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Nutritional quality of foods consumed by the Portuguese population according to the *Nutri-Score* and consistency with nutritional recommendations

Mariana Santos [a,b,g,*], Filipa Matias [a], Tânia Fontes [a], Ana Cristina Bento [a], Maria João Pires [a], Ana Nascimento [a], Susana Santiago [a], Isabel Castanheira [a], Ana Isabel Rito [a,c], Isabel Loureiro [e], Ricardo Assunção [a,d,f]

[a] *Food and Nutrition Department, National Health Institute Dr Ricardo Jorge, Av Padre Cruz, 1649-016 Lisboa, Portugal*
[b] *NOVA National School of Public Health, Universidade NOVA de Lisboa, Avenida Padre Cruz, 1600-560 Lisboa, Portugal*
[c] *Center for Studies and Research In Social Dynamics and Health (CEIDSS), Av Padre Cruz, 1649-016 Lisboa, Portugal*
[d] *CESAM, Centre for Environmental and Marine Studies, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal*
[e] *NOVA National School of Public Health, Public Health Research Center (CISP), Comprehensive Health Research Center, NOVA University of Lisbon, Avenida Padre Cruz, 1600-560 Lisboa, Portugal*
[f] *IUEM - Instituto Universitário Egas Moniz, Egas Moniz - Cooperativa de Ensino Superior, 2829-511 Caparica, Portugal*
[g] *Comprehensive Health Research Center (CHRC), Universidade NOVA de Lisboa, Lisbon, Portugal*

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ABSTRACT

In the last few years, public health authorities have shown interest in introducing front-of-pack labelling (FOPL), as one of the main policies to combat diet-related non-communicable diseases (NCDs). *Nutri-Score* is a FOPL that categorizes a food product into five categories according to its nutritional value.

This study aimed to investigate the ability of *Nutri-Score* to discriminate the nutritional quality of foods consumed by the Portuguese population and the consistency with the food-based dietary guidelines.

The applicability of *Nutri-Score* was assessed by applying it to 165 food products that were considered under the PT-Total Diet Study (PT-TDS).

At least three categories (colours/letters) of the *Nutri-Score* were observed for most of the food groups and for sub-groups a minimum of two categories were identified. The *Nutri-Score* showed moderate agreement with the Portuguese Nutrient Profile Model (PT-NPM) (k = 0.416).

The food classification according to the *Nutri-Score* was consistent with the nutritional recommendations. Food groups in which consumption is encouraged were more favourably classified than those in which consumption should be limited (i.e., Vegetables and Pastries were classified as A (93.0%) and E (57.1%), respectively).

Appropriate food labelling with a system such as *Nutri-Score* can be relevant to health-promoting purchasing choices, improving diet quality and consequently public health.

1. Introduction

Dietary risk factors are leading contributors to the global burden of disease, responsible for an estimated 11 million deaths from non-communicable diseases (NCDs) (22% of all adult deaths) and 15% of disability life years (DALYs) lost in 2017, with cardiovascular diseases, diabetes and cancer, leading contributors to dietary-related deaths (GBD, 2017 Diet Collaborators, 2019).

Addressing the challenges of NCDs linked to unhealthy dietary habits has led public health authorities to develop strategies and introduce policies focused on nutrition, which is one of the key modifiable determinants of chronic disease development (World Health Organization, 2013).

In recent years, there has been an increasing interest by public authorities in the implementation of front-of-package nutrition labelling (FOPL) as one of the key policies to fight NCDs (World Health Organization, 2017). FOPL empowers consumers to make informed, healthy and sustainable food choices (Global Food Research Programme., 2020).

* Corresponding author at: Food and Nutrition Department, National Health Institute Dr Ricardo Jorge, Av Padre Cruz, 1649-016 Lisboa, Portugal.
E-mail address: mariana.coelho@insa.min-saude.pt (M. Santos).

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The European Commission in its new "Farm to Fork' strategy", launched in May 2020, proposes the development of a mandatory harmonised FOPL system by the end of 2022 (European Commission, 2020a). Additionally, in the European region, FOPL is also recommended by the World Health Organization (WHO) European Food and Nutrition Action Plan 2015–2020, reflecting the importance to support consumers' choices, promoting in some cases the reformulation of products, and thereby promoting healthier diets World Health Organization (WHO), 2015a.

Since 1989, nutrition labelling on food packages has been voluntarily implemented by food companies (Kanter et al., 2018), however, over the last decade, several types of FOPL schemes have been developed (Kelly and Jewell, 2018) including i) nutrient-specific schemes, providing more or less detailed nutritional information on specific nutrients, and ii) 'summary indicator' schemes that rather provide a synthetic appreciation of the product's overall nutritional quality/healthfulness (Kanter et al., 2018; Savoie et al., 2013; World Health Organization, 2020).

Some examples of FOPLs currently in use in Europe are *Keyhole,* developed by the Swedish National Food Agency and the *Choices logo,* in the Netherlands (Choices International Foundation, 2016; Larsson et al., 1999), *Reference Intakes,* developed by members of the European food and drink industry (Food and Drink Federation, 2014) and *NutrInform Battery,* a voluntary front-of-package scheme based on the *Reference Intakes label,* proposed by Italy's Food and Beverage industries association and approved by the Italian government. The *NutrInform Battery* is not yet being applied on the European Union market (NutrInform Battery, 2020). From UK, the *United Kingdom Multiple Traffic Lights (UK MTL) scheme, was* developed by the UK Food Standards Agency (FSA) (Food Standards Agency, 2007) and is also an example of FOPLs.

In 2017, the French Ministry of Health developed the *Nutri-Score* scheme, a modified version of the Nutrient Profiling System (FSAm-NPS) developed by the British Food Standards Agency (Chantal and Hercberg, 2017) . Between 2018 and 2020 this scheme was adopted in Belgium, Spain, Germany, the Netherlands, Switzerland and Luxembourg (European Commission, 2020b) .

In Portugal, despite no single/unique FOPL has been yet officially adopted, several FOPL models are being used in food packages that are commercialized by different operators in the food industry (Feteira-Santos et al., 2021). The existence of multiple FOPLs can be a challenge for consumers to understand food labels, affecting their ability to make healthier food choices (Draper et al., 2013). According to the WHO report on FOPL, 40% of Portuguese consumers did not understand the nutritional information on food labels, and for consumers with a low level of education, this percentage was around 60% (Gomes et al., 2017).

Recently, an Health Impact Assessment on nutrition labelling conducted in Portugal appraised the impact of the adoption of a single FOPL, and which FOPL would be the most appropriate to promote healthy food choices and mitigate inequalities. The results of this study showed that although traffic light nutrition labelling appears to be the most appropriate model for Portuguese consumers to make healthy food choices, the results obtained for the other FOPL models (e.g. *Nutri-Score*, *Guideline daily amounts, Health Star Rating*) suggest that all of them have the potential to contribute to healthier food choices (Graça et al., 2020; Portugal. Ministério da Saúde. Direção-Geral da Saúde, 2019a).

Various studies showed that the algorithm underlying *Nutri-Score* can discriminate the nutritional quality of foods, obtaining a score mostly in line with nutritional recommendations (Dréano-Trécant et al., 2020; Julia et al., 2015). Furthermore, *Nutri-Score*, when compared to other nutrition labelling models, was found to be the most effective in terms of encouraging consumers to make healthier food choices and simultaneously helping to assess the nutritional quality of products (Egnell et al., 2019; Hercberg et al., 2021).

Several European countries are considering the implementation of the *Nutri-Score*, however, some concerns have been expressed especially regarding the validation, which was mainly conducted in the French context, and consequently, the algorithm may not reflect the food-based dietary guidelines from other countries (Julia et al., 2015; van Tongeren and Jansen, 2020).

According to the WHO "Manual to develop and implement front-of-pack nutrition labelling" the validation of nutrient profiling systems is one of the crucial steps to consider before the implementation of the algorithm underpinning the label (World Health Organization, 2020). The validity of a nutrient profiling system can be assessed in various ways. (Cooper et al., 2016). One of the most important validity testing methods is convergent validity. Convergent validity explores the way a nutrient profiling system would classify foods and the alignment with the food-based dietary guidelines (World Health Organization, 2020).

The Portuguese food-based dietary guidelines use a Food Wheel graphic divided into seven groups that represent the different food groups that should be considered: fats and oils, milk and dairy products; meat, fish, shellfish and eggs; pulses, cereals and cereal-based products, tubers; vegetables; fruits (FAO, 2019). The greater the segment size, the higher the recommended intake of those foods. Water is placed at the centre of the Food Wheel to highlight the importance of hydration. It is advised to eat the products that are included in the Food Wheel, to eat foods from each group every day to have a complete diet, to vary between the food groups, and vary them daily, weekly and seasonally (FAO, 2019; Rodrigues et al., 2006).

