follows: starch and starch products (70.0%), canned food (77.5%), and packaged drinking water (100.0%).

In the test dataset, 70.0% of the solid HFSS foods were biscuits, while solid beverages, meat, and vegetable products accounted for 10.0%. The red light foods consisted of 25.9% candy, 19.80% biscuits, 12.5% fried food and nut products, 11.3% puffed food, and 5.7% fast food. Within the category of yellow light foods, 15.2% of products were potatoes and puffed food, 12.2% were meat products, and confectionary items and convenience food accounted for 11.2% each. Within the category of green light foods, instant food products like oatmeal made up 22.5% of the total, fruit products accounted for 16.5%, canned food accounted for 14.2%, confectionery products such as jelly accounted for 12.4%, and confectionery, puffed food, and biscuits made up less than 4.0% of the total. This distribution is shown in Fig. 6.

Liquid HFSS foods encompassed several beverages, including milk tea and lattes. 40.2% of the foods classified as red light were fermented milk products, whereas 17.0% were prepared milk products. 29.2% of the yellow light items consisted of fruit and vegetable juices, while 17.3% were tea drinks. 31.6% of the green light items were of tea beverages, while 29.7% comprised other beverages such as bubbly water and functional beverages. The distribution is shown in Fig. 7.

Discussion

In this study, we developed the PHRI to evaluate the healthiness quality of prepackaged foods. To establish the validity of the PHRI, we analyzed the results using a dataset containing authentic prepackaged foods. Although

