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Initial Development and Evaluation of the Food Processing Knowledge (FoodProK) Score: A Functional Test of Nutrition Knowledge Based on Level of Processing

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ABSTRACT

Background Existing nutrition knowledge measures tend to be lengthy or tailored for specific contexts, making them unsuitable for population-based surveys. Given the growing emphasis within country-specific dietary guidelines on reducing consumption of highly processed foods, consumers' ability to understand and apply principles related to level of food processing could serve as a proxy measure of general nutrition knowledge.

Objective To examine the content validity of the Food Processing Knowledge (FoodProK) score based on subject matter expert consultation with Registered dietitian nutritionists (RDNs).

Methods RDNs in Canada (n = 64) completed an online survey, including the FoodProK, in January 2020. Participants rated the "healthiness" of 12 food products from four categories (fruit, meat, dairy, and grains) on a scale from 1 to 10. FoodProK scores were assigned based on concordance of ratings within each food category, with rankings according to the NOVA classification system, with less processed foods representing higher healthiness. For each category, one-way repeated-measures analysis of variance models tested whether the three product ratings were significantly different from one another. Descriptive statistics compared ratings and FoodProK scores across categories. Open-ended feedback was solicited to assess face validity of the score.

Results RDNs' FoodProK scores were strongly associated with level of food processing. Almost one in three RDNs received perfect FoodProK scores, and the mean score was 7.0 of 8.0 possible points. Within each category, the three foods received significantly different healthiness ratings, in the same order as the NOVA system ($P < 0.001$ for all contrasts). Open-ended responses showed that RDNs did not perceive meaningful differences between the processed meat products, suggesting the need to change one of the products in the meat category. Overall, 80% of RDNs reported level of processing as an important indicator of the healthiness of foods.

Conclusions Level of food processing represents a promising framework for assessing general nutrition knowledge in population-based surveys.
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NUTRITION KNOWLEDGE IS INTEGRAL TO CONsumers' ability to identify and select foods that contribute to a healthy diet.[1-4] Consumers obtain nutrition knowledge from numerous sources, including educational campaigns, media, and cultural and social contexts.[2,5-7] With rising rates of diet-related noncommunicable diseases,[8-10] understanding nutrition knowledge and its role in health behaviors is increasingly important. Nutrition knowledge is a complex phenomenon that can encompass a wide variety of constructs, including knowledge of dietary recommendations, ability to understand quantitative information, and food preparation skills.[11-14] Existing measures of nutrition knowledge range from single-item questions about one's perceived level of knowledge to elaborate scales that focus on different combinations of these constructs.[11-15]

Given the lack of consensus in the literature about nutrition knowledge assessment, subjective, self-rated measures of nutrition knowledge are commonly used. However, research has shown that consumers tend to overestimate their ability to understand quantitative nutrition information on such subjective measures, as demonstrated by lower scores on functional tasks compared with self-reported knowledge.[16-20] "Functional" nutrition knowledge measures are considered to

provide more accurate assessment,[14,16-19] and studies using these measures have demonstrated associations between nutrition knowledge and diet-related decisions and behaviors.[21-26] Currently, many functional measures assess knowledge of dietary recommendations that are specific to national contexts and therefore not applicable to other countries with different dietary guidelines.[12,26-28] As a result, the same nutrition knowledge measure is seldom used across studies, which creates challenges for comparing nutrition knowledge levels—as well as corresponding determinants of knowledge—across studies, geographic contexts, and populations.[15,29]

The wide variety of knowledge measures used in the literature also reflects differences in perceptions of what constitutes a "healthy food" within the nutrition community.[15,30,31] In the midst of this complexity, an increasing number of countries, including Brazil and Canada, have started to shift away from prescriptive quantitative food group recommendations toward dietary guidance that emphasizes how to eat, in addition to what to eat, with integration of messaging related to limiting consumption of highly or ultraprocessed foods.[32-34] Many countries specifically note the importance of limiting intake of foods high in saturated or trans fats, added sugars, and sodium in their dietary guidelines.[32-38]

