The Establishment of Nutrient Profiles for Solid Pre-packaged Food in China

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Authors' contribution

This work was carried out in collaboration among all authors. Authors JZ and YY designed the study. Author JZ performed statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors XX and XW performed the statistical analysis. Author HV provided overall advised on the study and presentation of results.

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ABSTRACT

Objectives: To provide scientific and practical criteria for Nutrient Profiles (NP) in China in order to evaluate the overall nutritional quality of solid pre-packaged food according to their nutrient composition.

Methods: Based on data obtained from a survey of experts' grading of foods available in China, a NP model was established, which covered scope of application, choice and balance of nutrients, choice of benchmarks and algorithm used.

Results: A NP model for solid foods was established as a scoring model, the reference amount was 100 g. The recommended intake standards were Nutrient Reference Value (NRV) in labeling regulation. Nutrients taken into account included qualifying nutrients (dietary fiber, vitamin C) and disqualifying nutrients (total fat, saturated fatty acid (SFA), sodium). A total score was calculated as

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(score of dietary fiber + score of vitamin C) – (score of total fat + score of SFA + score of sodium). Foods with a total score ≤-5were qualified as "less healthy", a score of -4 ≤ total score ≤ 2 was "intermediate" and a total score ≥3 indicated "healthier".

Conclusion: A NP model for pre-packaged foods in China was established that can be used to assess and compare the impact of different foods on diet, and help decide which pre-packaged foods are qualified to carry nutrition and health claims.

Keywords: Nutrient profiles; nutritional quality; solid pre-packaged food.

1. INTRODUCTION

The global burden of chronic non-communicable diseases is increasing tremendously [1]. Many studies show that an unhealthy dietary pattern is one of the main risk factors contributing to chronic diseases. Whereas diet is the combination of different foods, an inappropriate food choice is the primary reason causing unbalanced diets [2]. Traditionally, nutritional values of foods were assessed as per the following major aspects: composition and contents of nutrients, and their digestion, absorption and utilization status. Although these aspects form the basis of understanding of nutrition and nutritional evaluation of foods, they could not comprehensively assess the nutritional value of diet as a whole and its impact on public health [3].

Nutrient Profiles (NP) can be defined as "a scientific method for assessing the nutritional quality of food and beverage items" [4]. It can identify the relationship between foods and health for specific purposes by selecting nutrients and setting criteria under the guidance of scientific evidence [5]. NP is widely used in many areas and by different stakeholders, such as for use by authorities in the regulation of nutrition and health claims made on foods, or it serves as a nutrition education tool to guide consumers to choose better foods, or as the basis to choose suitable foods for children, or as a tool for food manufacturing and selling companies to do self-evaluation of products and innovation management [6-8].

With the rapid development of the food processing industry in China, the consumption of pre-packaged foods is continuously increasing [9] and consequently its impact on a balanced diet is also increasing. Nutrition and health claims are usually used as an important communication tool to consumers for pre-packaged food. Consumers generally believe that foods with claims are more nutritious and healthier than those without claims [4]. However, in China, foods bearing claims only need to meet the requirements for certain individual nutrients and circumvent the whole nutritional characteristics, resulting in uncertainty of the role of the food bearing a claim on health. Therefore, this study focuses on the main health issues currently in China and aims to establish a rational NP model based on understanding the established relationships between these health issues and nutrients, so as to effectively evaluate and compare the nutritional qualities of pre-packaged foods and their impacts on a healthy diet, and to provide criteria for foods to be suitable to carry nutrition and health claims.

2. MATERIALS AND METHODS

2.1 Scope

Solid pre-packaged foods are defined in the China food standards GB28050-2011, General Rules on Nutrition Labeling of Pre-Packaged Foods ("The General Rules" hereafter) [10], as foods which are packed in a quantified amount or kept into containers in advance for being supplied directly to consumers, and exist in solid form under ambient temperature and pressure. Food supplements, pre-packaged foods for special dietary uses and those with exemption of mandatory nutrient labeling were excluded from this study.

