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Review

Nutrient Profiling Models in Low- and Middle-Income Countries Considering Local Nutritional Challenges: A Systematic Review

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ABSTRACT

Micronutrient deficiencies, undernutrition, and overweight/obesity are prevalent in low- and middle-income countries (LMICs). Nutrient profiling models (NPMs), initially developed to help reduce the prevalence of diet-related chronic diseases in Western countries, could be one solution to promote nutrient-dense foods in LMICs. This study reviewed government-endorsed NPMs implemented in LMICs and assessed their key components in relation to country-specific nutritional challenges. The peer-reviewed and grey literature were systematically reviewed to identify government-endorsed NPMs implemented in LMICs to promote healthier choices among adults. Their key metrics, including scope, components, units, and validation method, were extracted. The prevalence of undernutrition; overweight/obesity; and iron, vitamin A, and iodine deficiencies were extracted from the Global Health Observatory and the Global Burden of Disease study. NPMs have been implemented in 16 LMICs to encourage healthier choices, mostly through front-of-pack labeling schemes. Warning Label schemes are used to strongly discourage the consumption of energy-dense products in countries where overnutrition affects most of the population, such as Latin American LMICs. A "Keyhole" front-of-pack labeling scheme was implemented only in North Macedonia. It limits sugar, fat, and salt while promoting fibers, fruits, vegetables, nuts, and legumes to prevent overnutrition and diet-related chronic diseases. "Choices" schemes that focus on positive messages have been implemented in Southeast Asia and Zambia where over- and undernutrition coexist. "Choices" criteria encourage the consumption of category-specific vitamins and minerals, in addition to advocating limiting certain nutrients. In LMICs, NPMs focus on discouraging the consumption of sugar, fat, and salt. Additionally, NPMs promote category-specific micronutrients in countries where undernutrition remains prevalent or food components associated with a reduced risk of diet-related chronic diseases, including whole grains and fibers, in countries where overnutrition is the main nutrition-related public health issue.

This study was registered at PROSPERO as CRD42023468807.

Keywords: nutrient profiling, malnutrition, double burden, nutrition policy, nutritional quality, public health, systematic review, food quality

Introduction

Overweight and obesity affected 2.5 billion adults in 2022, representing a major risk factor for cardiovascular diseases, diabetes, and certain cancers [1]. The prevalence of overweight/obesity is higher in high-income countries with 6 out of 10 people suffering from overweight/obesity disorders [2]. Despite their global spread, diet-related chronic diseases are largely preventable. Food policies, such as front-of-pack labeling (FOPL), marketing regulations, and food taxes are intended to promote dietary change by making healthier dietary choices more accessible and desirable [3]. The promotion of healthier food choices can be supported by nutrient profiling models (NPMs). These classify or rank foods according to their nutritional composition for reasons related to preventing disease and promoting health [4]. The use of NPMs to support FOPL schemes in high-income countries has resulted in healthier product purchases [5,6]. Three examples of efficient FOPL models are Nutri-Score [7], Health Star Rating [8], and Multiple Traffic Lights [9], all of which are based on the NPM developed by the UK Food Standard Agency for the broadcast

Abbreviations: FOPL, front-of-pack labeling; GINA, Global database of the Implementation of Nutrition Action; GNP, gross national product; LMIC, low- and middle-income country; NPM, nutrient profiling model; PAHO, Pan American Health Organization; USD, United States dollars.

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regulator, Ofcom [10]. Their implementation has been associated with improving the nutritional quality of consumers' shopping carts in France [11] and with reformulation of packaged food in New Zealand [12].

Dietary patterns across low- and middle-income countries (LMICs) have shifted over the past 50 years from local traditional diets to the consumption of readily available and accessible energy-dense foods [13], with an increased consumption of packaged foods and beverages [14]. Prevalence rates of overweight and obesity are rising in LMICs while undernutrition and micronutrient deficiencies remain 2 important public health issues [15]. Iodine and vitamin A deficiency are still widespread in Central sub-Saharan Africa, and dietary iron deficiency is prevalent in South Asia [16]. In this context of double burden of malnutrition, several NPMs have been developed or adapted in LMICs to reduce consumption of sugars, fats, and salt and promote nutrient-dense packaged foods. As an example, Colombia, Argentina, and Mexico have recently adapted the Chilean black warning system to restrict food products based on content in total sugars, saturated fats, sodium, and nonsugar sweeteners [17]. Likewise, Malaysia, Indonesia, and Thailand have implemented the Healthier Choice Logo, a category-specific FOPL scheme developed in Singapore to limit nutrients such as energy, fat, sodium, and total sugars and to encourage components including dietary fiber, whole grains, and some category-specific micronutrients [18]. However, limited information is available about how existing NPMs were adapted or new models developed to tackle the double burden of malnutrition and hidden hunger in LMICs.

The overall aim of this study was to review NPMs implemented in LMICs and assess their key components in relation to country-specific nutritional challenges. The following research questions were addressed:

1. How many LMICs have implemented NPMs?
2. What types of NP models have been implemented in LMICs to support healthier food choices among adults?
3. What are their key components?
4. Are there similarities between the metrics used per region, country's level of income, or most prevalent nutrition-related public health challenges?

The study focused on NPMs developed to support healthier choices in an adult population because WHO offices have already provided uniform guidance at a regional level for marketing to children [19,20].

Methods

Information on country-specific nutritional challenges as well as characteristics of NPMs implemented in LMICs were collected in 6 steps presented in Figure 1.

Two previously published systematic reviews from Labonté et al. (2018) [21] and Martin et al. (2023) [22] were used as a first source of information to identify which NPMs have been implemented in LMICs (Step 1) before 2020. To ensure that NPMs published after 2020 would be captured, we systematically reviewed the peer-reviewed and grey literature from 2020 to 2023 following the PRISMA statement, and a protocol was pre-registered with PROSPERO [CRD42023468807] (Step 2).