The focus on type of processing follows a global dietary shift toward greater consumption of highly processed foods in recent decades.[39-41] Ultraprocessed foods constitute more than half of total energy intake in high-income countries such as Canada, the United States, and the United Kingdom.[40,42-44] The high energy density and relatively low nutrient content of ultraprocessed foods contributes to poor diet quality,[39,40,45-47] which is associated with serious health consequences, including noncommunicable disease[44,47,48] and increased risk of morbidity.[45,46,49-51] To support inquiries of this nature, researchers have developed classification systems, such as NOVA, which differentiate foods based on the type, extent, and purpose of processing.[40,42] NOVA has been used in over 17 countries to aid in the development of dietary guidelines and nutrient profiling systems and to assess associations with diet-related health outcomes.[40] More specifically, NOVA has been used as an indicator of food product healthiness, because unprocessed and minimally processed foods are considered to have higher nutritional value and contribute to healthier diets compared with highly processed foods.[39,40,42,44,46,48]

Because of its relative simplicity as a general indicator of a food's nutritional quality, a focus on level of processing provides a potential means of evaluating consumer nutrition knowledge in population health surveys. Additionally, a measure with this focus could enable cross-country comparisons that are not possible with current measures. To this end, we developed the Food Processing Knowledge (FoodProK) score, a 12-item food rating task to measure nutrition knowledge based on consumers' ability to understand and apply principles related to level of processing. The current study examined the content validity of the FoodProK score based on subject matter expert consultation with registered dietitian nutritionists (RDNs), and the extent to which experts perceived level of food processing as an appropriate indicator of the general nutritional quality of foods.

RESEARCH SNAPSHOT

Research Question: Is a new functional test that assesses knowledge of level of food processing a reasonable indicator of consumers' general nutrition knowledge?

Key Findings: In this cross-sectional study, a convenience sample of 64 registered dietitian nutritionists (RDNs) participated in content validity testing of the consumer knowledge test and rated 12 food products based on perceived healthiness. Respondents were assigned a score reflecting congruence of their ratings with level of processing based on the NOVA classification system (ie, higher score if product ratings decreased as level of processing increased). Seventy-percent of RDNs scored 7 and above on the 8-point scale. Preliminary content validity evidence suggests this score is a reasonable measure of general nutrition knowledge.

MATERIALS AND METHODS

Sample

Dietitians were recruited using convenience sampling in January 2020 via an online survey link included in the bimonthly Registered Dietitians of Canada newsletter, which has a membership of 4,600 RDNs across Canada. Eligible participants were RDNs in Canada (assessed via self-report) and at least 18 years of age. RDNs were selected for the initial evaluation of the FoodProK given their subject matter expertise in nutrition, particularly in educating the public about healthy foods and eating behaviors. The survey was created using Survey Gizmo, an online platform that enabled survey administration via desktops, laptops, tablets, and smartphone devices. Respondents provided informed consent before completing the online survey. No incentives were provided; however, respondents were notified that results would be shared after study completion. The study was reviewed by and obtained clearance from a University of Waterloo Research Ethics Board (ORE #36005).

Food Rating Task and Calculation of the FoodProK Score

As part of ascertaining content validity of the FoodProK, respondents completed the 12-item measure and provided feedback on the extent to which the measure was relevant and appropriate as a proxy for the general nutritional quality of foods. First, respondents viewed and rated images of three food products within four categories (fruits, meat, dairy, and grains). These categories were selected based on the food groups that commonly appear in national dietary guidelines, such as Canada's Food Guide and the United States' Dietary Guidelines. Food product selection entailed shortlisting specific product options from the four food groups that represented different levels of food processing. Products in each category were reviewed and selected by the authors based on consensus. The final product shortlist was determined based on availability in multiple international contexts, and to represent varied levels of processing. Each category included a food in group 1 ("un/minimally processed"/"whole food"),

group 3 ("processed"), and group 4 ("ultraprocessed") based on the NOVA classification system (Figure). Three reviewers with nutrition training independently categorized the 12 foods according to NOVA, with no discrepancies identified across reviewers.

The 12 product images and corresponding Nutrition Facts tables (NFts) and ingredient lists were displayed on the screen one at a time, in random order. While viewing each product, respondents were asked, "Overall, how healthy is this food product?" using a scale from 0 to 10, with 0 representing "not healthy at all" and 10 indicating "extremely healthy." Branding on food packages was removed, and generic product names were used to minimize the potential for bias based on brand familiarity.