2.2 Source Materials and References Used

The following materials and references were used: China National Nutrition and Health Survey Report (2010-2013) [11,12] (hereinafter referred to as Ref A); Dietary Guidelines for Chinese Residents (2016) [13] (hereinafter referred to as Ref B); Chinese Residents Dietary Reference Intakes (DRIs) (2013) [14] (hereinafter referred to as Ref C); China's Health Statistics Yearbook 2019 [15] (hereinafter referred to as Ref D); China Food Composition (2002) [16] (hereinafter referred to as Ref E); China Food Composition (2004) [17] (hereinafter referred to as Ref F); and

Report on Diet, Nutrition, and the Prevention of Chronic Diseases (2003) issued by Joint WHO/FAO Expert Consultation [18] (hereinafter referred to as Ref G).

2.3 Methods

Based on data obtained from a survey of experts' grading of foods in China, a list of index foods and their "index categories" was obtained so as to establish a NP model which covered scope of application, choice and balance of nutrients, choice of benchmarks and algorithm used. All the index foods were scored in accordance with the established algorithms and the correlation and consistency were compared against their "index categories".

2.3.1 Survey of experts' grading on foods

Experts used for the validation of the NP model were selected on the basis of predefined criteria. "Experts" were members of staff in research institutes, universities, hospitals and food enterprises; they have5 or more years of nutrition research experience. "Authoritative experts" are professors with 20 or more years of nutrition research experience and have a large influence in the nutrition field.

Selected foods were graded by "Experts" by using self-administered questionnaires in combination with consulting "authoritative experts". Two hundred foods, which were commonly consumed in the Chinese diet, were investigated and graded based on their nutrient composition (Supplementary Table 1). All selected and scored foods were classified into five grades, the higher the grade, the more beneficial the food. Each food was effectively scored by at least 20 experts. A food was considered as graded if more than 50% of the experts gave the food the same grade; in contrast, if there was controversy mainly on two adjacent grades, the food was scored by authoritative experts.

Foods which in this way and by consensus got a grade were defined as "index foods". For these index foods, in order to simplify their categories, foods graded as 1 and 2 above mentioned were defined as "less healthy", graded as 3 were "intermediate", while graded as 4 and 5 were "healthier". And these new categories were called "index categories". As shown in Fig. 1, the "index categories" were further transferred into two subtypes to determine cut-off of less healthy and healthier. "Index categories A" included "less healthy" and "others", in which "others" comprise "intermediate plus healthier foods";"Index categories B" included "healthier" and "others", in which "others" comprise "intermediate plus less healthy foods".

2.3.2 Choice of nutrients

The choice of nutrients was followed the flow chart in Fig. 2. The nutrients selected for the NP model were energy and some essential nutrients. Those nutrients that were of highest importance to target populations and suitable to allow differentiation between foods were eventually determined as the selected nutrients in the NP model. The selection was performed as follows: Excessive or insufficient intake of nutrients was determined by assessing differences between daily intake of nutrients in Chinese residents by Source Materials A and the daily intakes recommended in Ref B and Ref C; Major health issues among Chinese residents were identified by analysis of diseases with a high prevalence rate and/or with a rapid increase as well as major fatal diseases by using Ref A and Ref D; Those nutrients strongly associated with major health issues of Chinese residents were determined based on the association of diet and chronic diseases as indicated in Ref G; The initial choice of nutrients was based on the combination of the nutrients which were of excessive or insufficient intake and were strongly associated with major health issues of Chinese residents and that were available in the China Food Composition database (Ref E and Ref F); The final choice of nutrients was determined by using the Spearman's rank correlation test to select those nutrients that significantly correlated to the experts' grades.