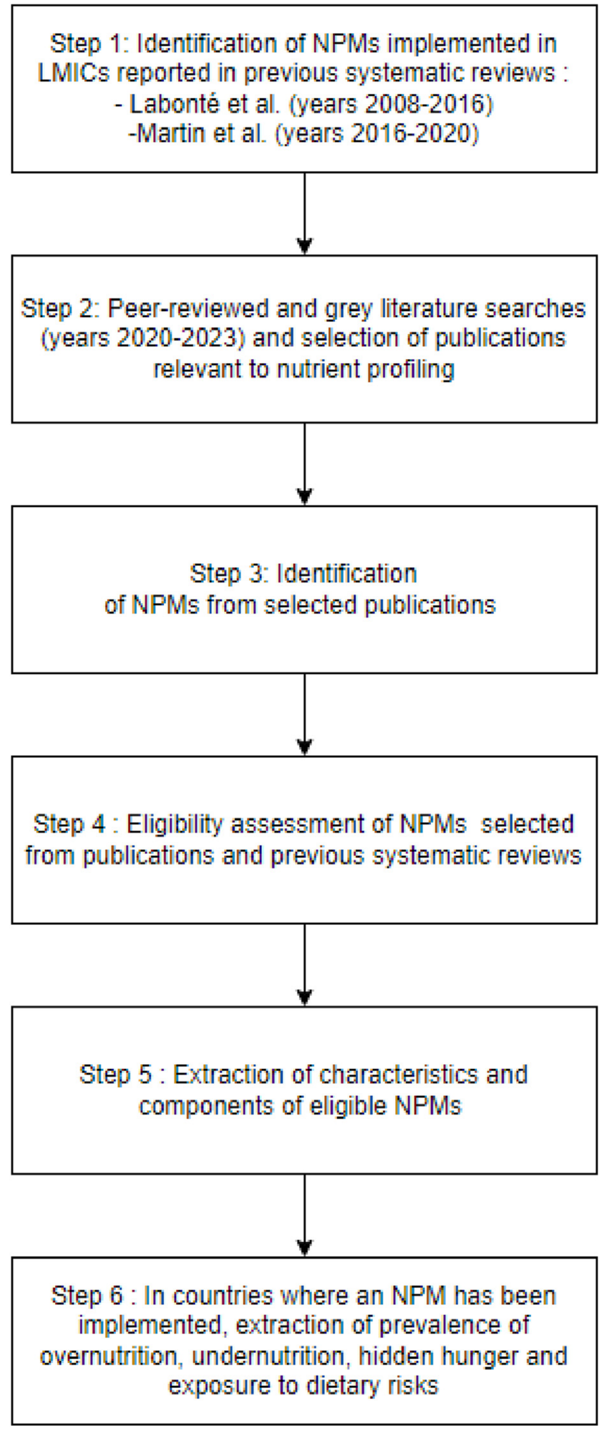

FIGURE 1. Steps of the systematic review. GINA, Global database of the Implementation of Nutrition Action; LMIC, low- and middle-income country; NPM, nutrient profiling model.

Publications relevant to the nutrient profiling field were selected (Step 2), and potential NPMs identified (Step 3). NPMs selected from publications and previous systematic reviews were assessed for eligibility (Step 4). Characteristics and components of each eligible model were extracted (Step 5). Finally, in countries where an NPM has been implemented, information on prevalence of overnutrition, undernutrition, and hidden hunger was extracted (Step 6).

Step 1. Identification of NPMs implemented in LMICs reported before 2020 in previous systematic reviews

The systematic reviews from Labonté et al. and Martin et al. provided a summary of NPMs endorsed by LMIC governments from 2008 to 2020 [21,22]. LMICs were defined according to the 2023 World Bank lending groups as countries with a gross national income per capita below $13,205 United States dollars (USD) in 2021 [23].

Step 2. Searches of peer-reviewed and grey literature between 2020 and 2023 to identify relevant reports

Literature searches were performed using 3 peer-reviewed scientific databases: Scopus, Web of Science and PubMed, and 4 grey literature databases: Google Scholar; World Cat, a global catalog of library materials [24]; the WHO Global database of the Implementation of Nutrition Action (GINA) [25]; and resources from the Global Food Research Program from University of North Carolina – Chapel Hill [26–28]. The following search terms were used: nutrient profil* or nutritional profil* or nutrition profil* or food classif* associated with low income countr* or middle income countr* or a country name from the 2023 World Bank lending groups list. Detailed search terms per database are provided in Supplementary Table 1. For peer-reviewed databases, the search was restricted to September 2020 to September 2023 to follow-up on the study from Martin et al. [22]. Precise dates could not be selected in the grey literature. World Cat was searched for literature from 2020 to 2023 and the GINA database for policies still in use in 2023. The Global Food Research Program maps were last updated in 2023. No language restriction was applied in these searches.

Two reviewers (MT and RVD) searched the literature and independently extracted relevant records on October 4, 2023, using Endnote X9.1 [29]. All reports were imported from Endnote X9.1 to Covidence, a web-based tool aimed at improving the production of systematic reviews [30]. Covidence software automatically checked for duplicates. Any remaining duplicates were identified and removed manually. Following the Covidence framework, MT and RVD independently screened titles, abstracts, and full text in Covidence. No restriction was applied on the type of record included provided that it was relevant to the topic of nutrient profiling in LMICs. Main reasons for exclusion were studies focusing on the nutritional composition of specific plants or ingredients, the health and nutritional status of a specific population, or models classifying foods according to processing level (e.g., NOVA) with no additional nutritional criteria [31]. Conflicts were resolved by consensus.

Step 3. Identification of potential NPMs from relevant publications and previous systematic reviews

From relevant reports, legislation, classifying systems, guidelines, or criteria aiming to classify or rank foods according to their nutritional quality were classified as potential NPMs. In scientific publications, models were mentioned in the abstract, introduction, or discussion section or tested as part of the study. In legislation, criteria underlying the model were described in the body of the text or in the annex. In the Global Food Research maps, the output of the model was displayed per country. NPMs implemented in LMICs and identified in the 2 preceding systematic reviews from Labonté et al. and Martin et al. were added to the list.

Information on the founding organization, endorsement by a government, country or region where the model was implemented, country or region where the model was tested, and year of implementation were retrieved from the reports. When elements were missing in the reports, targeted literature searches were performed in the Google search engine or relevant governmental websites.