FoodProK scores were calculated based on the concordance of healthiness ratings within each food category with the rankings based on the NOVA classification, with less processed foods representing higher healthiness. Respondents received a full score of 2 if their food product ratings corresponded with the order of NOVA food processing groups (eg, apple > apple sauce > apple juice). If the respondent ranked two of three products in a given category in accordance with NOVA (eg, apple > apple juice > apple sauce), they received a score of 1. Zero was assigned if the respondent's rankings did not align with those based on NOVA. Scores were summed across the four food categories to create the total FoodProK score, ranging from 0 to 8.

Capturing Open-Ended Feedback for the FoodProK Score

After the FoodProK scoring task, RDNs were queried about the appropriateness of this measure for assessing the general nutritional quality of foods. To assess face validity, RDNs were asked the open-ended question, "When you were rating each of the foods, what were the main factors that you considered in your rating?" The importance of processing was assessed by asking, "Overall, how important is level of processing to the healthiness of foods?" with five-point Likert-scale responses ranging from "very important" to "not important." The RDNs were also asked, "In your opinion, is level of processing (eg, "fresh" unprocessed vs ultraprocessed foods) a reasonable indicator of the general nutrition level of different foods?", with the response options "yes," "no," and a follow-up asking them to explain why or why not. Finally, RDNs were asked, "Were any of the food rating task questions confusing or unclear?" with response options "yes" or "no," and a follow-up question prompting an explanation. Respondents were not given the option to return to previous survey questions. This survey feature ensured that

NOVA Food Classification	Fruit products	Meat products	Dairy products	Grain products
Minimally processed (group 1)	Apple 	Chicken breast 	1% milk 	Oats 
Processed (group 3)	Apple sauce 	Deli meat 	Cheese block 	Cereal 
Ultra-processed (group 4)	Apple juice 	Chicken nuggets 	Processed cheese slices 	Cereal bar 

Note: NOVA Group 2 foods, defined as processed culinary ingredients extracted from whole foods (i.e., oils, flours, sugars), were not included as they are typically used in meal preparation rather than consumed on their own.

Figure. Food products rated by RDNs in the Food Processing Knowledge score based on levels of food processing from the NOVA food classification system.

respondents could not modify answers based on later survey questions that may have suggested the importance of food processing in the rating task.

Comparing Food Rating Task Performance with Alternate Question Formats

After rating the healthiness of 12 products presented individually, the RDNs were asked, "In general, which of the following foods is healthier?" using a multiple-choice format. This question was asked to compare the two processed food products in each category (ie, apple sauce vs apple juice, cheese block vs processed cheese slices, cereal vs cereal bar, deli chicken slices vs chicken nuggets), with the option of indicating "no difference" for each comparison. The RDNs were further asked to explain their choice and what the main difference was between the two foods in each category. Responses were coded as "correct" if the less processed food in each category was selected.

Statistical Analyses

Descriptive statistics were used to summarize the sample profile, food product ratings, and overall FoodProK score. A one-way repeated-measures (within-subject) analysis of variance was conducted to test for differences in mean food product ratings. Pairwise comparisons between food products in each category were tested, adjusting for multiple comparisons using the Bonferroni correction. A total of four tests were run to assess whether the mean ratings significantly differed for the three products within each food category (fruit, grain, dairy, meat). Analyses were conducted using SPSS Statistical Software (Version 26.0; IBM Corp., Armonk, NY; 2018). Values of $P < 0.05$ were considered statistically significant.

A sample size calculation was conducted to ensure sufficient power to detect a 1-point difference in FoodProK scores. The mean and standard deviation for the "processed" product in each food category (apple sauce, deli meat slices, cheese block, cereal) was input into an inference for means test comparing two independent samples to determine the required sample size at alpha = 0.05 and a desired power of 0.80 for a two-sided test. The minimum sample size required was 53 respondents to detect a 1-unit difference in product ratings.

To analyze the open-ended data, the first author reviewed all of the responses and created new variables representing common factors that the RDNs considered when completing the food product ratings. Participants' responses were coded according to whether they mentioned a particular factor. Other relevant open-ended comments were summarized, highlighting several example quotations.