Original grades	1	2	3	4	5
Index categories	Less healthy		Intermediate	Healthier	
Index categories A	Less healthy		Others		
Index categories B	Others			Healthier	

Fig. 1. Index categories and their subtypes transferred from original grades by "experts"
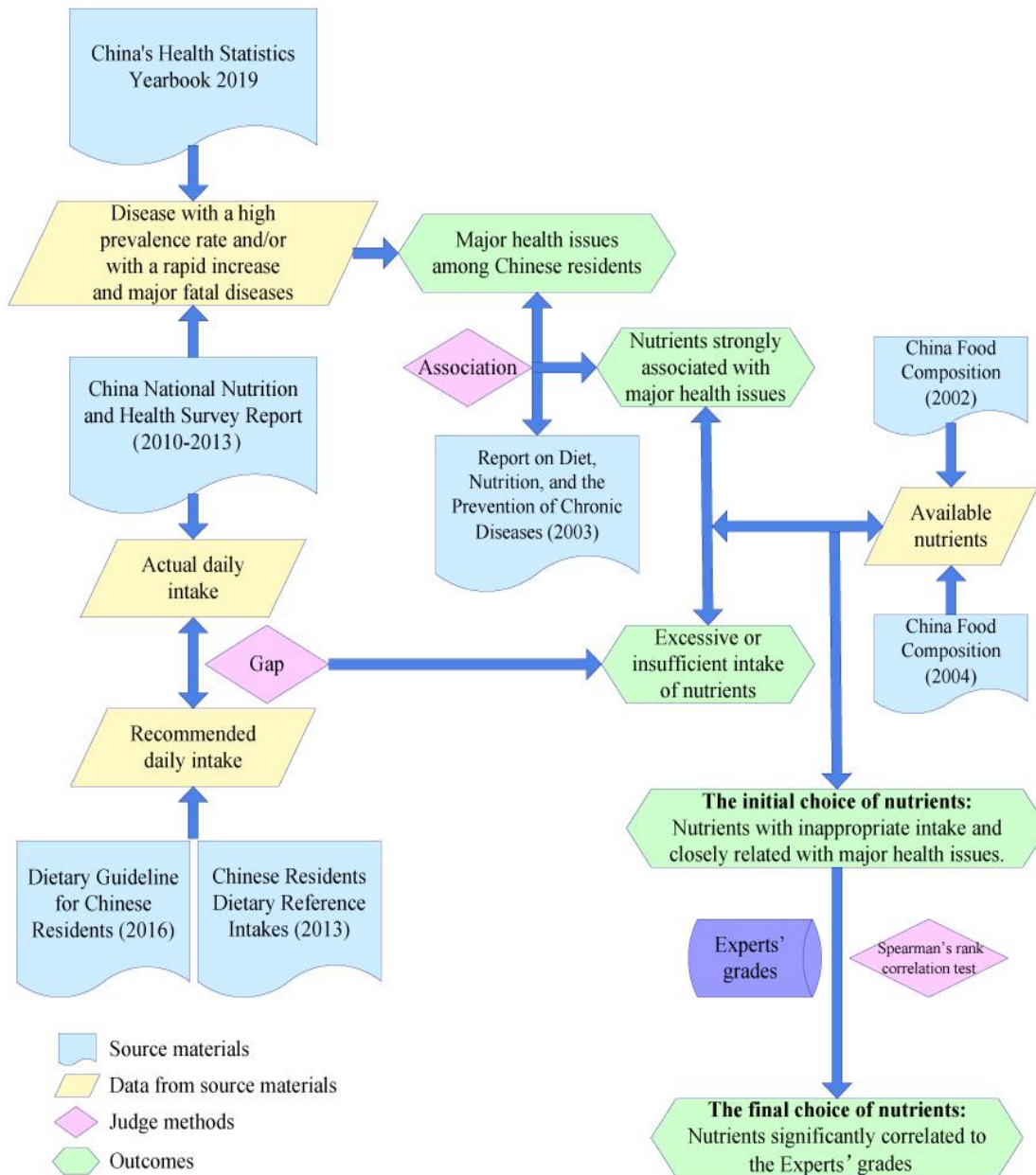
Fig. 2. The flow chart of choice of nutrients