Step 4. Eligibility assessment of potential NPMs selected from relevant publications and previous systematic reviews

The eligibility criteria to select potential NPMs appear in Table 1. The eligibility criteria used by Labonté et al. and Martin et al., labeled A through J in Table 1, were applied to identify NPMs from government-led nutrition policies. In addition, 2 new criteria were added to correspond with the objectives of this study: K, endorsed by a LMIC or region, defined according to the 2023 World Bank Lending Groups list; and L, models developed for application in adult populations including FOPL, food taxation, and nutrition or health claims communications. Criteria J was modified because translation software was used when details of NPMs were not available in French or English, namely Google Translate and ChatGPT 3.5.

Step 5. Extraction of characteristics and components of eligible NPMs

Eligible NPMs were described according to 7 characteristics: scope, components, reference quantity, output, validation, and application [4,32,33]. The scope of an NPM was either focused on certain food categories or across-the-board, i.e., the same criteria was applied to all food categories. Number and type of food categories were detailed for each model. NPM components included both nutrient and food components and could either be qualifying components such as vitamins, minerals, whole grains or fibers, or disqualifying components such as sodium, sugars, or SFAs. The reference quantity of NPM criteria was classified as per 100 g or 100 mL, 100 kcal or 100 kJ, or serving. The output of the model was either a score or a threshold. An NPM could be validated through content, face, construct/convergent, criterion/predictive methodology, or indirectly [21,22]. Details on each form of validation are provided in Supplementary Table 2. The application of a NPM could be FOPL, marketing or claims regulation, or food taxation. NPMs supporting FOPL schemes were also compared according to their expression, i.e., the tone of voice of the scheme (positive, mixed, or negative) [34]. NPMs that were derived from a previously implemented NPM were captured as an additional characteristic of the model [22].

Characteristics of each eligible NPM were independently extracted by MT and RVD, using information available in relevant reports, previous systematic reviews, targeted searches using a search engine (Google) and on government websites, or obtained from request to the authors of a model. Conflicts were resolved by consensus.

TABLE 1
Inclusion and exclusion criteria.

Reason	Inclusion criteria	Exclusion criteria
A	Models allowing for the classification of individual foods	Models only allowing for the classification of combinations of foods such as meals or diets
B	Models including criteria for >1 nutrient or food component	Models focusing criteria on 1 nutrient or component such as sugar-sweetened beverages
C	Models including criteria for ≥1 nutrient and possibly other food components	Models assessing nutritional quality based solely on the food category
D	Models in which the output includes at least an interpretive element	Models with no interpretative element, i.e., solely providing the nutritional composition of a product, without ranking between foods
E	Models endorsed by a government or intergovernmental organization	Models developed by other types or organization, i.e., research groups or food manufacturers
F	Models intended for use at a country or regional level	Models intended for a specific/narrow level use, i.e., below country-level
G	Details of the models are publicly available in peer-reviewed or grey literature	No details of the model are publicly available or found
H	Models that are currently in use	Models that have been discontinued or never implemented
I	Models that do not duplicate previously included information	Models that represent a duplication from another model
J	Full details of the model are available in English/French or could be translated using translation software (Google Translate or ChatGPT 3.5)	Details of the models could not be translated
K	Models endorsed by a low- or middle-income country or region, according to 2023 World Bank list	Models endorsed by a high-income country government/institution only, according to 2023 World Bank list
L	Models developed for adults including front-of-pack labeling, food taxation, and nutrition or health claims communications	Models developed for children only, i.e., marketing to children regulation, school food regulation

Step 6. Extraction of prevalence of overnutrition, undernutrition, and hidden hunger

The development of an NPM starts with identifying nutrient-related public health problems in the region of implementation and establishing their relationship with existing dietary patterns [4]. The goal of this last step was to understand in which country-specific nutritional context the selection of nutrient profiling characteristics and components was made. The prevalence of nutrition-related public health issues in countries where an NPM has been implemented was collected by assembling data from 2 sources.

The WHO Global Health Observatory database was used as a primary source of information for the prevalence of overnutrition and undernutrition. Given the focus on adult populations, over- and undernutrition were respectively captured as the prevalence of overweight /obesity (BMI ≥25 kg/m^2) and underweight (BMI <18.5 kg/m^2) among adults [35]. These estimates were based on the NCD-Risk Factor collaboration [36] and were retrieved from the year of implementation of the NPM in each concerned country. The most recent year available in the WHO Global Health Observatory database was 2022.

The Global Burden of Disease Compare tool from the Institute of Health Metrics and Evaluation provided further information on hidden hunger in populations of interest. The prevalence of iron, vitamin A, and iodine deficiencies was captured among males and females 15 to 49 years old [37]. Global Burden of Disease modeling methodology has been described elsewhere [38] and details on the definition of each deficiency is provided in the supplementary material. As for over- and underweight, data were retrieved from the year of implementation of the NPM in each concerned country up to 2021, the most recent year available.

Additionally, the World Bank provided gross national product (GNP) per capita in USD at the time an NPM was implemented. GNP has previously been associated with the double burden of malnutrition and nutrition transition in LMICs [15,35] and was hypothesized to be a summary indicator correlated with NPM characteristics.

Results

NPMs supporting a government-led nutrition policy in LMICs and their main characteristics

During literature searches, 1892 records in peer-reviewed and grey literature databases were identified (Figure 2). After exclusion of 1394 during title and abstract screening, 236 studies were considered relevant to the field of nutrient profiling and selected for full-text review.

From the 236 studies evaluated by full-text review, 81 potential NPMs were extracted. This list complemented the 17 NPMs identified by Labonté et al. and Martin et al. as being implemented in LMICs. After removing duplicates, 86 potential NPMs were assessed for eligibility and 18 models were included in the final study. The list of potential NPMs excluded is provided in Supplementary Table 3. The main reasons for exclusion during eligibility assessment were implementation in a high-income country and not a LMIC (31 models), application in a child population only (11 models), and the absence of endorsement by a government (11 models). Eight new models were identified compared to previous systematic reviews. However, 7 models previously identified as being implemented in LMICs by Labonté et al. and Martin et al. were assessed as not eligible for this study. A summary of the main characteristics of each NPM is presented in Table 2 [22,26,39–56].