Table 1. RDNs' mean food product ratings based on perceived healthiness and performance on the Food Processing Knowledge score (n = 64)

	Mean rating (SD)	*F*-statistic, *P* value	β (by product), *P* value	Category score = 1 2 of 3 products in correct order % (n)	Category score = 2 All 3 products in correct order % (n)
Fruit category				14.1% (9)	85.9% (55)
Apple	9.61 (0.68)	$F = 425.64$, $P < 0.001$	9.61, 0.001		
Apple sauce	7.50 (1.83)		7.50, 0.001		
Apple juice	2.38 (1.84)		2.38, 0.001		
Dairy category				14.1% (9)	85.9% (55)
1% milk	8.92 (1.06)	$F = 271.38$, $P < 0.001$	8.92, 0.001		
Cheese block	6.89 (1.52)		6.89, 0.001		
Processed cheese slices	3.39 (2.08)		3.39, 0.001		
Grain category				26.6% (17)	73.4% (47)
Oats	9.00 (1.07)	$F = 231.84$, $P < 0.001$	9.00, 0.001		
Cereal	7.05 (1.57)		7.05, 0.001		
Cereal bar	3.41 (1.74)		3.41, 0.001		
Meat category				45.3% (29)	54.7% (35)
Chicken breast	9.02 (1.11)	$F = 285.89$, $P < 0.001$	9.02, 0.001		
Deli chicken slices	4.27 (1.94)		4.27, 0.001		
Chicken nuggets	3.41 (1.87)		3.41, 0.001		

All food products within each category are listed in order of least to most processed. No RDN received a score of 0 in any of the food categories. "Correct" ordering refers to ratings that correspond with NOVA classification of processing, where group 1 foods are rated highest, group 4 foods are rated lowest, and group 3 foods are rated between group 1 and group 4 foods.

RESULTS

Sample Profile

A total of 81 RDNs responded to the survey. After excluding those with incomplete surveys (n = 17), 64 were included in the analysis. A total of 55 (85.9%) indicated their role involved educating patients or the public about nutrition. Dietitians reported a mean of 13.1 years' professional experience (standard deviation [SD] = 11.3) and median of 10 years. The survey took a median of 15 minutes to complete.

Performance on the FoodProK Score

Table 1 shows mean ratings for each food product, as well as results from the one-way repeated-measures analysis of variance tests. To illustrate congruence of the RDNs' rankings with those based on the NOVA system, the proportion of respondents who correctly ordered two vs all three food products in a given category are shown.

The RDNs' mean ratings for individual food products corresponded with NOVA groups within each of the four food categories, with 85.9%, 85.9%, and 73.4% correctly ordering food products based on level of processing in the fruit, dairy, and grain categories, respectively. The meat category was an exception, with approximately half of respondents (54.7%) correctly rating the healthiness of meat products based on the NOVA classification system.

Of a possible maximum of 2 points, the mean scores for the fruit and dairy categories were 1.86 (SD = 0.35), 1.73 (SD = 0.44) for grains, and 1.55 (SD = 0.50) for the meat category. The mean total FoodProK score was 7.00 out of 8.00 (SD = 0.82). Overall, 39.1% received 7 out of 8, and 31.2% of respondents received a perfect FoodProK score of 8.

Food Rating Task vs Multiple Choice

Most respondents who selected the correct response in the multiple-choice question also rated the individual food products in the same order (eg, higher rating for apple sauce than apple juice), with the exception of the grain and meat categories. Based on the multiple-choice format, when asked which grain product was healthier, 30.6% reported no difference between cereal and cereal bar, with 11.3% selecting "don't know." In the meat category, 49.3% of respondents reported no difference between deli chicken slices and chicken nuggets, and 9.9% selected "don't know" in response to the multiple-choice question.