2.3.3 Choice of benchmarks

As concerns the allocation of foods, three different options were selected:"across the board", "food category specific" and then the combination of these two. As concerns the reference base, three options were selected, e.g. per 100 g/ml, per 100 kcal/kJ, per portion. As concerns the reference intake of nutrients, two options were selected: Nutrient Reference Values (NRV) for labeling, according to "The General Rules", and Dietary Reference Intakes (DRIs) from Ref C.

2.4 Algorithm

For the basic values, they used for formulating the point or threshold were values which were generally considered as "source of certain nutrient" or its synonyms according to "The General Rules". For the working definition of less healthy foods, the basic concept for defining less

healthy foods can be set on different grounds. In addition, a threshold concept and a scoring method can be applied. See Supplementary Table 2 for details.

All "index foods" were categorized by different working definitions as "Less healthy" and "Others", in which "others" comprise "intermediate plus healthier foods". Next, the categories were compared with their "index categories A" by calculating sensitivity, specificity and Youden's index. The higher the Youden's index, the better ability of classification was the working definition. Then the better working definition of less healthy foods with calculating methods of threshold or scoring were used to further define the value of "healthier". Because the better working definition belonged to the "Threshold" type, the foods under "Others" cannot be further divided into "Intermediate" and "Healthier", so foods were only divided into "Less healthy" and "Others".

If the better working definition belonged to the "Scoring" type, total scores of all index foods were calculated, and the calculation methods were chosen by correlation analysis of "index categories" and total scores. The receiver operating characteristics (ROC) curve [19] was used to test the predictive accuracy of healthier foods compared with "index categories B".

All the index foods were categorized in accordance with the established algorithms and the correlation and consistency was compared against their "index categories". The algorithm that showed the largest correlation(Spearman's correlation coefficient)and consistency (Kappa index) was selected as the preferred algorithm for the NP model, which is the model that showed the largest correlation and consistency with the selection of qualifying and disqualifying nutrients, the scope of the application scope and reference base.

2.5 Statistical Method

SPSS18.0 was used for data statistics and analysis; the statistical indexes used were Spearman's correlation coefficient, sensitivity, specificity, Youden's index and the Kappa index.

3. RESULTS

3.1 Survey of Experts' Grading on Foods

In total of 137 experts were consulted. One hundred and thirty-seven questionnaires were sent out, and 103 of them were returned of which 100 (= 97%) were valid. Ninety-nine index foods were determined over five grades and three "index categories". See Table 1 for details.

3.2 Choice of Nutrients

3.2.1 Major health issues of chinese residents

According to health statistics, chronic diseases have been gradually becoming a major health issue. Cardiovascular diseases including cerebrovascular diseases and heart diseases are the leading causes of death; meanwhile hypertension, cardiovascular disease and diabetes are the diseases with the highest prevalence and thus are the target diseases, which need to be controlled. In addition, the overweight rate of Chinese residents is 30.1% and the obesity rate is 11.9% (total 42.0%, i.e. approaching half of the entire population [12]. It is well established that overweight and obesity are independent risk factors for many chronic diseases such as diabetes and cardiovascular diseases [20]. Therefore, overweight and obesity are targets to be controlled.

3.2.2 Major health issues related nutrients

Nutrients were selected by their close correlation with the health issues mentioned above and nutrients of which the intake is too high or too low. According to the strength of evidence on factors that might promote or protect against chronic diseases and weight gain and obesity [21] and the results of national nutrition surveys, high energy density, saturated fatty acid (SFA), trans fatty acid (TFA), sodium and total fat etc, are closely related to the health issues mentioned above. By comparing the intake of Chinese residents with dietary reference intakes, the nutrients for which the intake is too high include: fat, sodium, whereas the nutrients for which the intake is too low include: dietary fiber, vitamin A, thiamine, riboflavin, vitamin C, calcium, potassium and zinc.