In LMICs, most NPMs support a nutrition-related policy implemented after 2019, usually a FOPL scheme. Other models set criteria for nutrition or health claims, food taxes, or advertisements for the general population. Policies supported by an NPM were not evenly distributed across regions. In Latin America, 7 of 26 LMICs have launched a FOPL scheme, sometimes in addition to food taxes or regulations on advertisement

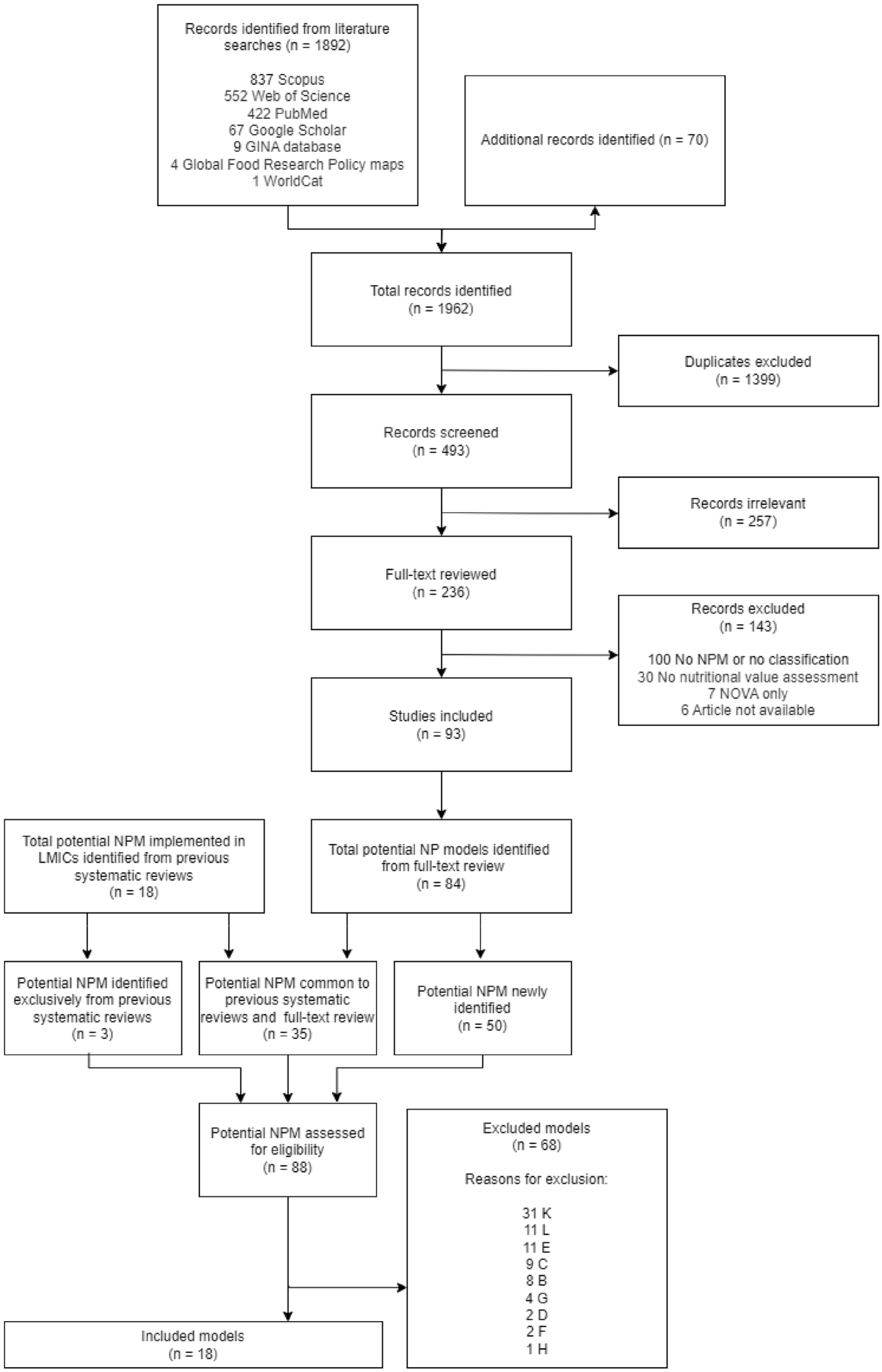

FIGURE 2. Flow diagram of records and nutrient profiling models selection. Reasons for exclusion, listed by letter, are defined in Table 1.

TABLE 2
Characteristics of nutrient profiling models implemented in LMICs to support government-led nutrition-related policies.

World Bank Region	LMIC	Model name	Date of implementation or dissemination	Organization name	Main purpose	If main purpose is front-of-pack labeling, type of scheme (tone of voice)	Model derived from other models? (Country)	Identified in previous reviews	References
Sub-Saharan Africa	Ethiopia	Ethiopia Fiscal policy	2020	Republic of Ethiopia	Food taxes	—	No	No	[39]
Sub-Saharan Africa	Zambia	Zambia Good Food Logo	2020	Zambia's Ministry of Health, Scaling Up Nutrition Business Network (SBN), Zambia Bureau of Standards, The National Food and Nutrition Commission of Zambia	Front-of-Pack Labeling	Choices (positive)	Yes, Choices (International)	Yes, Martin et al, 2023	[22]
Sub-Saharan Africa	South Africa	South African Nutrient Profiling Model	2013	Centre of Excellence for Nutrition, North-West University, South Africa; Food Standards Australia New Zealand	Nutrition or health claims	—	Yes, Food Standard Australia New Zealand NPM (Australia, New Zealand)	Yes, Labonté et al, 2018	[40]
Sub-Saharan Africa	South Africa	South African Warning Labels	2023	South Africa Department of Health	Front-of-Pack Labeling	Warning Labels (negative)	Yes, Warning Labels (Chile)	No	[40]
Middle East and North Africa	Iran	Iran Traffic Lights Labelling System	2015	Iran's Ministry of Health and Medical Education	Front-of-Pack Labeling	Traffic Light Labels (mixed)	Yes, Traffic Light Labelling (United Kingdom)	Yes, Martin et al, 2023	[41,42]
Europe and Central Asia	North Macedonia	North Macedonia Keyhole	2015	Swedish National Food Administration, Norwegian Directorate of Health and Norwegian Food Safety Authority, Danish Veterinary and Food Administration	Front-of-Pack Labeling	Keyhole (positive)	Yes, Keyhole (Sweden, Northway, Denmark, Iceland)	No	[26,43]
East Asia and Pacific	Indonesia	Indonesian Healthier Choice Logo	2019	Indonesian Food and Drug Authority	Front-of-Pack Labeling	Choices (positive)	Yes, Choices (International)	No	[44]
East Asia and Pacific	Thailand	Thai Healthier Choice Logo	2016	Thailand's Ministry of Public Health, Thai Health Promotion Foundation, The Institute of Nutrition7, and Thailand's Food Service FDA	Front-of-Pack Labeling	Choices (positive)	Yes, Choices (International)	Yes, Martin et al, 2023	[45,46]
East Asia and Pacific	Malaysia	Malaysia Healthier Choice Logo	2017	Malaysia's Ministry of Health - Nutrition Division	Front-of-Pack Labeling	Choices (positive)	Yes, Choices (International)	Yes, Martin et al, 2023	[47]
South Asia	Sri Lanka	Sri Lanka Traffic Light Labelling System	2019	Sri Lanka Ministry of Health, Nutrition and Indigenous Medicine with the Food Advisory Committee	Front-of-Pack Labeling	Traffic Light Labels (mixed)	Yes, Traffic Light Labelling (United Kingdom)	Yes, Martin et al, 2023	[48]
Latin America & the Caribbean	Bolivia	Bolivia Traffic Light Labelling System	2016	Bolivia Ministry of Health	Front-of-Pack Labeling & regulation of advertisement	Traffic Light Labels (mixed)	Yes, Traffic Light Labelling (United Kingdom)	No	[49]