In 2019, a statutory regulation was approved in the Portuguese Parliament to restrict the marketing of foods high in saturated fat, trans-fat, salt or added sugars to children. To apply the law the Directorate-General of Health (DGS), developed the Portuguese Nutrient Profile Model (PT-NPM), adapting the WHO-EURO model. The nutrient profiling system developed intend to evaluate the healthfulness of foods and should be aligned with the national dietary recommendations (Portugal. Ministério da Saúde. Direção-Geral da Saúde, 2019b; World Health Organization (WHO), 2015b).

Considering that data available on the classification of food products using *Nutri-Score* and its relation with the Portuguese dietary guidelines are scarce, this study aims to investigate: 1) the discriminatory capacity of *Nutri-Score* to evaluate the nutritional quality of foods consumed by the Portuguese population, and 2) the consistency of *Nutri-Score* food classification and the Portuguese dietary guidelines, as a contribution to the validation of this FOPL in the Portuguese context.

2. Materials and methods

2.1. Food selection

For this study food composition data from the Total Diet Study (TDS) carried out in Portugal (PT-TDS) were used (Vasco et al., 2021).

The TDS approach is recognized as a cost-effective method of assessing dietary exposure, including for nutrients through food, especially if precautions in the preparation (culinary treatments) are taken (European Food Safety Authority, Food and Agriculture Organization of the United Nations, W.H.O, 2011; Vin et al., 2014). Through the combination of food intake data with analytical data from food products collected following the methodologies of the TDS, it was possible to evaluate the nutrient intake of a population (Dofkova et al., 2016).

The PT-TDS study considered the selection, collection and analysis of representative foods from the Portuguese diet. The selection of foods was based on food consumption data from the Portuguese Population's Food Habits and Lifestyles study conducted by the Portuguese Society of Food and Nutrition Sciences (Poínhos et al., 2009). The design of one 24-h recall was used and data were collected for 3529 individuals from all regions of the country, including the islands, both sexes and ages 18–93 years. A TDS harmonized list has been established considering foods that cover at least 90% of the daily food consumption (g/day/-person) (Poínhos et al., 2009).

After the selection of foods, a PT-TDS food list with 169 TDS food products coded with the respective FoodEx2 codes and names was

established (Dofkova et al., 2016; Vasco et al., 2021). According to the TDS methodology, each food product is a representative mixture of an individual food or several different food items, from which a laboratory sample is taken (composite sample). In the PT-TDS study, each food product is a combination of 12 samples of the same food, reflecting its importance regarding consumption. Seasonality was also considered for the food groups vegetables, fruits, starchy roots and fish. It is also important to remark that food products were selected to generate a representative collection of the most frequently consumed foods in Portugal. The 'Additives, flavours, baking and processing aids' and 'Food products for young population' were not included as the consumption was very low by the adult and elderly populations. Also, Products for non-standard diets, food imitates and food supplements or fortifying agents (n = 2) and Alcoholic beverages (n = 2), were excluded as they were out of the scope of *Nutri-Score* (Julia et al., 2014; Partearroyo et al., 2019). Overall, a total of 165 food products and beverages were considered in this study.

2.2. Food Classification and Composition Data

Nutritional analyses of the 165 food products were performed according to the ISO/IEC 17025 (ISO/IEC 17025, 2017) and according to the methods of analysis (AOAC, 2000; EN 16943, 2017) described in Table 1.

The results obtained through the laboratory nutritional analysis were compiled in a database that integrates the following elements: Food Classification and Food Composition.

2.2.1. Food classification

Under the present study, FoodEx2, the hierarchic food coding system from EFSA was chosen as the food classification system. FoodEx2 has emerged from the identified need for a single and universal food classification system that would work as an aggregator of different sources of information. This hierarchical system, provided by EFSA, integrates a great number of individual food items grouped into wider food groups and food categories (European Food Safety Authority, 2015).

A total of 165 food products were categorized into 16 food groups (FoodEx2 system of classification level 1): "Grains and grain-based products" (n = 21); "Vegetables and vegetable products" (n = 19); "Starchy roots or tubers and products thereof, sugar plants" (n = 1); "Legumes, nuts and oilseeds" (n = 8); "Fruits and fruits products" (n = 14); "Meat and meat products" (n = 11); "Fish, seafood, amphibians, reptiles and invertebrates" (n = 29); "Milk and dairy products" (n = 6); "Eggs and egg products" (n = 1); "Sugar, confectionery and water-based sweet desserts" (n = 3); "Animal and vegetable fats and oils" (n = 2); "Fruit and vegetable juices and nectars" (n = 2); "Water and water-based beverages" (n = 4); "Coffee, cocoa, tea and infusions" (n = 4); "Composite dishes" (n = 35) and "Seasoning, sauces and condiments" (n = 5). Each food group was split into 75 lower-level subgroups (FoodEx2 system of classification level 3).

Table 1
List of analytical methods used for nutritional composition analysis of PT-TDS food products.

Component	Method	Reference
Protein (total nitrogen × 6.25)	Kjeldahl	AOAC method 991.20
Total fat	Acid hydrolysis with extraction	AOAC method 948.15
Fatty acids (includes saturates, mono-unsaturates, polyunsaturates)	Gas chromatography-flame ionization detection (GC-FID)	AOAC method 996.06
Total dietary fibre	Enzymatic–gravimetric	AOAC method 985.29
Total sugars (includes monosaccharides and disaccharides)	Munson–Walker	AOAC method 950.50; AOAC method 906.03; AOAC method 945.2
Sodium (Na) (covert to salt = sodium × 2.5)	Inductively coupled plasma optical emission spectrometer (ICP-OES)	EN 16943:2017

2.2.2. Food composition data

The analyses were performed according to established analytical method criteria in terms of precision and accuracy, the limit of quantification (LoQ), selectivity, and an effective internal and external quality control programme, including appropriate use of Certified Reference Materials (CRMs) and participation in appropriate Proficiency Test schemes (PTs) launched by accredited PTs providers such as FAPAS.

For each food product analysed the following data was computed in the database: total energy (kJ), total protein (g), total carbohydrates (g), total sugars (g), total fat (g), saturated fatty acids (g), total dietary fibre (g) and sodium (mg).

2.3. FSAm-NPS score computation

For the current study, *Nutri-Score* calculation guidelines were followed (Santé Publique France, 2021).

Nutri-Score is based on a modified version of the Nutrient Profiling System (FSAm-NPS) developed by the British Food Standards Agency (Rayner et al., 2009). The *Nutri-Score* category was found after calculating the FSAm-NPS score.

The algorithm was applied, assigning points based on the nutritional composition per 100 g or 100 mL of the product (beverages). "Unfavourable points" were allocated to food components that should be limited, including energy (kJ, 0–10 points), total sugars (g, 0–10 points), saturated fatty acids (g, 0–10 points), and sodium (mg, 0–10 points). "Favourable points" were allocated to food components that should be promoted, including protein (g, 0–5 points), dietary fibre (g, 0–5 points), percentage of fruits, vegetables, legumes, nuts (FVLN %), olive, walnut and rapeseed oils (0–5 points).

The information on the component FVLN was not available per se, and therefore to estimate FVLN % for each product, we use the methodology described by Vergeer et al. (Vergeer et al., 2020). The estimation of the FVLN% was carried out by three team members, to overcome possible incorrect classifications/interpretations that could occur. In the case of differences in the final classification being identified, these were discussed until consensus was achieved.

The total score of the product was calculated by subtracting the points corresponding to the food components to encourage from the points corresponding to the food components to limit . Thus, the final FSAm-NPS score for each food/beverage was based on a scale that could range from - 15 (most healthy) level, to + 40 (least healthy). The overall score is translated into letters code and colour range from A/ dark green (higher nutritional quality) to E/red (lower nutritional quality) (Chantal and Hercberg, 2017)

In line with the French National Nutrition and Health Program and the French High Council for Public Health, specific modifications were applied to the scoring criteria for cheese, added fats and beverages. The Nutri-Score was also calculated for un/minimally processed fruit and vegetables and fresh meat/ fish products for the evaluation of alignment with the dietary guidelines. The food products coffee, tea and infusions were assessed as beverages and powder cocoa and derivatives as general food (Santé Publique France, 2021).

The process of score computation and the attribution of the categories for *Nutri- Score* can be found in the Supplementary Material. All the calculations were performed with the Microsoft Office® software.

2.4. Consistency of Nutri-Score with national dietary guidelines

In the context of FOPL harmonization in Europe, this study intended to investigate the nutritional quality of foods consumed by the

Portuguese population according to the *Nutri-Score* system and the consistency of the scores derived from the *Nutri-Score* with Portuguese dietary guidelines, as described elsewhere (Dréano-Trécant et al., 2020; Szabo de Edelenyi et al., 2019; van Tongeren and Jansen, 2020).

The second step was to assess the agreement between Nutri-Score and the PT-NPM, which was designed to restrict the marketing of unhealthy foods for children. The PT-NPM, developed by the Directorate-General of Health (DGS), is based on WHO Regional Office for Europe Nutrient Profile Model with some adaptations to align the nutrient thresholds for some food categories with the values defined by European Union legislation and to reflect the nutrition composition of foods available on the Portuguese market (Portugal. Ministério da Saúde. Direção-Geral da Saúde, 2019b).