Open-Ended Feedback on the FoodProK Scoring Task

When asked to explain their food product ratings, respondents commented on core nutrient differences. In the fruit category, respondents noted higher fiber content and satiety, as well as lower sugar content in apple sauce compared with apple juice. When comparing the dairy products, respondents commented that the cheese block had fewer additives, less sodium, and overall processing than the cheese slices. In the grain category, respondents noted there was less sodium, sugar, and additives in cereal compared with the cereal bar. Those who selected "no difference" between the two grain products commented that specific product details were required to assess which product was healthier. For example, one RDN said, "This depends on the product. Many cereals are over-processed and full of added sugar and salt! Some bars have a decent amount of protein and not as much added sugar. Again—this varies greatly." With respect to the meat category, respondents noted that deli chicken slices contained less total/saturated fat and fewer ingredients compared with the nuggets, with several respondents commenting on differences in sodium, carbohydrates, and calories. Respondents who said there was no difference between these products commented that both were highly processed and contained a lot of sodium.

When rating each of the foods, the main factors respondents reported considering were the nutritional value of the food products (ie, presence of "positive" and "negative" nutrients), degree of processing, and ingredient lists (Table 2).

Approximately 80% of respondents reported level of processing as important to the healthiness of foods (3.1% "slightly important," 17.2% "moderately important," 39.1% "important," 40.6% "very important"). Overall, 81% of respondents agreed that level of processing is a reasonable indicator of the general healthiness of foods. When asked to explain their response, respondents noted that level of processing reflected amounts of negative nutrients such as salt, fat, and sugar, and that unprocessed foods have higher nutritive value; however, it is not the only factor that should be considered, because many nutritious foods are also processed. One RDN stated, "As foods are more heavily processed, they tend to contain higher levels of salt, sugar, and saturated fat. Higher processed foods also tend to be lower in whole grains, vitamins, and minerals (unless added during processing). This is an easy indicator (usually)." Finally, 89% reported that the FoodProK was not confusing or unclear. Among the 11% who indicated concerns with survey question clarity, feedback included issues with the use of the term *extremely healthy*, and difficulty rating healthiness without specific guidelines.

Table 2. Factors considered in rating the healthiness of 12 food products included in the Food Processing Knowledge score by Registered Dietitians in Canada (n = 64)

Factor	Frequency (n)
'Negative' nutrient amounts (ie, sodium, saturated fat, sugar)	45
Degree of processing	32
'Positive' nutrient amounts (ie, fiber, protein, vitamin/mineral content)	30
Ingredients lists	20
Whole food	9
Full nutrient profile	9
Congruence with dietary guidelines	5
Other (eg, freshness, caloric content, plant vs animal based)	5

Each respondent provided a list of factors; therefore, the frequency reflects the total number of times each factor was mentioned.

DISCUSSION

This study examined initial content validity of the FoodProK score—a proxy measure of consumer nutrition knowledge based on level of food processing. Despite the wide range of factors that contribute to the nutritional profile of foods, RDNs rated the healthiness of 12 food products in congruence with the NOVA system, which confirmed the expected relationship between the FoodProK score and level of processing (ie, more processed foods were perceived as less healthy). In addition to completing the FoodProK measure, content validity was further assessed via open-ended feedback to determine whether level of food processing was a relevant indicator of the general nutritional value of foods. The multiple-choice food ranking task question provided a point of comparison for individual product healthiness ratings in the FoodProK, and reiterated RDNs' mean food ratings based on level of processing.

Although the FoodProK is intended for use among consumers, this initial assessment among RDNs was a critical first test to determine whether the premise of using level of food processing as a proxy for nutrition knowledge was relevant and appropriate. Moreover, before testing among consumers, the congruence of RDNs' food product ratings with the NOVA system was necessary for testing the scoring system.

A closer look at the FoodProK scores showed a potential issue with the meat category, because only 55% of RDNs correctly ordered all meat products according to NOVA. Qualitative feedback demonstrated that some RDNs did not perceive meaningful differences between the processed meat products because of high sodium content in both deli chicken slices and chicken nuggets. These findings suggest that several improvements can be made to the next iteration of the FoodProK, including use of a different processed meat product to better illustrate the distinction between group 3 and 4 NOVA categories.

More importantly, the findings highlight the complexity of food processing as a concept. Many RDNs provided responses such as "it depends," indicating that a simple rating task cannot fully capture the nuances that RDNs considered when rating the healthiness of foods. This finding reiterates the importance of including NFts and ingredient lists alongside food product images in the FoodProK, as this enabled respondents to make informed ratings.