(*continued on next page*)

TABLE 2 (*continued*)

World Bank Region	LMIC	Model name	Date of implementation or dissemination	Organization name	Main purpose	If main purpose is front-of-pack labeling, type of scheme (tone of voice)	Model derived from other models? (Country)	Identified in previous reviews	References
Latin America & the Caribbean	Ecuador	Ecuador Traffic Light Labelling System	2014	Ministry of Public Health	Front-of-Pack Labeling	Traffic Light Labels (mixed)	Yes, Traffic Light Labelling (United Kingdom)	Yes, Labonté et al, 2018	[50]
Latin America & the Caribbean	Colombia	Colombia Warning Labels	2022	Ministry of Health and Social Protection	Front-of-Pack Labeling	Warning Labels (negative)	Yes, Chile Warning Labels and PAHO (Chile, PAHO)	No	[51]
Latin America & the Caribbean	Colombia	Colombia Fiscal policy	2022	Congress of Colombia	Food taxes	—	No	No	[52]
Latin America & the Caribbean	Peru	Peru Warning Labels	2017	Peru's Ministry of Health	Front-of-Pack Labeling & regulation of advertisement	Warning Labels (negative)	Yes, Chile Warning Labels and PAHO (Chile, PAHO)	Yes, Martin et al, 2023	[53]
Latin America & the Caribbean	Brazil	Brazilian Black Magnifying Glass	2020	The Brazilian Health Regulatory Agency	Front-of-Pack Labeling & nutrition claims	Warning Labels (negative)	No	Yes, Martin et al, 2023	[54]
Latin America & the Caribbean	Mexico	Mexican Warning Labels	2020	Mexican Ministry of Health	Front-of-Pack Labeling & nutrition or health claims	Warning Labels (negative)	Yes, PAHO	Yes, Martin et al, 2023	[55]
Latin America & the Caribbean	Argentina	Argentina Warning Labels	2022	Argentina's Ministry of Public Health	Front-of-Pack Labeling	Warning Labels (negative)	Yes, PAHO	No	[56]

LMIC, low- or middle-income country; FDA, Food and Drug Administration; NPM, nutrient profiling model; PAHO, Pan American Health Organization.

TABLE 3
Key components of each nutrient profiling system implemented in a low- or middle-income country.

Model name	Scope				Components																			Reference quantity					Output		References
					Disqualifying components									Qualifying components																	
	Across the board	Food category	Number of major subcategories	Number of subcategories	Energy	Sugars (total, added or free)	Salt or sodium	Fats (total, SFA, TFA, added)	Specific food groups	Caffeine	Sweeteners	Cholesterol	Number of disqualifying components	Proteins	Dietary fiber	Whole grains	Calcium	Iron	Additional vitamins & minerals	ω-3 or PUFA	Probiotic	Fruit, vegs, nuts and seeds or legumes	Number of qualifying components	per 100 g/mL	per 100 kcal/kJ	Energy %	Per serving	Other units	Scoring	Threshold	
Ethiopia Fiscal policy		Y	5	11		Y		Y	Y		Y		4										0	Y				Y		Y	[39]
Zambia Good Food Logo		Y	12	31	Y	Y	Y	Y					4		Y		Y	Y	Y				4	Y		Y		Y		Y	[22]
South African Nutrient Profiling Model		Y	3		Y	Y	Y	Y					4	Y	Y							Y	2	Y				Y	Y		[40]
South African Warning Labels		Y	2			Y	Y	Y			Y		4										0	Y						Y	[40]
Iran Traffic Lights Labelling System		Y	2			Y	Y	Y					3										0	Y			Y			Y	[41,42]
North Macedonia Keyhole		Y	11	33		Y	Y	Y					3		Y	Y						Y	2	Y		Y		Y		Y	[43]
Indonesian Healthier Choice Logo		Y	20	22		Y	Y	Y					3		Y		Y						2	Y						Y	[44]
Thai Healthier Choice Logo		Y	14	43	Y	Y	Y	Y					4	Y	Y		Y	Y					4	Y	Y		Y		Y*	Y	[45,46]
Malaysia Healthier Choice Logo		Y	11	60	Y	Y	Y	Y					4	Y	Y	Y	Y	Y	Y	Y	Y		8	Y				Y		Y	[47]
Sri Lanka Traffic Light Labelling System	Y					Y	Y	Y					3										0	Y						Y	[48]
Bolivia Traffic Light Labelling System		Y	2			Y	Y	Y					3										0	Y						Y	[49]
Ecuador Traffic Light Labelling System		Y	2			Y	Y	Y			Y		4										0	Y						Y	[50]
Colombia Warning Labels		Y	2			Y	Y	Y			Y		4										0	Y	Y	Y				Y	[51]
Colombia Fiscal policy		Y	1			Y	Y	Y					3										0	Y	Y	Y				Y	[52]
Peru Warning Labels		Y	2			Y	Y	Y					3										0	Y				Y		Y	[53]
Brazilian Black Magnifying Glass		Y	2			Y	Y	Y					3										0	Y						Y	[54]
Mexican Warning Labels		Y	2		Y	Y	Y	Y		Y	Y		6										0	Y	Y	Y				Y	[55]
Argentina Warning Labels		Y	2		Y	Y	Y	Y		Y	Y		6										0	Y	Y	Y				Y	[56]