Food groups whose consumption is encouraged by recommendations should have a *Nutri-Score* 'A' or 'B', and food groups whose consumption has to be limited should be classified as *Nutri-Score* 'D' or 'E'.

The recommendations for the Portuguese adult population for food groups are to increase the consumption of vegetable products and fresh fruit; reduce the consumption of fats, particularly solid and overheated fats; preference is given to olive oil; increase fish consumption. The dietary guidelines include the recommendation to reduce the consumption of sugar and sugar-like products; reduce salt consumption; reduce the consumption of alcoholic drinks (FAO, 2019).

The composite dishes (meals), Seasoning, sauces and condiments are not specifically mentioned in the recommendations of the Portuguese Food Wheel Guide and are, therefore, only included to calculate the agreement between *Nutri-Score* and the Portuguese nutrient profile model (PT-NPM).

The discriminating ability of *Nutri-Score* and the comparison with the Portuguese dietary recommendations established by the Food Wheel for Food groups and other important categories are described in Supplementary Material (Table S2).

2.5. Statistical analyses

Statistical analysis was performed using the Statistical Package for Social Sciences software (IBM SPSS Statistics, Version 26.0, IBM corp., Chicago, IL, USA).

Double-entry tables were analysed to study the frequencies of the categorisation obtained by the *Nutri-Score* of the groups and subgroups. The ability of the system to discriminate the different nutrient profiles of foods and beverages was assessed by the number of available colours in each food group and for similar food products in the same subgroups as a discriminant performance indicator. When three or more colours were available in a food group, the performance of *Nutri-Score* was considered good, as described in previous studies (Dréano-Trécant et al., 2020; Julia et al., 2015; Szabo de Edelenyi et al., 2019). For similar food products in the same subgroups, the presence of two colours was considered a satisfactory discriminant performance.

The level of convergence between *Nutri-Score* and PT-NPM was evaluated using Cohen's kappa (κ). The proportion of "higher nutritional quality products" was calculated considering the criteria: *Nutri-Score:* 'A' or 'B'; PT-NPM: permitted for marketing. (Wicks et al., 2016). The degree of agreement was scored as follows: 0.00–0.20 "light", 0.21–0.40 "fair", 0.41–0.60 "moderate", 0.61–0.80 "substantial", and 0.81–1.00 "almost perfect"(McHugh, 2012).

3. Results

3.1. The discriminating ability of Nutri-Score

The distribution of the different *Nutri-Score* categories within food groups and beverages is shown in Tables 2 and 3. The variability in FSAm-NPS scores is illustrated through boxplots of the distribution (Figs. 1 and 2). The *Nutri-Score* classification of the food products considered in the study is shown in Table 4.

In the 16 food groups under study, at least three categories of the *Nutri-Score* were observed for 75.0% (n = 124) of food products (Tables 2) and 44.4% (n = 4) of beverages (Table 3), under analysis.

The distribution of *Nutri-Score* among the foods analysed (Table 2) (beverages excluded) revealed, that 37.8% (n = 59) of the foods were classified in category A, 25.6% (n = 40) in category B, 17.9% (n = 28) in category C, 16.0% (n = 25) in the category D and 2.6% (n = 4) in the category E.

Table 2
Distribution (n, %) of the *Nutri-Score* categories among each main food group (beverages excluded).

Food group (FoodEx2 level 1)	A (Min- −1))	B (0–2)	C (3–10)	D (11–18)	E (19-Max)	N	Score (median) P25;P75
Grains and grain-based products	**2 (9.5%)**	**2 (9.5%)**	**3 (14.3%)**	**12 (57.1%)**	**2 (9.5%)**	**21**	**14.0 (5.50;15.5)**
Vegetables and vegetable products	**19 (100%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**19**	**-6.00 (−8.00;−5.00)**
Starchy roots or tubers and products thereof, sugar plants	**1 (100%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**1**	**-6.00[a]**
Legumes, nuts, oilseeds and spices	**6 (75.0%)**	**0 (0%)**	**2 (25.0%)**	**0 (0%)**	**0 (0%)**	**8**	**-9.00 (−11.0;2.00)**
Fruits and fruits products	**11 (79.0%)**	**2 (14.0%)**	**1 (7.1%)**	**0 (0%)**	**0 (0%)**	**14**	**-4.00 (−4.00;−1.25)**
Meat and meat products	**0 (0%)**	**3 (27.3%)**	**3 (27.3%)**	**5 (45.4%)**	**0 (0%)**	**11**	**5.00 (2.00;12.0)**
Fish, seafood, amphibians, reptiles and invertebrates	**5 (17.2%)**	**12 (41.4%)**	**9 (31.1%)**	**3 (10.3%)**	**0 (0%)**	**29**	**2.00 (0.00;4.00)**
Milk and dairy products	**2 (33.3%)**	**0 (0%)**	**3 (50.0%)**	**1 (16.6%)**	**0 (0%)**	**6**	**1.00 (−1.25;8.50)**
Eggs and egg products	**1 (100%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**1**	**-1.00[a]**
Sugar, confectionery and water-based sweet desserts	**0 (0%)**	**1 (33.3%)**	**0 (0%)**	**1 (33.3%)**	**1 (33.3%)**	**3**	**14.0 (7.50;18.0)**
Animal and vegetable fats and oils	**0 (0%)**	**0 (0%)**	**1 (50.0%)**	**0 (0%)**	**1 (50.0%)**	**2**	**16.0 (7.00;25.0)**
Coffee, cocoa, tea and infusions	**0 (0%)**	**1 (100%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**1**	**0.00[a]**
Composite dishes	**12 (34.3%)**	**18 (51.4%)**	**5 (14.3%)**	**0 (0%)**	**0 (0%)**	**35**	**0.00 (−2.00;2.00)**
Seasoning, sauces and condiments	**0 (0%)**	**1 (20.0%)**	**1 (20.0%)**	**3 (60.0%)**	**0 (0%)**	**5**	**11.0 (3.50;12.5)**
Total	**59 (37.8%)**	**40 (25.6%)**	**28 (17.9%)**	**25 (16.0%)**	**4 (2.6%)**	**156**	**-**

[a] For product groups with one composite sample, the result of score is present as the mean value of the replicate analyses; N is the total number of food products analyzed in a given food group.

Table 3
Distribution (n, %) of the *Nutri-Score* categories among beverages.

Food group (FoodEx2 level 1)	A (Water)	B (Min-1)	C (2–5)	D (6–9)	E (10-Max)	N	Score (median) P25;P75
Fruit and vegetable juices and nectars	**0 (0%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**2 (100%)**	**2**	**13.0 (12.0;14.0)**
Water and water-based beverages	**1 (25.0%)**	**0 (0%)**	**0 (0%)**	**1 (25.0%)**	**2 (50.0%)**	**4**	**8.50 (1.50;11.0)**
Coffee, cocoa, tea and infusions	**0 (0%)**	**3 (100%)**	**0 (0%)**	**0 (0%)**	**0 (0%)**	**3**	**1.00 (1.00;1.00)**
Total	**1 (11.1%)**	**3 (33.3%)**	**0 (0%)**	**1 (11.1%)**	**4 (44.4%)**	**9**	**-**

N is the total number of food products analyzed in a given food group

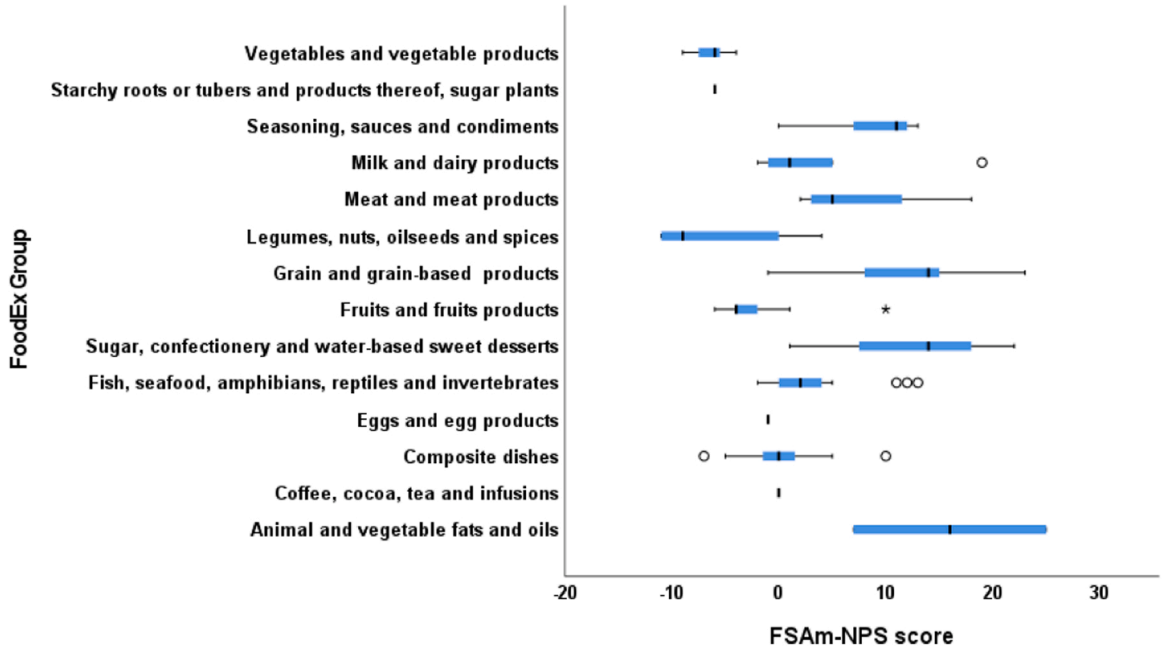

Fig. 1. Boxplot of the FSAm-NPS score across the categories of the food products (exclude beverages) (n = 156). The boundary of the box nearest to the right indicates the 25th percentile, the line within the box marks the median, and the boundary of the box furthest from the right indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the lower limit (25th percentile −1.5 (interquartile range)) and the upper limit (75th percentile + 1.5 (interquartile range)). The circles are individual outlier points.