3.2.3 Determination of choice of nutrients

Following on from to the above analysis, the first choice of qualifying nutrients was dietary fiber, vitamins A, C, B_1, B_2, calcium, potassium and zinc, while disqualifying nutrients were total fat, SFA and sodium.

Table 1. List of index foods

Grades	Index categories	Quantity	Names of foods
1	Less healthy	16	Fritters, fatty pork, pork intestine, pork brain, bacon, ham, fried chicken, egg yolk mooncake, fried dough twist, Egg crisp (sachima), instant wheat noodles, butter bread, potato chips, spun sugar, toffee candy, salted mustard root
2	Less healthy	13	Broad bean (fried), pork kidney, Guangdong sausage, spiced beef, lamb skewer(grilled), Beijing roasted duck, spring roll, cake, crunchy rice candy, walnut cake, chocolate pie, malted milk, salted radish
3	Intermediate	14	Wheat noodle, steamed rice, rice noodle, pea starch, winter melon, pear (canned in syrup), chicken, squid, cold noodle, chicken burger, pizza with cheese, assorted fried rice, bread, coffee bean
4	Healthier	21	Wheat, black rice, barley, soybean milk powder, pea, green bean sprouts, Chinese chive, bok choi, water-soaked bamboo slice, lotus root, seaweed, persimmon, mango, walnut, sesame seed(black), pigeon, milk tablet, loach, belt fish, corn flake(low sodium), dried sweet potato
5	Healthier	35	Corn, millet, buckwheat, Adlay, sweet potato, soybean, green bean, tofu, carrot, long bean, bell pepper, tomato, pumpkin, cabbage, green broccoli, spinach, bamboo shoot, Chinese yam, needle mushroom, wood ear fungus, apple, jujube, cherry, grape, kiwi fruit, orange, banana, beef (lean), low-fat milk powder, egg, egg white, small yellow croaker, shrimp, wheat flake, oatmeal

The Spearman's correlation test was used to position these selected nutrients versus the "index categories" (Table 2). Spearman's correlation coefficient of dietary fiber, vitamin C, total fat, SFA and sodium were statistically significant and hence these nutrients were included into the model.

3.2.4 Choice of benchmarks

As scope of application an "across the board" approach was chosen for all solid pre-packaged foods defined in paragraph 1.1 with exceptions of pure cooking oil products since pure cooking oil is main source of fat in diet so it does not provide other selected nutrients such as dietary fiber, vitamin C and sodium which is not suitable to assess according to the nutrient profiles in this study. As reference base the amounts per 100 g and per 100 kcal were chosen because there is no reference portion size in China. As reference intake of nutrients NRV for labeling was chosen (Supplementary Table 3).

Table 2. Spearman's correlation coefficient between nutrients and "index categories"

Qualifying nutrients	R Value	Disqualifying nutrients	R value
Zinc	-0.114	SFA	-0.434*
Vitamin B_2	-0.088	Total fat	-0.515*
Calcium	0.013	Sodium	-0.530*
Vitamin B_1	0.045		
Vitamin A	0.163		
Potassium	0.166		
Dietary Fiber	0.303*		
Vitamin C	0.497*		

Indicates a significant difference

3.3 Determination of Algorithm

3.3.1 Basic values

For qualifying nutrients, "basic values" (BV) can directly be set by using the amount that is legally determined to carry a "source of nutrient" claim according to the General Rules. Meanwhile, 30% NRV is defined as "rich in" according to the General Rules, so for disqualifying nutrients, the basic values per 100 g is 30% NRV, while the basic values per 100 kcal is in reference with the Chinese residents' DRIs. See Supplementary Table 4 for a summary.