There is a lack of consensus in the nutrition community more broadly regarding what is a "healthy food,"[15,30,32] which further complicates the measurement and content validity testing of nutrition knowledge based on an understanding of product "healthiness." The FoodProK assesses only one component of nutrition knowledge and does not assess other important factors that determine diet quality, such as food purchasing and the frequency with which different foods are consumed. However, the design of the FoodProK is consistent with existing evidence that supports use of level of processing as an indicator of product healthiness.[39,40,42,44,46,48,51] In addition, the use of "level of processing" as a proxy measure of nutrition knowledge is consistent with greater emphasis on food processing within national dietary guidelines, such as in Brazil and Canada.[11-15,32-34]

In an attempt to reflect some of the nuance in the concepts of healthiness and processing, the NOVA classification system was specifically selected because of its ability to distinguish among various levels of processing.[40,42] Monteiro et al. (2019) argue that binary classification of products as processed/not processed is less useful given that most foods are processed in some way.[40] NOVA functions similarly to other nutrient classification systems such as the Ofcom nutrient profiling model in the United Kingdom, which scores foods based on positive and negative nutrient content,[52] and the Health Star Rating system in Australia, which assigns a star rating to foods based on positive and negative nutrient content across different food categories.[19] Regardless of the system used, these nutrient profiling systems reflect the association between level of processing and healthfulness, because more highly processed foods have a greater proportion of "negative nutrients" (ie, sodium, sugars, fats) and therefore receive lower scores.[39,40,42,51]

Overall, the FoodProK score has the potential to serve as a functional test of general nutrition knowledge across contexts because of the use of food products that can be found in multiple settings and adaptability of NFts to country-specific guidelines. Use of such a measure in large population-based studies can enable cross-country comparisons unlike longer, more complex measures to shed light on consumer nutrition knowledge patterns.

The findings of this study should be interpreted in light of several limitations. The study relied on a convenience sample of RDNs; hence, we cannot determine whether the sample is representative of the overall dietetic community. Open-ended questions were used to obtain qualitative feedback; however, in-person methods may have facilitated more detailed responses. Although the NOVA system does not consider portion size,[42] we addressed this limitation by providing images of NFts in the FoodProK scoring task. In addition, NOVA provides definitions and food product examples to aid classification (i.e., deli meat is a 'processed' group 3 food), but specific ingredients lists were not used in determining the classification, which affected the NOVA classifications for several products. Finally, the current study only tested face and content validity among subject matter experts, but not among general consumers. Next steps include FoodProK testing and cognitive interviews among consumers in Canada and other geographic contexts, which span various age, sex, education, and literacy levels to assess whether similar issues in the FoodProK are identified, and whether further modifications are required. Test–retest reliability or other types of validity (eg, convergent, criterion) were not assessed; thus, further psychometric testing in diverse samples is necessary to build validity evidence for the FoodProK score.

Finally, the development of the FoodProK is not intended to assess level of processing as the only or most important factor in diet quality. Overall quality of dietary intake can include a wide range of foods and is largely determined by the frequency with which these foods are consumed; however, for consumers to achieve this balance, they require some understanding of which foods should be consumed more or less frequently. The FoodProK assesses consumers' basic ability to evaluate foods based on the broad category of levels of processing. Nevertheless, the FoodProK should be

assessed in conjunction with other measures of nutrition knowledge, as well as dietary intake, to examine comparability with existing tools.

CONCLUSIONS

Level of food processing may provide a reasonable proxy for assessing basic consumer nutrition knowledge, particularly in population-based surveys that require brief assessment tools. The FoodProK may provide a basis for comparing nutrition knowledge across countries, although specific food products may need to be adapted for different national food markets. Finally, revision of the processed products used in the "meat" category would likely enhance agreement between the FoodProK score and RDNs' ratings. Future validity testing among consumers will contribute to validity evidence for the FoodProK.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

The authors have no affiliations with the food industry and there are no conflicts of interest to declare.

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All authors contributed to development of the survey. JB and DH collected the data, conducted analyses, and wrote the first draft with contributions from SIK, LV, and MGH. All authors reviewed and commented on subsequent drafts, and provided final approval of the manuscript.