Among the Grains and grain-based products, only 19.0% were classified as dark green (A) or green (B) while 66.6% of the products were classified as orange (D) or dark orange (E). This food group include foods such as bread, breakfast cereals, spaghetti, and other pastas, as well as grain-based products, such as fine bakery (biscuits, cakes, shortcrust pastry). The fine bakery represents 54.0% (n = 12) of the dark orange (E) category (Tables 2 and 4).

A total of 93.0% of products from Fruits and fruit products, 100% of Vegetables and vegetable products, Starchy roots or tubers and 75.0% of Legumes, nuts and oilseeds were classified as dark green (A) or green (B).

For the food group Meat and meat products, the *Nutri-Score* differs between the different types of meat products. Unprocessed meats are mainly classified between green (B) and yellow (C) and processed meat scores a *Nutri-Score* D.

The food group Fish, seafood, amphibians, reptiles and invertebrates, include a range of *Nutri-Scores* with 58.6% of products categorized between dark green (A) or green (B), and 41.4% of products categorized between yellow (C) and orange (D).

The food groups Legumes, nuts and oilseeds and Eggs and egg products, 75.0% (n = 6) and 100% (n = 1) of the products were represented by the category dark green (A), respectively.

The Composite dishes group showed a distribution of *Nutri-Score* between dark green (A) and yellow (C), with soups mainly categorized as *Nutri-Score* A or B and Pizza *Nutri-Score* D (Table 4).

For the food group Sugar, confectionery and water-based sweet desserts 66.6% of the products were classified as orange (D) or dark orange (E). The Milk and dairy products showed 83.3% of *Nutri-Score* distribution between dark green (A) and yellow (C) (Table 2).

In the food group Animal and vegetable fats and oils, olive oil has a lower ratio of saturated fat to total fat content and obtained the classification yellow (Category C) (Table 4).

For beverages, water was classified as healthier (*Nutri-Score* A) and coffee, tea and herbal infusion were categorized as green (*Nutri-Score* B); Fruit juices and fruit nectars were categorized as dark orange (*Nutri-Score* E) (Table 4).

The variability in the FSAm-NPS scores was the widest for Grain and grain products; Meat and meat products; Sugar, confectionery and water-based sweet desserts and Seasoning, sauces and condiments (Figure1). For beverages, the food group water and water-based beverages showed the widest range of variability due to soft drinks with tea extracts and soft drinks with fruit juice (Fig. 2).

For similar food products in the same subgroups, at least two colours (two categories) were identified: the subgroup cakes (muffins; cream puffs; leavened, chocolate and other diverse cakes) is distributed between C and D categories; the subgroup Marine fish (flounder; sardine; seabass; hake; fresh cod; ling; diverse marine fish) is distributed in four categories from *Nutri-Score* A to *Nutri-Score* D; the subgroup Milk (milk; flavoured milk) is distributed between A and C category.

The Grains and grain-based products and Fish, seafood, amphibians, reptiles and invertebrates food groups showed a wide distribution (4 or 5 *Nutri-Score* categories represented in the food subgroups), which

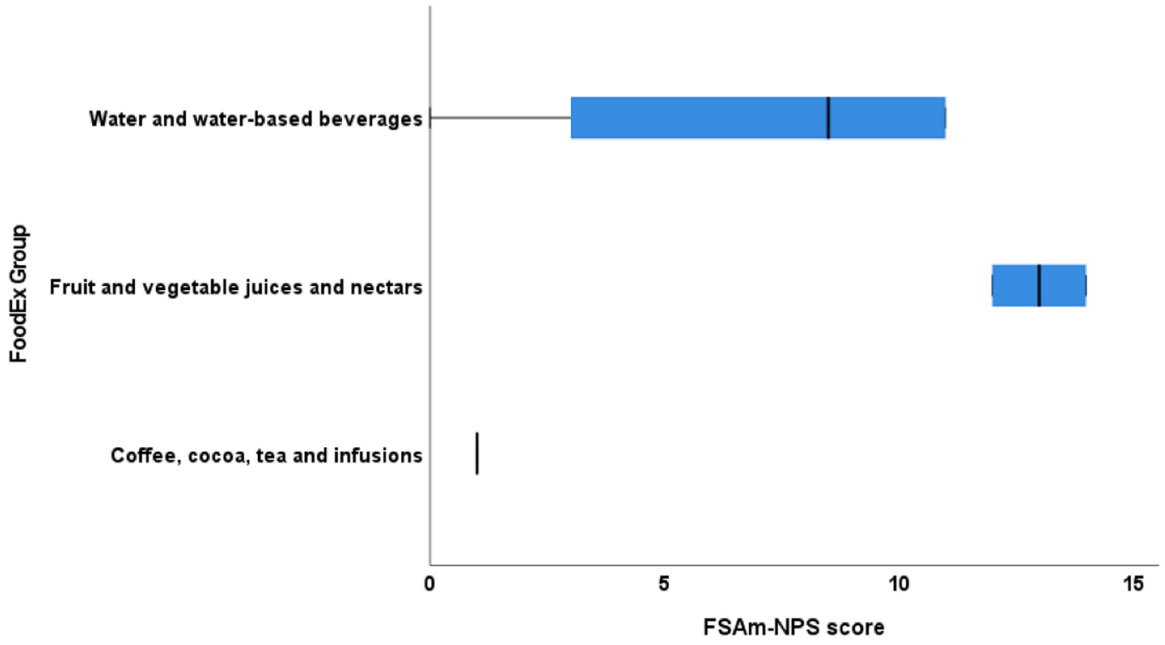

Fig. 2. Boxplot of the FSAm-NPS score across the categories of beverages (n = 9). The boundary of the box nearest to the right indicates the 25th percentile, the line within the box marks the median, and the boundary of the box furthest from the right indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the lower limit (25th percentile −1.5 (interquartile range)) and the upper limit (75th percentile + 1.5 (interquartile range)).

highlighted the large variability in prepared products in terms of nutritional quality, for which the *Nutri-Score* is a very useful tool to identify healthier options.

The categories where *Nutri-Score* was not able to discriminate between products (only 1 or 2 categories) were homogeneous food groups (e.g., Legumes, nuts, oilseeds and spices; Fruits and fruits products) and food groups with a small number of products (e.g., Starchy roots or tubers and products thereof, sugar plants; Eggs and egg products).

In addition, the classification with the *Nutri-Score* also permitted a distinction between manufactured and raw foods. For example, in the category Grains and grain-based products, breakfast cereals and cookies and crackers which are considered highly processed foods were classified between categories C and E; pasta and rice were identified in categories A and B.

3.2. Evaluation of alignment between Nutri-Score and the national food-based dietary guidelines

For an overview of the consistency of *Nutri-Score* classification of the food products with the Portuguese food-based dietary guidelines, see Table S2. The *Nutri-Score* is in line with these guidelines as food for which an increased consumption is recommended were more favourably classified, i.e., Vegetables and vegetable products and all pulses 100% were classified as *Nutri-Score* A, Fruits and fruits products 93% were classified as *Nutri-Score* A and B. Dairy products, milk and fermented milk received a score A and dairy desserts are classified as *Nutri-Score* C.

Food products whose consumption should be limited were classified as *Nutri-Score* D or E. Cheeses were classified as *Nutri-Score* D, and butter due to the higher ratio saturated fat / total fat content and salt content, was classified as *Nutri-Score* E. Sugar and sugar products (e.g. Biscuits, muffins, cakes, and pastry) (89.1%) and Drinks (Fruit juices, water-based beverages) (100%) were classified between *Nutri-Score* D and E.

The agreement between the scoring system - *Nutri-Score* - and the binary system PT-NPM - for the food groups under study is presented in Table 5.