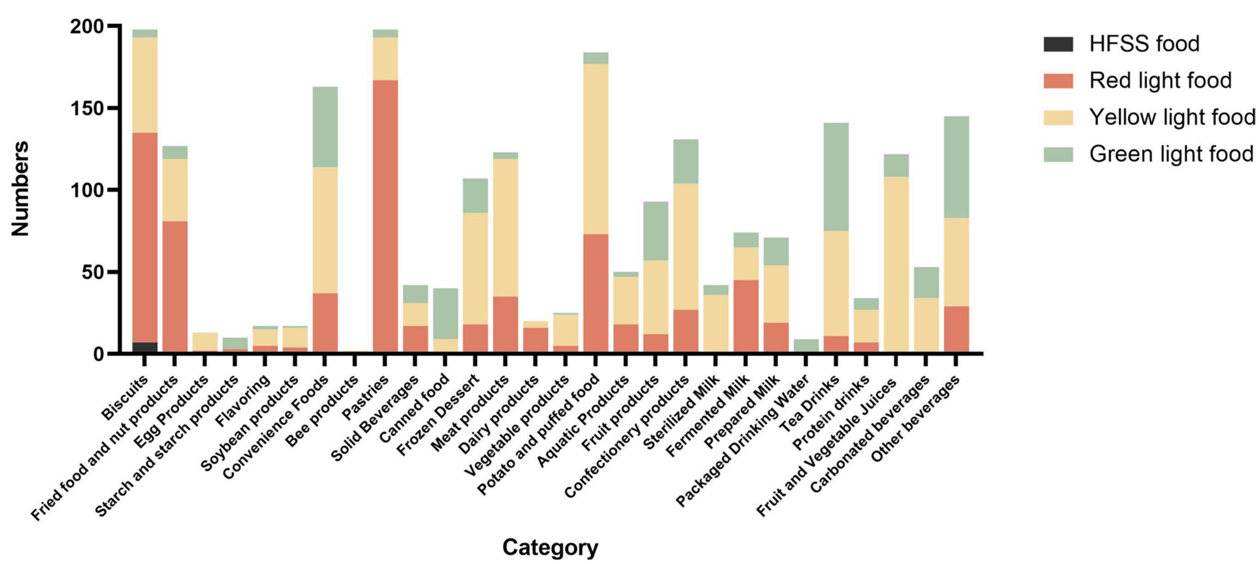

Fig. 5 Distribution of food grades by category

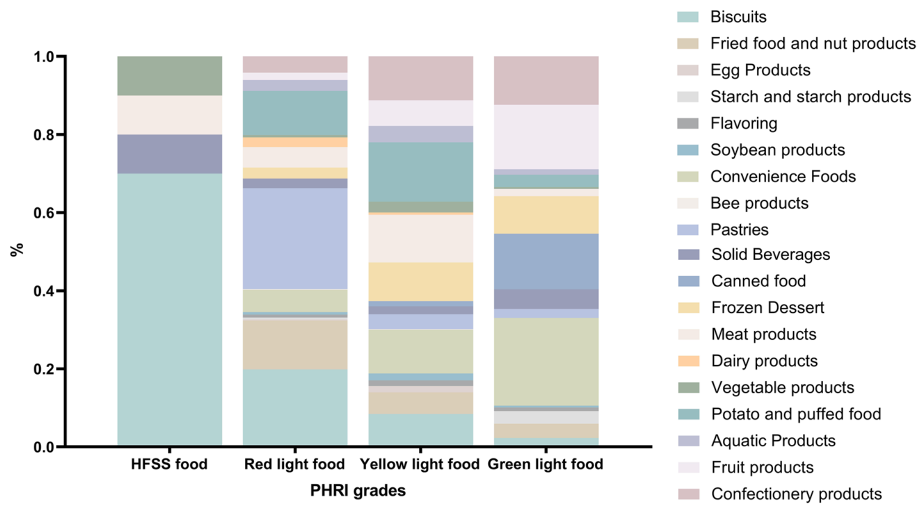

Fig. 6 Percentage of solid food types by level

policies aimed at preventing HFSS foods from entering schools currently exist, retailers and school administrators struggle to implement them effectively. Hence, it is imperative to develop a user-friendly FOPL that enables consumers to easily assess the healthiness of a product. Summary labels offer the advantage of conveying the overall health status of a product in a straightforward manner, without necessitating extensive nutritional expertise from users. Therefore, we opted to create the PHRI as a summary label for this purpose. The PHRI can simplify these policies' implementation and provides food manufacturers with health guidance and a new approach for FOPL systems. To ensure the scientific validity of the PHRI, the index was revised using Delphi expert correspondences. After two rounds of Delphi survey, the basic calculation scheme of PHRI was determined on the basis of experts' opinions.

Subsequently, we used the test dataset to identify the most suitable range of upper limit values for fat, sugar, and sodium for the Chinese market. The dataset was gathered by the research team in the field at a large supermarket and 10 campus supermarkets in Zhejiang Province. Additional data from campus food suppliers was also included, ensuring that our test dataset accurately represented prepackaged food products available on campus.

Analysis of the data showed that approach 2 tended to categorize foods as HFSS excessively, leading to practical difficulties. However, approach 4, while more lenient, underestimated the prevalence of HFSS foods. As a result, approaches 1 and 3 were identified as more suitable options for determining upper limits for solid foods. In evaluating liquid foods, approaches 1 and 4 displayed less effective grading discrimination than approaches 2