3.3.2 Working definition of less healthy foods

The basic concept for defining less healthy foods can be set application of a threshold or after using a scoring method. Following the basic formula in Supplementary Table 2 and Basic Values in Supplementary Table 4, the following 12 working definition of less healthy foods were deduced. See Supplementary Table 5 and Supplementary Table 6 for details.

3.3.3 Performance of working definition of less healthy foods

All 99 index foods were categorized by different working definitions as "Less healthy" and "Others", and the categories were compared with the results obtained from experts ("index categories A"). For each of these approaches the sensitivity, specificity and Youden's index were calculated (Table 3).

The performance for the threshold type was not as good as for the scoring types. As a result, the definitions which needed to give further consideration were all scoring types as SA, SB, SC, SD, SE and SF.

3.3.4 Judgment of healthier foods

Total scores of index foods were calculated based on SA, SB, SC, SD, SE and SF. Spearman's correlation tests were conducted between total scores of index foods and their "index categories". There were significant positive correlations between all scoring calculation methods and the "index categories", and the Spearman's correlation coefficients of SD and SF were higher than 0.700 (Table 4).

Receiver operating characteristic (ROC) curve was used to test the prediction of "healthier" compared with "index categories B". The results showed the areas (A_Z) under the ROC curve were significant for all scoring calculation methods, noticeably, SD had an A_Z larger than 0.9 indicating a high predictive value (Fig. 3).

Table 3. Performance of working definition of less healthy foods

Code	Sensitivity (%)	Specificity (%)	Youden's index (%)
TA	82.8	64.3	47.0
TB	69.0	90.0	59.0
TC	72.4	81.4	53.8
TD	58.6	95.7	54.3
TE	72.4	80.0	52.4
TF	62.1	94.3	56.4
SA	93.1	55.7	48.8
SB	82.8	82.9	65.6
SC	86.2	77.1	63.3
SD	82.8	92.9	75.6
SE	93.1	74.3	67.4
SF	75.9	92.9	68.7

Table 4. Cut-off point for judgment of healthier foods and statistical indexes

No	Rs[a]	A_Z	Sensitivity	Specificity	Youden's index	Cut-off point
SA	0.545*	0.768*	0.893	0.558	0.451	≥ -12
SB	0.643*	0.804*	0.714	0.791	0.505	≥ -1
SC	0.673*	0.861*	0.732	0.837	0.569	≥ -1
SD	0.758*	0.909*	0.714	0.930	0.645	≥ 2
SE	0.685*	0.870*	0.714	0.884	0.598	≥ 0
SF	0.713*	0.881*	0.750	0.860	0.610	≥ 0