Overall, the *Nutri-Score* showed moderate agreement with the PT-NPM, with k = 0.416 (Table 5). For Dairy products, and Beverages the agreement is perfect (k = 1.000). A lower agreement was observed for Processed fruit, vegetables, and legumes (k = 0.250). Therefore, the % of the agreement was also calculated, with 4 categories at 100%. For Ready-made and convenience foods and composite dishes, the % of the agreement was lower (28.5%). The PT-NPM show to be stricter, especially for Fresh and frozen meat, poultry, eggs, fish and similar and Animal and vegetable fats and oils.

4. Discussion

These results represent a key step in the discriminatory ability of *Nutri-Score* as a nutrient profiling system to classify foods adequately and in accordance with the Portuguese Food-Based Dietary Guidelines (FAO, 2019).

The *Nutri-Score* system was consistent with the National Programme for the Promotion of Healthy Eating Portugal (PNPAS) and with the Integrated Strategy for the Promotion of Healthy Eating (EIPAS), aiming to improve the nutritional status of the Portuguese population as well as to encourage healthier food consumption habits (Despacho n.o 11418/2017, 2017; Despacho n.o 404/2012, 2012).

The PNPAS and EIPAS intend to promote cross-sectoral actions that encourage the consumption of foods of good nutritional quality; to modify the supply of certain foods, particularly those with high sugar, high salt and high-fat content; to promote the consumption of food categories directly related to the prevention of chronic disease, namely fresh fruit and vegetables, across the population; to encourage actions of nutritional reformulation of food products through an articulated action with the food industry (Despacho n.o 11418/2017, 2017)

Among more favourable foods are foods with low salt content (i.e. as not containing more than 0.3 g of salt per 100 g or 100 mL) and food with low sugar content (i.e. as not containing more than 5 g of sugar per 100 g for solid foods or 2.5 g of sugar per 100 mL) (National Health Service England, 2019). The *Nutri-Score* classified these food products as A or B. In addition, Fruits and fruits products (79.0%), and Vegetables and vegetable products (100%) were classified *Nutri-Score* A.

The FSAm-NPS score for fats and oils was optimised to better take into account the content of saturated fatty acids, which is more consistent with the evidence obtained from several epidemiological and experimental studies that thoroughly support the beneficial health

Table 4
Nutri-Score classification of the food products considered in the study.

Food group and Product group (FoodEx2 level 1 and level 3)	*Nutri-Score* categories				
Grains and grain-based products	**A**	**B**	**C**	**D**	**E**
Shortcrust pastry	-	-	-	Fruit; milk and chocolate pies	-
Leavened bread and similar	Cornbread	Bread	-	-	-
Yeast leavened pastry	-	-	Milk bread	-	Croissants
Cakes	-	-	Leavened cakes	Muffins; Cream puffs; Chocolate and other diverse cakes	-
Biscuits and crackers	-	-	-	Salt crackers; Biscuits and crackers	Chocolate Biscuits
Breakfast cereals	-	-	Cereals and Chocolate cereals	-	-
Pasta and similar products	Pasta	-		-	-
Cereal grains and cereal-like grains	-	Rice	-	Popcorns	-
Vegetables and vegetable products	**A**	**B**	**C**	**D**	**E**
Solanacea	Tomato(*) Pepper(*)	-	-	-	-
Turnips and similar	Turnip greens(*)	-	-	-	-
Sweet corn and similar	Corn	-	-	-	-
Cucurbits fruiting vegetables	Melon(*) Cantaloupe(*); Watermelon(*)	-	-	-	-
Broccoli sprouts	Sprouts(*)	-	-	-	-
Beans (with pods) and similar	String beans(*)	-	-	-	-
Asparagus and similar	Asparagus	-	-	-	-
Head brassica	Portuguese cabbage; Brussels sprouts; White cabbage	-	-	-	-
Cauliflowers and similar	Cauliflower(*)	-	-	-	-
Fungi	Mushroom	-	-	-	-
Carrots and similar	Carrot(*)	-	-	-	-
Onions and similar	Onion(*)	-	-	-	-
Broccoli and similar	Broccoli(*)	-	-	-	-
Lettuces and salad plants	Lettuce(*)	-	-	-	-
Starchy roots or tubers and products thereof, sugar plants	**A**	**B**	**C**	**D**	**E**
Potatoes and similar	Boiled potato(*)	-	-	-	-
Legumes, nuts, oilseeds and spices	**A**	**B**	**C**	**D**	**E**
Pulses (dried legume seeds)	Bean Chickpea Black-eyed beans	-	-	-	-
Legumes fresh seeds	Broad beans; Peas; Lupines	-	-	-	-
Oilseeds	-	-	Peanuts	-	-
Oil fruits	-	-	Olives	-	-
Fruits and fruits products	**A**	**B**	**C**	**D**	**E**
Berries and small fruits:	Grapes* Strawberries	-	-	-	-
Miscellaneous fruits *	Fruits salad	-	-	-	-
Miscellaneous fruits with inedible peel, small	Kiwi	-	-	-	-
Canned or jarred fruits	Canned fruits	-	-	-	-
Stones fruits	Peach	-	-	-	-
Jams of fruits and vegetable spreads and similar	-	-	Marmalade	-	-
Pomme fruits *	Apple* Pear	-	-	-	-
Citrus fruits *	Orange	-	-	-	-
Dried fruits		Dry fig* ; Raisins	-	-	-
Miscellaneous fruits with inedible peel, large:	Pineapple Banana		-	-	-
Meat and meat products	**A**	**B**	**C**	**D**	**E**

(*continued on next page*)

Table 4 (*continued*)

Food group and Product group (FoodEx2 level 1 and level 3)	*Nutri-Score* categories				
Mammals	-	Bovine fresh meat Rabbit fresh meat	Calf fresh meat; Swine fresh meat	Sheep fresh meat	-
Generic poultry	-	Chicken fresh meat	Turkey fresh meat	-	-
Cooked cured (or seasoned) meat	-	-	-	Ham	-
Raw cured (or seasoned) meat	-	-	-	Smoked ham and Bacon	-
Preserved or partly preserved sausages	-	-	-	Frankfurter type sausages; Charcuteries	-
Fish, seafood, amphibians, reptiles and invertebrates	**A**	**B**	**C**	**D**	**E**
Marine fish	Ling; Conger European Other pelagic marine fishes (*Physycis phycis*, Forkbeard, rosefish, redfish) Other marine fish (Wrasse, *Trisopterus luscus*, Red porgy, Red seabream,)	Flounder Sea bream Hake Gilthead bream Mackerel Horse mackerel Fresh tuna	Seabass Swordfish Snapper Cod, Atlantic (Fresh cod)	European Sardine(*)	-
Diadromous fish	-	-	Salmon	-	-
Freshwater fish	Nile perch		Catfish	-	-
Squids, cuttlefishes, octopuses	-	Octopus, common	Squid, common	-	-
Mussels	-	Mussels	-	-	-
Bivalves (Clams, cockles, arkshells)	-	-	-	Bivalve molluscs (*Donax variabilis*, Clam)	-
Crustaceans	-	Marine Shrimps or prawns cooked	-	-	-
Terrestrial invertebrates	-	-	-	Snails	-
Processed or preserved fish:	-	Canned sardine Cod, dried	Fish fingers, breaded Canned tuna	-	-
Milk and dairy products	**A**	**B**	**C**	**D**	**E**
Milk	Milk (partly skimmed milk, skim milk)	-	Flavoured milk	-	-
Fermented milk products:	Fermented probiotic milk-like drinks	-	Yoghurts (natural, flavoured, fruit and cereals)	-	-
Firm-ripened cheese	-	-		Flemish cheese	-
Dairy desserts	-	-	Dairy desserts	-	-
Eggs and egg products	**A**	**B**	**C**	**D**	**E**
Whole eggs	Eggs (cooked)	-	-	-	-
Sugar, confectionery and water-based sweet desserts	**A**	**B**	**C**	**D**	**E**
Sugars				Common sugar	
Chocolate and chocolate products					Chocolate dessert
Water based desserts spoonable	-	Gelatine	-	-	-
Animal and vegetable fats and oils	**A**	**B**	**C**	**D**	**E**
Vegetable fats and oils, edible	-	-	Olive oil	-	-
Butter	-	-		-	Butter (with salt)
Fruit and vegetable juices and nectars	**A**	**B**	**C**	**D**	**E**
Fruit juices	-	-	-	-	Fruit juices
Fruit nectars	-	-	-	-	Fruit nectars
Water and water-based beverages	**A**	**B**	**C**	**D**	**E**
Soft drinks:	-	-	-	Soft drink with tea extracts	Soft drink with fruit juice Cola soft drinks
Bottled water:	Natural mineral water	-	-	-	-
Coffee, cocoa, tea and infusions	**A**	**B**	**C**	**D**	**E**
Cocoa ingredients	-	Powder cocoa and derivatives	-	-	-
Coffee ingredients	-	Coffee and coffee with milk)	-	-	-
Tea beverages	-	Herbal and other non-tea infusions	-	-	-