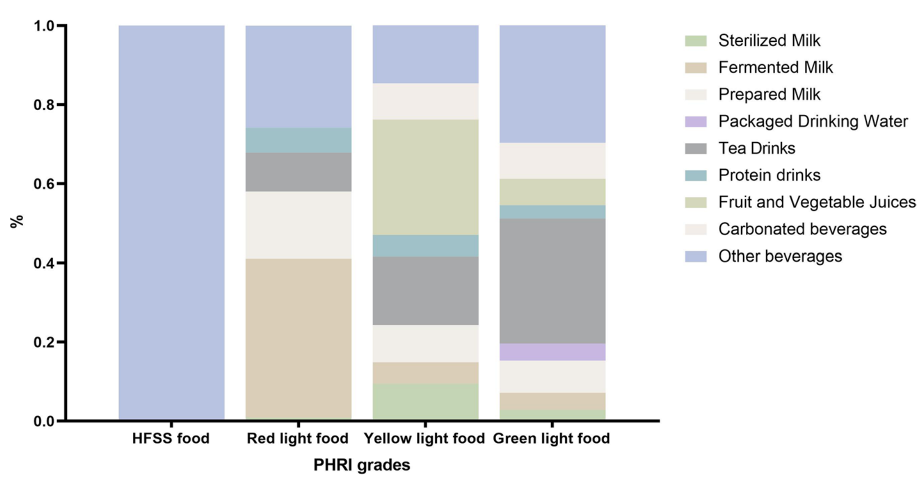

Fig. 7 Percentage of liquid food types by health level

and 3. To maintain consistency in assessment systems, it is recommended to use the conventional practice of halving liquid-to-solid indicator values. Therefore, adopting 15% NRV (as per approach 3) as the high threshold for liquid foods is advisable. As a result, a threshold of 30% NRV was established for solid foods and 15% NRV was established for liquids, endorsing the use of approach 3.

Clarifying the definition of sugar is also important to understand and utilize PHRI. The World Health Organization defines free sugar as including monosaccharides and disaccharides added to foods and beverages by manufacturers, cooks, or consumers, as well as sugar naturally present in honey, syrups, fruit juices, and fruit juice concentrates. Added sugar refers specifically to sugars added during food processing and excludes sugars that are naturally present in food. However, this distinction can be problematic. For instance, in the USA, food labels must indicate the content of "added sugar." Some food companies use fruit juice concentrates instead of sugar and syrups to circumvent the labeling of "added sugar," even though the high sugar concentration can still impact health negatively. In summary, free sugar encompasses added sugar and naturally occurring sugars in food.

In the current study, the definition of sugar, as outlined in the "Methods" section, encompasses glucose, fructose, sucrose, and maltose, aligning closely with the World Health Organization's concept of free sugar. It is important to note the consistency of this definition with the latest version of China's General Principles for Nutrition Labeling of Prepackaged Foods (draft for public comments). This alignment is crucial for ensuring accessibility and scientific accuracy of nutritional information. By harmonizing the definition of sugar with the new General Principles for Nutrition Labeling, we can facilitate more precise evaluation of the healthiness of prepackaged products on the basis of their nutritional content.

In addition, the estimation of sugar was conducted by calculating the ratio of sugar to carbohydrates. This methodology enhances the accuracy of the assessment and provides more informative evaluation outcomes. Furthermore, the obtained results were more consistent with the general public's perception of unhealthy foods [44], indicating that PHRI can effectively evaluate the healthiness ranking associated with prepackaged foods.

After analyzing the foods in the dataset, it was found that the average values of fat, sugar, and sodium in these foods fall within moderate cut-off values. Notably, biscuits, fried food and nut products, and dairy products had higher average fat content. Meanwhile, biscuits, condiments, bee products, pastries, and solid beverages had higher average sugar content. The average sodium content was higher in egg products, soybean products, convenience instant foods, meat products, vegetable products, aquatic products, and fruit products.

PHRI evaluation was performed on various types of food in the test dataset. It was observed that the majority of the solid HFSS and red light foods are biscuits, pastries, and puffed foods. This aligns with previous analyses of food composition [45], indicating that biscuits and pastries contain high levels of fat and sugar. Puffed foods also had high levels of added fat, salt, and sugar. Among liquid foods, HFSS foods were mostly milk tea and coffee, which contained high levels of sugar. Formulas such as cream and additives were added to enhance the flavor, making them high in fat and sodium. Among the green light foods, solid foods were mostly convenience foods, and canned foods such as cereal muesli and canned porridge, fruit products such as freeze-dried strawberries, and confectionery products such as jelly. Green light foods in the category of liquids included purified water, skimmed milk, tea beverages, and vitamin functional drinks. Analysis of the test dataset indicated that the PHRI effectively identified food groups with higher levels of fat, salt, and sugar, suggesting that the PHRI was capable of ranking the healthiness of prepackaged food.