TFA, *trans*-fatty acid; veg, vegetable.

and nutrition or health claims. However, in the Middle East and North Africa, as well as in Europe and Central Asia, only 1 LMIC has used NPM to support a FOPL scheme.

Four different FOPL schemes have been implemented in LMICs, mostly derived from models developed in high-income countries. These include Warning Labels, Traffic Light Labeling, Healthier Choice Logos, and "Keyhole." In Latin American, 5 LMICs have implemented Warning Labels: Peru (2017) [53], Brazil (2020) [54], Mexico (2020) [55], Colombia (2022) [51], and Argentina (2022) [56]. Warning Labels have also been implemented recently in South Africa (2023) [40]. Warning Labels were first used in Chile and conveyed negative messaging by framing nutrients present in excess in black octagons [57]. In Brazil, octagons have been replaced with a black magnifying glass logo with "high in" warnings and in South Africa with black triangles. Except for the Brazilian and South African models, Warning Labels are aligned with NPMs published by the Pan American Health Organization (PAHO) in 2016 [58].

The second scheme, Traffic Light Labelling, has been implemented in Ecuador (2014) [50] and Bolivia (2016) [49], as well as Iran (2015) [41] and Sri Lanka (2019) [48]. This scheme was first launched in the United Kingdom in 2007 [9]. It delivers a mixed message by coloring nutrients differently depending on their level: red for high, yellow for moderate, and green for low.

In South-East Asian countries and Zambia, FOPL schemes have been developed following the Choices International nutrient profiling methodology leading to Healthier Choice Logos in Thailand (2016) [45], Malaysia (2017) [47], and Indonesia (2019) [44] and the Good Food Logo in Zambia (2020) [22]. This scheme conveys a positive message by putting forward the best options per food category. The "Keyhole" scheme in North Macedonia (2015) follows the same principle as "Choices" even though it was based on a system developed in Sweden, Norway, Denmark, and Iceland [43].

Components of NPMs supporting a government-led nutrition policy in LMICs

A summary of the key components of each NPM is provided in Table 3 [22,39–56].

The scope of most NPMs is defined by food categories and not across-the-board. Traffic Light Labeling and Warning Labels schemes are both mainly supported by 2 sets of criteria, one for solid and the other for liquid foods. However, the scope for Warning Labels is restricted to processed and ultra-processed foods or prepackaged food. For "Choices" and "Keyhole" schemes, criteria were developed for at least 10 major food categories and from 11 to 60 subcategories. The number and types of food categories differed in each country depending on the most commonly consumed foods. For example, the Thai Healthier Choice has different criteria for dark soy sauces, black sweet sauce, Asian sweet sauce, and oyster sauce, whereas in Malaysia, only 1 criterion for soy sauces has been set. Similarly, the fiscal policy in Ethiopia is category-specific. On the contrary, the Sri Lanka Traffic Light Labeling system and the Colombian fiscal policy feature the same criteria across-the-board.

Disqualifying components are common to all NPMs in LMICs. Each model contains criteria for at least one type of fat (total, saturated, *trans*-, added), one type of sugar (total, added, free), and salt or sodium. The only exception is the Ethiopian fiscal policy, for which no criterion was set for salt or sodium. Energy was considered a disqualifying component in 9 of the 16 countries. In Ethiopia, South Africa, Ecuador, Colombia, Mexico, and Argentina, presence of sweeteners was also penalized, as well as caffeine in the 2 latter countries.

Criteria for qualifying (positive) components were developed in only 6 countries. Dietary fibers were promoted in all 6 countries. Additionally, in Zambia, Malaysia, Indonesia, and Thailand, products had to meet a minimum level in category-specific vitamins and minerals to obtain a "Choices" logo. Protein was considered as a nutrient to encourage in South Africa, Thailand, and Malaysia. Finally, the North Macedonian "Keyhole" scheme and the South African NPM included criteria for fruits, vegetables, legumes, and nuts.

Details on the validation of each NPM are provided in Supplementary Table 4. No form of validation was identified for either the Ethiopian or Colombian fiscal policies. Thirteen NPMs were validated indirectly because they were derived from NPMs developed and validated in high-income countries – Choices, Traffic Lights, Warning Labels – even though some substantive adaptations were made to the initial model, such as the addition or removal of criteria. In Iran for instance, the previously validated UK Traffic Light was adapted to include criterion on *trans*-fatty acids because of the relevance of this nutrient for risk for cardiovascular diseases in the country.

Eleven NPMs were tested for a direct form of validity. Seven NPMs were developed in consultation with experts, which constitutes some form of content validity. The FOPL scheme and the reference quantities of the Brazilian NPM were developed during a technical meeting of the National Health Surveillance Agency ANVISA. In addition, it was presented for public consultation, which implies a limited form of face validity. Four additional models, in Argentina, Colombia, Indonesia, and Thailand, were tested for face validity by assessing consumer understanding. Construct or convergent validity was tested for 5 models by comparing the performance of the NPMs with previously validated models on a subset of a country's food supply. For example, the proportion of products eligible for the Thai Healthier Choice model was calculated in a database gathering recent launches in Thailand. The nutritional quality of eligible products was assessed through a validated NPM: Health Star Rating. The authors demonstrated agreement between the 2 models, despite some category-specific inconsistencies. The "Keyhole" NPM was the only model tested for criterion/predictive validity, in a Danish cohort. Since North Macedonia "Keyhole" use the initial criteria of the Nordic "Keyhole", it was considered as directly validated, even though no proof of validation in a North Macedonian context could be identified.