(*continued on next page*)

Table 4 (*continued*)

Food group and Product group (FoodEx2 level 1 and level 3)	*Nutri-Score* categories				
Composite dishes	**A**	**B**	**C**	**D**	**E**
Soups (dry mixture uncooked): diverse vegetables, legumes, chicken, fish or seafood soups	Legume's soup (Legume beans soup)	Tomato soup Vegetable's soup (Mixed vegetables soup, with puree or pieces) Cabbage soup (Mixed vegetables soup) Chicken soup (Meat soup, with pieces)	Seafood cream and fish soup	-	-
Prepared mixed egg/meat/fish/vegetable salad dishes: Russian salad; salad with legumes and fish	Salad with legumes and fish	Russian salad	-	-	-
Mixed vegetable salad: salad of lettuce and tomato	Salad of lettuce and tomato	-	-	-	-
Dishes excluding pasta or rice dishes, sandwiches and pizza	Chickpea, pasta and various meats Smashed potato Beans, meat, and vegetable meal Fish pie Tripe (Beans and meat meal); Diverse dishes with meat (Meat-based dishes Bolognese) Stews; Brás and Gomes de Sá style cod (Fish and potatoes meal)	Omelet; Meat pie; Portuguese stew (Beans, meat, and vegetable meal) Meatballs Bread and breadcrumbs dish; Cod with cream and boiled cod with potatoes, chickpeas and an olive-oil	Sandwich with fillet steak, ham and smoked sausage covered with cheese and a spicy sauce Hamburger's	-	-
Sandwiches; pizza and other stuffed bread-like cereal products	-	-	Meat and vegetable quiches	Pizzas; Snacks (Finger food)	-
Pasta and rice (or other cereal)-based dishes	-	Seafood rice; Vegetable rice; Poultry rice (Rice and meat meal); Fish rice; Valencian rice (Rice-based dishes cooked); Meat and vegetarian lasagne	-	-	-
Sushi with fish and seaweed	-	Sushi with fish and seaweed	-	-	-
Seasoning, sauces and condiments	**A**	**B**	**C**	**D**	**E**
Stock cubes or granulate (bouillon base)	-	-	Meat broths	-	-
Vinegar	-	Vinegar	-	-	-
Savoury sauces	-	-	-	Ketchup; Mayonnaise; Various sauces	-

(*) Seasonal sample (sampling was conducted in the 4 seasons to account for seasonal variation)

effects of olive oil (Gómez-Donoso et al., 2021; Guasch-Ferré et al., 2020, 2014; Ministère des solidarités et de la santé, 2017).

In the present study, the distribution of foods within the *Nutri-Score* categories showed a good performance of the FOPL to discriminate the nutritional quality of products within main food groups and subgroups, and across relevant food groups.

Similar results were previously reported by Hafner and Pravst study, which observed *Nutri-Score* had a high ability to discriminate food products based on nutritional composition and was aligned with Slovenian nutritional recommendations. Food groups promoted by dietary guidelines (fruits, vegetables, cereals) were graded A or B, while less desirable categories, such as confectioneries and snack foods, were mostly graded D or E (Hafner and Pravst, 2021).

Gómez-Donoso et al., in their study also found that the classification of foods in accordance with the nutrient profiling system underlying the *Nutri-Score* was consistent with the Mediterranean and national dietary recommendations. The higher the FSAm-NPS Dietary Index (DI), the lower the adherence to the Spanish Mediterranean Dietary Index (Gómez-Donoso et al., 2021).

Our results are likewise consistent with other research using the European Food Information Resource (EUROFIR) nutritional composition databases. Dréano-Trécant et al. analysed the applicability of the *Nutri-Score* using data from generic food composition tables for eight European countries, and highlighted a high discriminating ability for all food groups, with similar trends in the eight countries, and the food classification by *Nutri-Score* was generally consistent with public health nutritional recommendations. The majority of products containing mainly fruit and vegetables are classified in A or B, while the majority of sweet and salted snacking products, sauces and animal fats are classified in D or E (Dréano-Trécant et al., 2020).

Consistency was also confirmed within specific food groups, i.e. in the Grain or grain products, pulses, pasta and rice are overall ranked higher than breakfast cereals; in the milk and dairy products, milk and yoghurt are ranked lower than cheese. Composite dishes are widely

Table 5
Agreement between the *Nutri-Score* and PT-NPM for main food groups using Cohen's kappa and percentage of agreement.

Category	*Nutri-Score* vs PT-NPM	
	Cohen's Kappa	% of agreement
Cereal, and Cereal Products (Bread, bread products, Fresh or dried pasta, rice and grains, n = 4)	NA	100
Fresh and frozen fruit, vegetables, and legumes (n = 34)	NA	75.0
Processed fruit, vegetables, and legumes (n = 8)	0.250	62.5
Fresh and frozen meat, poultry, eggs, fish and similar (n = 33)	NA	57.6
Processed meat, poultry, fish and similar (n = 8)	NA	75
Dairy products (milk, yoghurts, cheese, n = 6)	1.000 * *	100
Sugar and sugar products (cakes, sweet biscuits and pastries, n = 21)	NA	90.5
Animal and vegetable fats and oils (butter and other fats and oils, n = 2)	NA	50.0
Beverages (juices and other beverages, n = 8)	1.000 * *	100
Ready-made and convenience foods and composite dishes (n = 35)	0.000	28.6
Sauces, dips and dressings (n = 5)	1.000 *	100
Total	0.416 * *	71.5

NA. Cohen's kappa cannot be calculated because variables are constants; *p < 0.05; * *p < 0.005;

distributed, highlighting the variability of products in this particular category. Finally, beverages, while most fruit juices are rated C, soft drinks are rated E and only water is A (Dréano-Trécant et al., 2020).

Assessing the level of convergence between *Nutri-Score* and PT-NPM we observed a moderate agreement (k = 0.416). Although the agreement ratio was > 70%, differences were noted for the food categories Processed fruit, vegetables, and legumes and Composite dishes. This can be explained by differences in the algorithms, as *Nutri-Score* consider the content of total sugars and the PT-NPM excludes some products based on the added sugars. For composite dishes, the difference can be explained by the cut-offs considered by PT-NPM are stricter for the content of saturated fatty acids, sodium (salt), and energy.

The Cohen's Kappa could not be calculated for groups "Cereal, and Cereal Products" and "Fresh and frozen fruit, vegetables, and legumes" because the whole category was classified as healthy (*Nutri-Score* A or B and permitted by PT-NPM). Fresh and frozen meat, poultry, fish and similar, were categorized as healthy by PT-NPM and for Sugar and sugar products all products were excluded by PT-NPM.

From the analysis, there is an alignment between the two models concerning food products that are classified as "suitable" and "unsuitable" for food marketing to children and also an agreement with the recommendations of the Portuguese Food Wheel to limit consumption of products with high sugar or salt content (FAO, 2019; Portugal. Ministério da Saúde. Direção-Geral da Saúde, 2019b).

Our results are in line with a recent study that used data from 15,822 products available in the Slovenian food supply, to evaluate the *Nutri-Score* discriminating ability and compare it with the national food-based dietary recommendations based on the adapted WHO Europe profile, and revealed that *Nutri-Score* had a moderate agreement with the WHO Europe profile (k = 0.57) with differences noted for some food categories (Hafner and Pravst, 2021).

The present study showed that the *Nutri-Score* based on FSAm-NPS profile had a good performance to discriminate the nutritional quality of products across and within food groups and product groups, with at least three classes of *Nutri-Score* represented. The discriminating ability of the *Nutri-Score* is particularly important to help consumers to rank food products by nutritional quality (Aguenaou et al., 2021; Egnell et al., 2020b, 2020a). Furthermore, the results of our specific study in the Portuguese context showed good consistency between the *Nutri-Score* classification concerning the national dietary recommendations, in line with previous studies that have been conducted (Hafner and Pravst, 2021; Julia et al., 2015; Szabo de Edelenyi et al., 2019).

According to Goiana-da-Silva et al., it is safe to assume that *Nutri-Score* would be an adequate FOP labelling system to be considered and endorsed by Portugal (Goiana-da-Silva et al., 2019).

Our study presents some limitations, e.g. the data obtained from food samples collected for the PT-TDS study. Although the PT-TDS study was primarily designed to assess exposure to contaminant residues, we used this public health tool approach since it is possible to assess dietary exposure not only to contaminants but also to beneficial substances (nutrients) (Santé Publique France, 2021). Additionally, our study also considers a different number of food items in the different food groups, despite the obtained is consistent with the available literature.

Currently, a method to compare the classifications of nutrient profile models with the recommendations of food-based dietary guidelines is not defined and we selected an approach similar to previous studies, to assess the consistency of the *Nutri-Score* classification with the dietary guidelines (Dréano-Trécant et al., 2020; Gómez-Donoso et al., 2021; Hafner and Pravst, 2021; Szabo de Edelenyi et al., 2019).