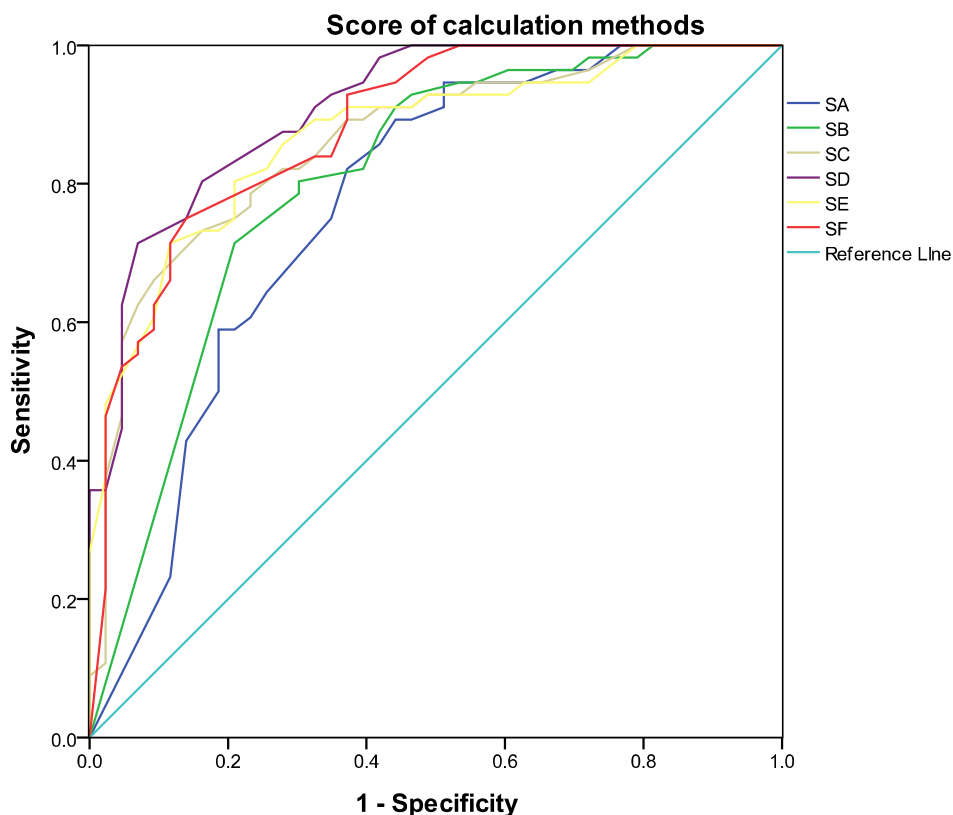*: p<0.05;a: Rs: Spearman's correlation coefficients*

Fig. 3. Receiver operating characteristic (ROC) curves for 6 scoring calculation method (SA, SB, SC, SD, SE and SF) in the prediction of healthier foods in index foods with "index categories B"

Table 5. Score for nutrients in resulting NP model (per 100 g)

Scores	Dietary Fiber (g)	Vitamin C (mg)	Total Fat (g)	SFA (g)	Sodium (mg)
0	<0.6	<3	≤ 3.6	<1.2	≤ 120
1	≥ 0.6	≥ 3	>3.6	≥ 1.2	>120
2	≥ 1.2	≥ 6	>7.2	≥ 2.4	>240
3	≥ 1.8	≥ 9	>10.8	≥ 3.6	>360
4	≥ 2.4	≥ 12	>14.4	≥ 4.8	>480
5	≥ 3.0	≥ 15	>18.0	≥ 6.0	>600
6	≥ 3.6	≥ 18	>21.6	≥ 7.2	>720
7	≥ 4.2	≥ 21	>25.2	≥ 8.4	>840
8	≥ 4.8	≥ 24	>28.8	≥ 9.6	>960
9	≥ 5.4	≥ 27	>32.4	≥ 10.9	>1080
10	≥ 6.0	≥ 30	>36.0	≥ 12.0	>1200

For each cut-off point in ROC curve, the sensitivity, specificity and Youden's index were calculated. The cut-off point which had the highest Youden's index was considered as the one to distinguish healthier foods from others (i.e. intermediate and less healthy foods) (Table 4).

3.3.5 Correlation and consistency analysis of established algorithms

All the index foods were categorized in accordance with SA, SB, SC, SD, SE, SF and their cut-off points of distinguish "less healthy", "intermediate" and "healthier" and then the

correlation and consistency was compared against their "index categories". The results showed that SD had the largest correlation (Spearman's correlation coefficient) and the largest consistency (Kappa index) (Supplementary Table 7). Therefore, SD and its cut-off points were selected as the preferred algorithm for the NP model.