Prevalence of malnutrition in countries where an NPM has been implemented

Key findings on the prevalence of over- and undernutrition and specific micronutrient deficiencies and country's level of income at the time of implementation of a new NPM are presented below (Figure 3).

The year "Choices" NPM was first implemented, the prevalence of overweight and obesity among adults was <51% while the prevalence of underweight was >6%, as presented in Figure 3A. Traffic Light Labels have been implemented in countries where overnutrition prevalence among adults ranged from 35% (Sri Lanka) to 61% (Ecuador) and undernutrition from 2%

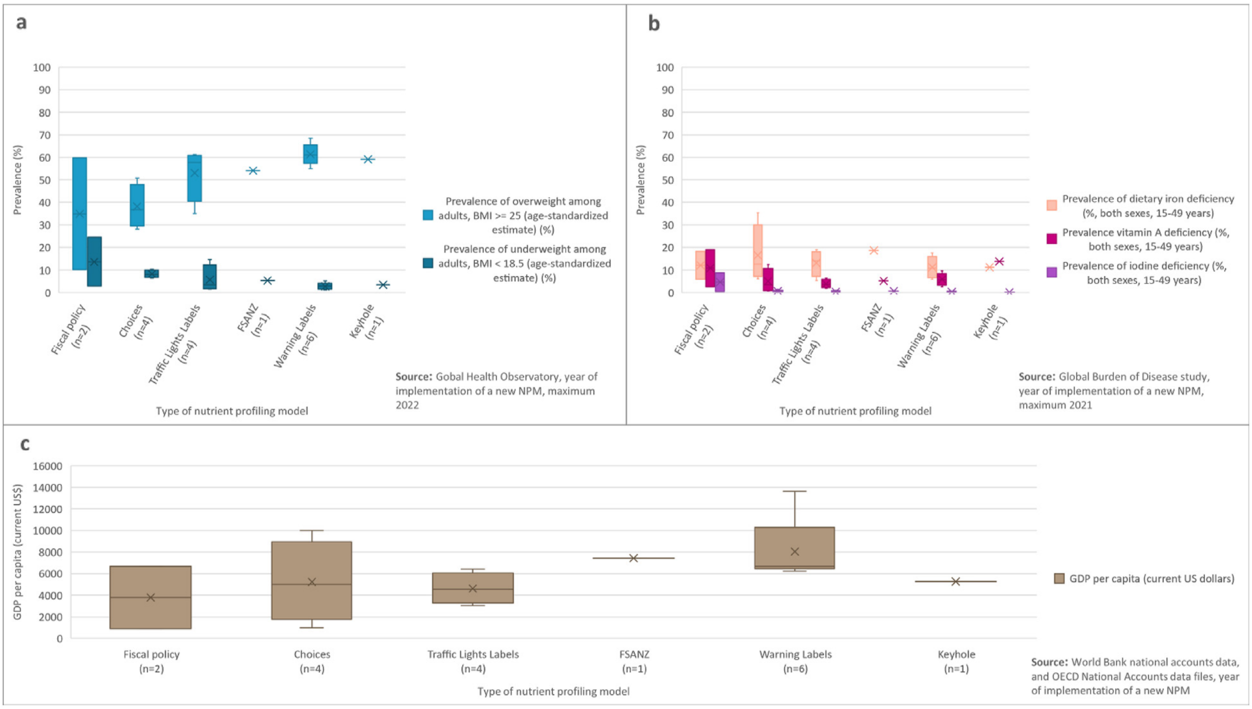

FIGURE 3. Prevalence of undernutrition, overnutrition, deficiencies in iodine, vitamin A, and iron and country's level of income at the time of implementation of a new nutrient profiling model. (A) Boxplot of the prevalence of overweight/obesity and underweight the year a new NPM was implemented by type of NPM. (B) Boxplot of the prevalence of iron, vitamin A, and iodine deficiency the year a new NPM was implemented by type of NPM. (C) Boxplot of GDP per capita the year a new NPM was implemented by type of NPM. BMI, body mass index; FSANZ, Food Standard Australia New Zealand; GDP, gross domestic product; NPM, nutrient profiling model.

(Ecuador and Bolivia) to 15% (Sri Lanka). In Latin American countries and South Africa where Warning Labels have been used, more than 55% adults were either overweight or obese while <5% of them were underweight the year the new NPM was implemented. Similarly, in North Macedonia, the prevalence of over- and undernutrition were respectively 59% and 4%. Dietary iron deficiency affected from 11% to 35% of the population in countries where the "Choices" NPM was implemented, while in countries where Traffic Lights and Warning Labels were implemented, it ranged from 5% to 19% and from 6% to 18% respectively. The "Choices" NPM features category-specific criteria to promote products high in iron in Zambia and Malaysia.

Prevalence in iodine deficiency was <2% at the time of implementation of a new NPM in all countries except Ethiopia (9%). Vitamin A deficiency affected <10% of the population in most countries with some exceptions: Ethiopia (19%), North Macedonia (14%), Zambia (12%), and Brazil (10%). In Zambia, the "Choices" NPM features a criterion for vitamin A.

The year "Choices," Traffic Lights, and Warning Labels were implemented, GDP per capita ranged from USD $958 to $9980, $3014 to $6437, and $6253 to $13,651, respectively.

Discussion

This study systematically reviews NPMs implemented in LMICs and provides a comparison of their characteristics in relation to country's nutrition-related public health challenges and level of income at the time of implementation. Our findings show that, since 2013, 18 NPMs have been endorsed by LMIC governments to promote healthier choices among adults. Most models support FOPL policies and were adapted from models initially developed for application in high-income countries. All NPMs encompassed criteria for at least one nutrient to limit (e.g., sugar, fat, or salt or sodium), but differences in qualifying (positive) components were observed per region and related to the most prevalent forms of malnutrition in the country of implementation.