Before selecting a FOPL, future research will be needed to investigate the consumer's ability to understand and use the available schemes, an essential step to ensure the efficacy of influencing food purchase and consumption.

Despite these limitations, our study provides evidence to support the application of *Nutri-Score* as FOPL in the Portuguese context.

5. Conclusions

There is currently a global public debate on the need to introduce simplified nutritional labelling on food, as part of a wider policy approach to improve human diets. FOPL is a public health measure that can represent significant advantages for literacy and population health. However, these tools will have a sub-optimal impact if they are not linked to public health policies that address the causes of poor diet quality in the social determinants of health.

In this study, the distribution of food products within the *Nutri-Score* categories showed a good capacity to discriminate the nutritional quality of products within main food groups and across relevant product groups and is aligned with national food-based dietary guidelines. We also observed a moderate agreement between the *Nutri-Score* and the PT-NPM, with differences noted for the food categories Processed fruit, vegetables, and legumes and Composite dishes.

The discriminating ability of the *Nutri-Score* is particularly important to help consumers to rank food products by nutritional quality. The results of our study contribute to support the choice of the graphical format *Nutri-Score* in the Portuguese context, as a complement and facilitator system of food literacy, thus enabling healthier food choices for Portuguese consumers.

Appropriate food labelling with a system such as *Nutri-Score* can be relevant to health-promoting purchasing choices, improving diet quality and consequently public health.

Author agreement statement

The authors whose names are listed immediately below certify that the undersigned declare that the manuscript title "Nutritional quality of foods consumed by the Portuguese population according to the *Nutri-Score* and consistency with nutritional recommendations" is original, has not been published before and is not currently being considered for publication elsewhere. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final

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Authors Statement

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Declaration of Competing Interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jfca.2023.105338.

References

Aguenaou, H., El Ammari, L., Bigdeli, M., El Hajjab, A., Lahmam, H., Labzizi, S., Gamih, H., Talouizte, A., Serbouti, C., El Kari, K., Benkirane, H., El Berri, H., AL-Jawaldeh, A., Yahyane, A., 2021. Comparison of appropriateness of nutri-score and other front-of-pack nutrition labels across a group of moroccan consumers: awareness understanding and food choices. Arch. Public Heal 79, 1–13. https://doi.org/10.1186/s13690-021-00595-3.

Chantal, J., Hercberg, S., 2017. Development of a new front-of-pack nutrition label in France: the five-colour Nutri-Score. Public Heal. Panor. 03 (04), 712–725.

Choices International Foundation, 2016. Choices Program. Int. Prod. Criteria.

Cooper, S.L., Pelly, F.E., Lowe, J.B., 2016. Construct and criterion-related validation of nutrient profiling models: a systematic review of the literature. Appetite 100, 26–40. https://doi.org/10.1016/j.appet.2016.02.001.

AOAC, 2000. Association of Official Analytical Chemists. In Official methods of analysis chemists, 17th ed. Washington, DC.

Despacho n.o 11418/2017, 2017. Estratégia Integrada para a Promoção da Alimentação Saudável, Diário da República ª2. série – N.° 249 – 29 de dezembro de 2017.

Dofkova, M., Nurmi, T., Berg, K., Reykdal, Ó., Gunnlaugsdóttir, H., Vasco, E., Dias, M.G., Blahova, J., Rehurkova, I., Putkonen, T., Ritvanen, T., Lindtner, O., Desnica, N., Jörundsdóttir, H.Ó., Oliveira, L., Ruprich, J., 2016. Development of harmonised food and sample lists for total diet studies in five European countries. Food Addit. Contam. Part A 33, 933–944. https://doi.org/10.1080/19440049.2016.1189770.

Draper, A.K., Adamson, A.J., Clegg, S., Malam, S., Rigg, M., Duncan, S., 2013. Front-of-pack nutrition labelling: are multiple formats a problem for consumers? Eur. J. Public Health 23, 517–521. https://doi.org/10.1093/eurpub/ckr144.

Dréano-Trécant, L., Egnell, M., Hercberg, S., Galan, P., Soudon, J., Fialon, M., Touvier, M., Kesse-Guyot, E., Julia, C., 2020. Performance of the front-of-pack nutrition label nutri-score to discriminate the nutritional quality of foods products: a comparative study across 8 European Countries. Nutrients 12, 1303. https://doi.org/10.3390/nu12051303.

Egnell, M., Talati, Z., Gombaud, M., Galan, P., Hercberg, S., Pettigrew, S., Julia, C., 2019. Consumers' responses to front-of-pack nutrition labelling: results from a sample from The Netherlands. Nutrients 11, 1817. https://doi.org/10.3390/nu11081817.

Egnell, M., Galan, P., Farpour-Lambert, N.J., Talati, Z., Pettigrew, S., Hercberg, S., Julia, C., 2020a. Compared to other front-of-pack nutrition labels the nutri-score emerged as the most efficient to inform Swiss consumers on the nutritional quality of food products. PLoS One 15, e0228179. https://doi.org/10.1371/journal.pone.0228179.

Egnell, M., Talati, Z., Galan, P., Andreeva, V.A., Vandevijvere, S., Gombaud, M., Dréano-Trécant, L., Hercberg, S., Pettigrew, S., Julia, C., 2020b. Objective understanding of the nutri-score front-of-pack label by European consumers and its effect on food choices: an online experimental study. Int. J. Behav. Nutr. Phys. Act. 17, 146. https://doi.org/10.1186/s12966-020-01053-z.

EN 16943, 2017. Foodstuffs. Determination of calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium, sulfur and zinc by ICP-OES.

European Commission, 2020b. Report from The Commission to The European Parliament and The Council regarding the use of additional forms of expression and presentation of the nutrition declaration [WWW Document]. URL https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:52020DC0207 (accessed 11.22.21).

European Food Safety Authority, 2015. The food classification and description system FoodEx 2 (revision 2). EFSA Support. Publ. 2015EN-804 2, 90.

European Food Safety Authority, Food and Agriculture Organization of the United Nations, W.H.O, 2011. Towards a harmonised Total diet study approach: a guidance document. EFSA J. https://doi.org/10.2903/j.efsa.2011.2450.

FAO, 2019. Food-based dietary guidelines [WWW Document]. URL http://www.fao.org/nutrition/education/ food-dietary-guidelines/en/ (accessed 10.24.21).

Despacho n.o 404/2012, 2012. Os programas de saúde prioritários a desenvolver pela Direção-Geral da Saúde (DGS), Diário da República 2.ª série – N.° 10 – 13 de janeiro de 2012.

European Commission, 2020a. A Farm to Fork Strategy for a Fair, Healthy and Environmentally-Friendly Food System [WWW Document]. URL https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0381.

Feteira-Santos, R., Alarcão, V., Santos, O., Virgolino, A., Fernandes, J., Vieira, C.P., João Gregório, M., Nogueira, P., Costa, A., Graça, P., 2021. Looking ahead: health impact assessment of front-of-pack nutrition labelling schema as a public health measure. Int. J. Environ. Res. Public Health 18, 1422. https://doi.org/10.3390/ijerph18041422.

Food and Drink Federation. GDAs explained. [WWW Document], 2014. URL ⟨https://www.gdalabel.org.uk/gda/gda_values.html⟩ (accessed 5.15.21).

Food Standards Agency, 2007. Front of Pack Nutritional Signpost Labelling. Technical Guidance.

GBD 2017 Diet Collaborators, 2019. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 393, 1958–1972. https://doi.org/10.1016/S0140-6736(19)30041-8.

Global Food Research Program., 2020. Front-of-Package (FOP) Food Labelling: Empowering Consumers to Make Healthy Choices. [WWW Document]. URL https://www.globalfoodresearchprogram.org/wp-content/uploads/2020/08/FOP_Factsheet_UNCGFRP_2020_September_Final.pdf (accessed 4.23.22).

Goiana-da-Silva, F., Cruz-e-Silva, D., Gregório, M.J., Nunes, A.M., Calhau, C., Hercberg, S., Rito, A., Bento, A., Cruz, D., Almeida, F., Darzi, A., Araújo, F., 2019. Nutri-Score: a public health tool to improve eating habits in Portugal. Acta Med. Port. 32, 175. https://doi.org/10.20344/amp.11627.

Gomes, S., Nogueira, M., Ferreira, M., Gregorio, M.J., 2017. Portuguese consumers' attitudes towards food labelling. World Health Organization Regional Office for Europe.

Gómez-Donoso, C., Martínez-González, M.Á., Perez-Cornago, A., Sayón-Orea, C., Martínez, J.A., Bes-Rastrollo, M., 2021. Association between the nutrient profile system underpinning the nutri-score front-of-pack nutrition label and mortality in the SUN project: a prospective cohort study. Clin. Nutr. 40, 1085–1094. https://doi.org/10.1016/j.clnu.2020.07.008.

Graça, P., Gregório, M.J., Freitas, M., da, G., 2020. A decade of food and nutrition policy in Portugal (2010–2020). Port. J. Public Heal. 38, 1–25. https://doi.org/10.1159/000510566.