The distribution of PHRI ratings in the test dataset for various types of food indicated that only three categories of prepackaged food currently account for over 60% of green light foods. This suggests that the proportion of green light foods in the market is extremely low. However, numerous products are amenable to reducing the addition of fat, salt, and sugar, which would reduce their negative health effects. It is imperative for food developers to prioritize reducing fat, sugar, and sodium in their products to enhance the availability of green light food options across various categories. Products like pastries that cannot effectively reduce fat, salt, and sugar should be restricted from entering campuses.

In future, the PHRI could be used to inform consumers about the nutrient content of specific foods (fat, sugar, and salt) when these amounts exceed a threshold that is considered to be too high for maintaining a balanced diet.

However, several limitations involved in the current study should be considered. First, PHRI evaluation is based on the consideration of only three indicators: fat, sugar, and sodium. This method excludes consideration of critical health hazards like saturated fatty acids and food additives, thereby limiting the scope of the evaluation. These indicators are currently not labeled in the nutrient composition table of prepackaged foods in China, making it challenging to obtain data on them and assess their health rank.

In addition, the sample size used for the measurements in the current study was limited. The dataset only included 1560 solid food products and 706 liquid food items, representing only a small proportion of all prepackaged food items on the market. To obtain more accurate findings, we plan to further expand our prepackaged food dataset to include prepackaged foods sold in more regions and in more scenarios to test the ability of the PHRI to distinguish health grades in future. Furthermore, additional studies are needed to explore the association of PHRI ratings with noninfectious chronic diseases (NCDs) and other health outcomes.

In future research, the PHRI could be applied to various prepackaged food sales scenarios, such as supermarkets, retail shops, and vending counters. Calculating the health ranking of prepackaged food using the PHRI could assist consumers in selecting healthier options. This could be achieved through categorization, labeling, and combining with behavioral theories to explore more effective solutions for intervening in consumers' choices of healthy prepackaged food.

Additionally, the PHRI could guide food manufacturers to adjust food ingredients and reduce the amounts of fat, sugar, and sodium in their product. This approach can attract consumers and improve the overall healthiness of prepackaged foods. Finally, consumers can learn about the nutritional properties of fat, sugar, and sodium through the application of PHRI in real-life settings. This approach may be more effective than passive classroom learning of nutritional knowledge. The PHRI, as a basic health ranking measurement tool for prepackaged food, has the potential for widespread use in various settings.

Conclusions

We developed the PHRI index to assess the health rankings of prepackaged foods. The results indicated that this tool can be used to quickly assess the health rank of prepackaged foods, potentially enabling individuals to make informed choices about their food purchases. Additionally, PHRI may be useful for guiding food manufacturers to modify their products to reduce negative health impacts and improve overall nutritional quality. Future research should aim to broaden the scope of PHRI evaluations by increasing the sample size and studying a wider range of prepackaged foods. This will enhance the accuracy and representativeness of the evaluation method, ensuring consistent results and ultimately leading to advancements in health education, practice, and policy.

Abbreviations

PHRI	Prepackaged Foods Healthiness Ranking Index
FOPL	Front-of-pack labeling
HFSS	High in fat, salt, and sugar
RIs	Reference intakes
NRVs	Nutrient Reference Values
GDA	Guideline Daily Amounts
MTL	Multiple Traffic Lights
F	Fat content score in prepackaged foods
S	Sugar content score of prepackaged foods
Na	Sodium content score of prepackaged foods
Ca	Experts' judgment on the survey content
Cs	Experts' knowledge of the survey content
Cr	The coefficient of expert authority
NCDs	Noninfectious chronic diseases

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

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Authors' contributions
FW led the writing of the article and played a key role in conducting the calculations for the Delphi process and dataset. YQ focused on optimizing the language used in the article and revision of the manuscript. DH collated the prepackaged food dataset and summarized the average proportion of added sugar in each food type. SX was responsible for designing the framework of the PHRI and the basic calculation approach. GZ played a key role in data collection and technical support. Corresponding authors MY and DZ provided guidance on article topics, opinions, and writing. All authors reviewed and approved the final manuscript.

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Competing interests
The authors declare no competing interests.

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