NPMs were built and expressed differently depending on the most prevalent forms of malnutrition locally. A positive FOPL scheme, "Choices," was implemented in countries with a lower GDP per capita and where undernutrition, micronutrient deficiencies, and overnutrition coexist such as Southeast Asia and Zambia. "Choices" encourages the consumption of the best product options per food category. To obtain a "Choices" logo, a product must have limited content of sugar, fat, and/or sodium, 3 public-health-sensitive nutrients associated with an increased risk of overweight, obesity, and cardiovascular diseases if consumed in excess [59–62]. Criteria are also set to encourage products high in dietary fiber, a component associated with reduced risk of overnutrition-related chronic diseases [61]. In Zambia and Malaysia, where >10% of the population is iron deficient, "Choices" promotes products high in certain micronutrients such as iron.

In contrast, in LMICs with higher income per capita, where most of the population is overweight or obese and the prevalence of underweight is low among adults, Warning Labels or a "Keyhole" scheme have been implemented to tackle the rise in overconsumption. Warning Labels focus on strongly discouraging the consumption of public-health-sensitive nutrients with the same thresholds across the board. They have been implemented across Latin American LMICs and more recently in South Africa. The "Keyhole" scheme implemented in North Macedonia relies on criteria to limit sugar, fat, and salt as well as to encourage dietary fibers and food groups associated with a reduced risk of weight gain and noncommunicable diseases, such as fruits and vegetables [63].

Traffic Light Labels were implemented between 2014 and 2019 in countries where overweight/obesity and underweight prevalence ranged from 35% to 61% and from 2% to 15% respectively. This FOPL provides guidance on the level of public-health-sensitive nutrients in packaged products with a mixed tone of voice by highlighting in green or red the best and worst product options across the board. Finally, in Ethiopia, where over- and undernutrition are equally prevalent, one new system was developed for food tax purposes. Regardless of the prevalence of under- and overnutrition or level of income in LMICs, NPMs include criteria for at least one type of fat, sugar, and sodium, which is aligned with what Labonté et al. [21] and Martin et al. [22] previously reported on a global scale.

The choice of FOPL scheme and underlying NPM in LMICs has also been influenced by examples from neighboring high-income countries and by regional guidance. In each World Bank region, no more than 2 different FOPL schemes were implemented, usually adapted from models in high-income countries. In addition, the number of LMICs implementing food policies supported by an NPM has increased in the past 5 y. Ten of the 18 NPMs recorded were launched after 2019, and 8 of them had not been captured in the 2 previous global reviews of NPMs published (Labonté et al. in 2018 [21] and Martin et al. in 2023 [22]). During our searches, we noted that more LMIC authorities were working on the development of their own NPM at the time of the review. In particular, in sub-Saharan Africa where prevalence of double burden of malnutrition is rising and only 3 countries have implemented a NPM so far, Ghana and Kenya have partnered with the International Development Research Centre in 2023 to develop national NPMs [64]. This highlights the need for further research to closely monitor the implementation of new NPMs to support government-led nutrition policies.

Most NPMs have gone through a validation process, albeit sometimes indirectly or in a limited manner. Sixteen of 18 models reviewed have been validated either indirectly because they were derived from a system developed in a high-income country or directly in the country of implementation by assessing face, construct/convergent, or content validity. This represents a higher proportion than previously reported in global reviews. Labonté et al. and Martin et al. reported validation for <50% of NPMs endorsed by governments globally [21,22]. This is likely due to a higher proportion of NPMs being derived from previously validated models in LIMCs (e.g., indirect validation). Despite theoretical validation, the impact of each policy on purchase behavior and product reformulation in the country of implementation remains unknown for most models and could be the object of further studies.

This is the first study to systematically review NPMs endorsed across LMICs considering most prevalent forms of malnutrition at the time of implementation. Previous work has focused on systematically reviewing NPMs globally without considering country-specific nutritional challenges [21, 22] or assessing the characteristics of FOPL in a given region, such as South-East Asia [18] and the Americas [65]. The rigorous systematic protocol model followed has allowed the identification of 8 new models compared with previous systematic reviews.

However, some limitations are to be considered. The scope of this review focuses on government-endorsed NPMs, which excludes NPMs implemented in LMICs by nongovernmental organizations. The Nigerian Heart Check put in place by the Nigerian Heart Association and the Chinese Healthier Choice Logo developed by the Chinese Nutrition Society [66] were therefore not considered in our analysis. Furthermore, NPMs developed by research groups and tested in LMICs such as the Nutrient Rich Food Index in Ghana [67] were also excluded despite their performance in assessing the nutrient density of LMICs food supply. Despite a robust systematic review protocol, some models also had to be excluded because no information on their characteristics could be found in the peer-reviewed or grey literature.

Data availability on the prevalence of hidden hunger globally is limited. In the Global Burden of Disease study, the prevalence of deficiency was available for 3 micronutrients only: iron, vitamin A, and iodine. Other nutritional deficiencies may also exist in LMICs but are not systematically monitored.

In conclusion, this systematic review showed that NPMs focus on discouraging the consumption of sugar, fat, and salt in LMICs. Additionally, NPMs promote category-specific micronutrients in countries where undernutrition remains prevalent. In LMICs where overnutrition is the primary nutrition-related public health issue, food components associated with a reduced risk of diet-related chronic diseases, including whole grains and fibers, are featured. This work provides an overview of the different models currently operating in LMICs and can be used to inform policymakers in the selection of appropriate NPMs to tackle the nutritional challenges specific to their country.

Author contributions

The authors' responsibilities were as follows – MT, ALE, TNM, EJF, AD: designed research; MT, RVD: conducted research and analyzed data; MT, ALE, TNM: wrote the paper; and all authors: read and approved the final manuscript.

Conflict of interest

MT, ALE, TNM, and RVD were employed by Nestlé at the time of the study. AD is a member of scientific advisory boards for Nestlé, Friesland Campina, BEL, and the National Pork Board; has served on the Carbohydrate Quality Expert Panel funded by Potatoes USA; has advised Ajinomoto, Kraft Heinz, Meiji, MS-Nutrition, Nutrition Impact, and Samsung on nutrient density issues; and has received grants, contracts, and honoraria from both public and private entities with an interest in dietary nutrient density and nutrient profiling of foods.

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Data availability

Data described in the manuscript will be made available upon request to the corresponding author.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT 3.5 as a translation tool. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cdnut.2024.104530.

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