3.4 Characteristics of the Resulting NP Model

The characteristics of the resulting NP model developed in this study were as follows: (1) Application scope: "across the board" for all solid prepackaged foods (except cooking oil). (2) Reference base: per 100g; (3) Reference intake: NRV; (4) Type: scoring; (5) Nutrients chosen were both qualifying nutrients and disqualifying nutrients. Qualifying nutrients: Dietary fiber, vitamin C; Disqualifying nutrients: total fat, SFA, sodium (6) Total score = (score of dietary fiber + score of Vitamin C)-(score of total fat+ score of SFA + score of sodium). Table 5 showed the details of scores for nutrients. (7) Food categorization: Foods with a total score ≤-5were qualified as "less healthy", while a total score ≥ 3 indicated "healthier", and a score of -4 ≤ total score ≤ 2 was "intermediate".

4. DISCUSSION

Different foods contain different nutrients and have different roles on diets. This can influence the diet and health of the individual consumer as well as public health in general. Nutrient profiling systems are an important tool for governments, non-governmental organizations and for the food industry, to help consumers make healthier food choices.

As concerns, the scientific setting of NP system, there is no mere scientific rationale on which to base nutrient profiling models [22,23]. There are many scientific and policy aspects associated with choosing within the various nutrient profiling schemes. These will not be discussed here as there are already several recent, good and thorough reviews available in this area such as from the UK-FSA [2,24-27], EFSA [5], ILSI [28-31], Sweden [32], France [33], Canada [3] and USA [34]. In these articles/reports, full descriptions of the various systems with the (dis-) qualifying criteria and nutrients can be found.

When developing and setting a system for nutrient profiling, there are several choices to be made: 1. Whether profiles should be set for food in general (across the board) and/or categories of food, 2. Whether only qualifying and or only disqualifying nutrients should be taken into account, or both, 3. Which qualifying and disqualifying nutrients should be chosen, 4, Which reference base should be taken into account (on the basis of g/ml, on the basis of energy/kcal, or on the basis of portions/reference amounts), 5. Whether a threshold or a scoring system should be applied. In all instances, any system for setting NP has to be validated and checked. Each of these aspects has their inherent advantages and disadvantages.

We have found that an across the board system performs better for our purpose than a food category-based system (provided cooking oils are excluded). As concerns the choice of nutrients, the basic principle is to match with both scientific and practical aspects, therefore consider health conditions and nutritional demands of target populations and objective of NP model. In our study, this includes two meanings: firstly, the chosen nutrients need to be capable of achieving the objective effectively and meeting the demand of the Chinese population; secondly, the chosen nutrients need to be of appropriate number rather than taking all the nutrients into NP model which makes the model too complicated and hard to apply. Moreover, the data of certain nutrients need be available in food composition database or nutrition labeling in China.

There are two types of models for NP which are used at present: either a threshold model or a scoring system. The NP model established in this study is a scoring system, in which discrete numbers are given for specific cut-off values of both qualifying and disqualifying ingredients.

The choice of all the components in the NP system depends on the purpose of the model and the scope of the system. The validation of NP system during usage will help modify it to better meet the purpose.

5. CONCLUSION

On the basis, of a series of ruggedness analyses, in this study we have selected the most suitable, i.e. the best performing, NP system for pre-packed foods in China on the basis van 100 Chinese index foods. The best performing Characteristics of the resulting NP model were:

- An across the board system (with cooking oils excluded)
- Qualifying ingredients (dietary fiber, vitamin C) as well as disqualifying ingredients (total fat, SFA, sodium)
- 100 g as reference base
- A scoring system on the basis of recommended intake standards (Nutrient Reference Values), in which the total score = (score of dietary fiber + score of Vitamin C)-(score of total fat+ score of SFA + score of sodium).
- On the basis of the developed NP model, prepacked foods in China can be categorized as:
- "Less healthy" (foods with a total score ≤-5)
- "Intermediate" (foods with a score of -4 ≤ total score ≤ 2)
- "Healthier" (foods with a total score ≥ 3)

The established NP system could be applied in multiple foods across the categories as the resulted scores are comparable among pre-packed foods. However, if and how this model will be used on prepacked foods in China is a policy decision, is not a scientific issue and hence beyond the purpose of this paper.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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