Guasch-Ferré, M., Hu, F.B., Martínez-González, M.A., Fitó, M., Bulló, M., Estruch, R., Ros, E., Corella, D., Recondo, J., Gómez-Gracia, E., Fiol, M., Lapetra, J., Serra-Majem, L., Muñoz, M.A., Pintó, X., Lamuela-Raventós, R.M., Basora, J., Buil-Cosiales, P., Sorlí, J.V., Ruiz-Gutiérrez, V., Martínez, J.A., Salas-Salvadó, J., 2014. Olive oil intake and risk of cardiovascular disease and mortality in the PREDIMED Study. BMC Med. 12, 78. https://doi.org/10.1186/1741-7015-12-78.

Guasch-Ferré, M., Liu, G., Li, Y., Sampson, L., Manson, J.E., Salas-Salvadó, J., Martínez-González, M.A., Stampfer, M.J., Willett, W.C., Sun, Q., Hu, F.B., 2020. Olive oil consumption and cardiovascular risk in U.S. Adults. J. Am. Coll. Cardiol. 75, 1729–1739. https://doi.org/10.1016/j.jacc.2020.02.036.

Hafner, E., Pravst, I., 2021. Evaluation of the ability of nutri-score to discriminate the nutritional quality of prepacked foods using a sale-weighting approach. Foods 10, 1689. https://doi.org/10.3390/foods10081689.

Hercberg, S., Touvier, M., Salas-Salvado, J., 2021. Thenutri-score nutrition label: apublic health tool based on rigorous scientific evidence aiming to improve thenutritional

status of the population. int.j. vitam. nutr.Res. 0, 1–11. https://doi.org/10.1024/0300-9831/a000722.
Julia, C., Touvier, M., Méjean, C., Ducrot, P., Péneau, S., Hercberg, S., Kesse-Guyot, E., 2014. Development and validation of an individual dietary index based on the British food standard agency nutrient profiling system in a French context. J. Nutr. 144, 2009–2017. https://doi.org/10.3945/jn.114.199679.
Julia, C., Ducrot, P., Péneau, S., Deschamps, V., Méjean, C., Fézeu, L., Touvier, M., Hercberg, S., Kesse-Guyot, E., 2015. Discriminating nutritional quality of foods using the 5-color nutrition label in the French food market: consistency with nutritional recommendations. Nutr. J. 14, 1–13. https://doi.org/10.1186/s12937-015-0090-4.
Kanter, R., Vanderlee, L., Vandevijvere, S., 2018. Front-of-package nutrition labelling policy: global progress and future directions. Public Health Nutr. 21, 1399–1408. https://doi.org/10.1017/S1368980018000010.
Kelly, B., Jewell, J., 2018. What is the evidence on the policy specifications development processes and effectiveness of existing front-of-pack food labelling policies in the WHO European Region? Copenhagen: WHO Regional Office for Europe; (Health Evidence Network (HEN) synthesis report 61).
Larsson, I., Lissner, L., Wilhelmsen, L., 1999. The 'Green keyhole' revisited: nutritional knowledge may influence food selection. Eur. J. Clin. Nutr. 53, 776–780. https://doi.org/10.1038/sj.ejcn.1600839.
ISO/IEC 17025, 2017. General requirements for the competence of testing and calibration laboratories., International Organization for Standardisation.
McHugh, M.L., 2012. Lessons in biostatistics interrater reliability: the kappa statistic. Biochem. Med. 22, 276–282.
Ministère des solidarités et de la santé, 2017. Arrêté du 31 octobre 2017 fixant la forme de présentation complémentaire à la déclaration nutritionnelle recommandée par l'Etat en application des articles L. 3232-8 et R 3232–7 du code de la santé publique. J. la République Fr. 1–5.
NutrInform Battery [WWW Document], 2020. URL https://www.nutrinformbattery.it/ (accessed 5.15.21).
Portugal. Ministério da Saúde. Direção-Geral da Saúde, 2019a. Improving Nutrition Labelling in Portugal Health Impact Assessment. Lisboa.
National Health Service England, 2019. 8 tips for healthy eating -Eat well [WWW Document]. Natl. Heal. Serv. Engl. URL https://www.nhs.uk/live-well/eat-well/eight-tips-for-healthy-eating/ (accessed 10.17.21).
Partearroyo, T., Samaniego-Vaesken, M., de, L., Ruiz, E., Aranceta-Bartrina, J., Gil, Á., González-Gross, M., Ortega, R.M., Serra-Majem, L., Varela-Moreiras, G., 2019. Sodium intake from foods exceeds recommended limits in the spanish population: the anibes study. Nutrients 11, 2451. https://doi.org/10.3390/nu11102451.
Poínhos, R., Franchini, B., Afonso, C., Correia, F., Teixeira, V.H., Moreira, P., Durão, C., Pinho, O., Silva, D., Lima Reis, J.P., Veríssimo, T., De Almeida, M.D.V., 2009. Alimentação e estilos de vida da população portuguesa: metodologia e resultados preliminares. In: Rev. Aliment, 15. Humana,, pp. 43–60.
Rayner, M., Scarborough, P., Heart, B., Health, F., 2009. The UK Ofcom Nutrient Profiling Model. UK Ofcom 1–11.
Rodrigues, S.S.P., Franchini, B., Graça, P., de Almeida, M.D.V., 2006. A new food guide for the Portuguese population: development and technical considerations. J. Nutr. Educ. Behav. 38 https://doi.org/10.1016/j.jneb.2006.01.011.
Portugal. Ministério da Saúde. Direção-Geral da Saúde, 2019b. Perfil Nutricional – Restrições à publicidade alimentar dirigida a crianças. Lisboa.
Santé Publique France, 2021. Santé Publique France – Conditions of Use of the Nutri-Score Logo [WWW Document]. URL https://www.santepubliquefrance.fr/content/download/150258/file/20210908_RU_International_Users_regulation_ENG.pdf (accessed 10.17.21).
Savoie, N., Barlow, K., Harvey, K.L., Binnie, M.A., Pasut, L., 2013. Consumer perceptions of front-of-package labelling systems and healthiness of foods. Can. J. Public Heal. 104, e359–e363. https://doi.org/10.17269/cjph.104.4027.
Szabo de Edelenyi, F., Egnell, M., Galan, P., Druesne-Pecollo, N., Hercberg, S., Julia, C., 2019. Ability of the nutri-score front-of-pack nutrition label to discriminate the nutritional quality of foods in the german food market and consistency with nutritional recommendations. Arch. Public Heal 77, 28. https://doi.org/10.1186/s13690-019-0357-x.
van Tongeren, C., Jansen, L., 2020. Adjustments needed for the use of nutri-score in the netherlands: lack of selectivity and conformity with dutch dietary guidelines in four product groups. Int. J. Nutr. Food Sci. 9, 33. https://doi.org/10.11648/j.ijnfs.20200902.11.
Vasco, E., Dias, M.G., Oliveira, L., 2021. The first harmonised total diet study in Portugal: planning sample collection and sample preparation. Food Chem. 363. https://doi.org/10.1016/j.foodchem.2021.130258.
Vergeer, L., Ahmed, M., Franco-Arellano, B., Mulligan, C., Dickinson, K., Bernstein, J.T., Labonté, M.-È., L'Abbé, M.R., 2020. Methodology for the determination of fruit, vegetable, nut and legume points for food supplies without quantitative ingredient declarations and its application to a large canadian packaged food and beverage database. Foods 9, 1127. https://doi.org/10.3390/foods9081127.
Vin, K., Papadopoulos, A., Cubadda, F., Aureli, F., Oktay Basegmez, H.I., D'Amato, M., De Coster, S., D'Evoli, L., López Esteban, M.T., Jurkovic, M., Lucarini, M., Ozer, H., Fernández San Juan, P.M., Sioen, I., Sokolic, D., Turrini, A., Sirot, V., 2014. TDS exposure project: relevance of the total diet study approach for different groups of substances. Food Chem. Toxicol. 73, 21–34. https://doi.org/10.1016/j.fct.2014.07.035.
Wicks, M., Wright, H., Wentzel-Viljoen, E., 2016. Restricting the marketing of foods and non-alcoholic beverages to children in South Africa: are all nutrient profiling models the same? Br. J. Nutr. 116, 2150–2159. https://doi.org/10.1017/S0007114516004244.
World Health Organization, 2013. Global nutrition policy review: What does it takes to scale up nutrition action? World Health Organization,, Copenhagen, Denmark.
World Health Organization, 2017. Tackling NCDs: "best buys" and other recommended interventions for the prevention and control of noncommunicable diseases. World Health Organization,.
World Health Organization, 2020. Manual to develop and implement front-of-pack nutrition labelling. World Health Organization,, Copenhagen, Denmark.
World Health Organization, 2015b. WHO Regional Office for Europe Nutrient Profile Model. Copenhagen, Denmark.
World Health Organization, 2015a. European Food and Nutrition Action Plan 2015–2020. Copenhagen, Denmark.