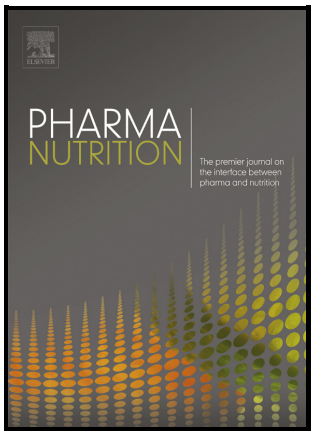
Publication bias and Nutri-Score: A complete literature review of the substantiation of the effectiveness of the front-of-pack logo Nutri-Score



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Publication bias and Nutri-Score: A complete literature review of the substantiation of the effectiveness of the front-of-pack logo Nutri-Score.[1]

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Abstract

Background: The front-of-pack label Nutri-Score is currently proposed as the system of choice in seven EU countries. However, there is still much scientific debate about the validation and efficacy of Nutri-Score and there is much discussion about author affiliation and study outcome.

Methods: To address these issues, we conducted a complete PubMed search on Nutri-Score which resulted in n=180 results and selected all papers that address the relevance of the evidence for the validation of Nutri-Score (n=104).

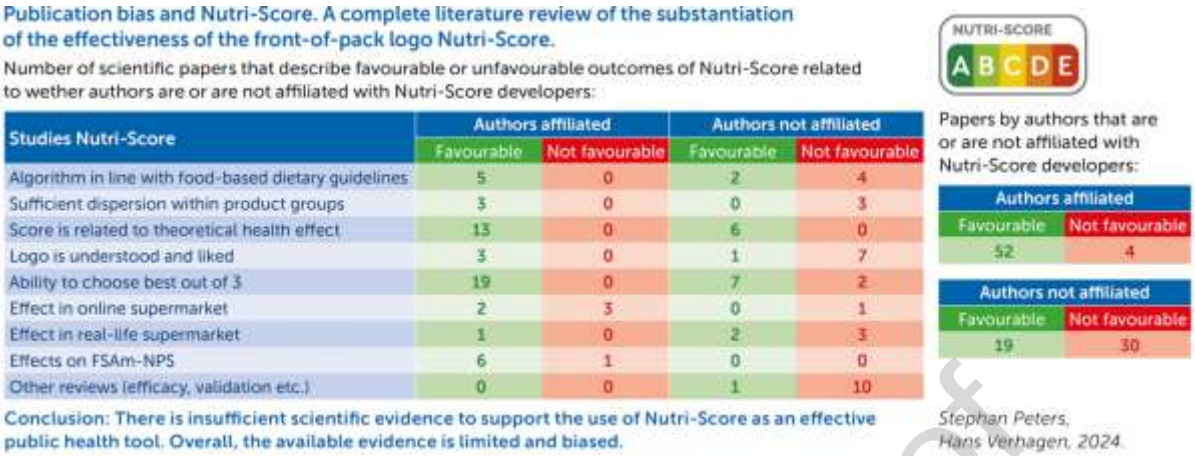
Results: Our main observations are that the large majority of studies that support the Nutri-Score are carried out by the developers of Nutri-Score. In contrast, the majority (61%) of studies that are carried out independently from the developers of Nutri-Score showed unfavourable results. A second observation is that even though the theoretical effect of Nutri-Score is validated on a multi-nutrient algorithm (FSA-NPS), there is no real-life evidence of any beneficial effects of Nutri-Score on this algorithm in a complete supermarket range. In conclusion, there is insufficient scientific evidence to support the use of Nutri-Score as an effective public health tool.

Discussion: Overall, the available evidence is limited and biased, and more research is needed to substantiate or disprove the effectiveness of Nutri-Score.

Keywords: Front-of-pack logos; FOPL; Nutri-Score; Publication bias; review

[1] Abbreviations: ESL = Electronic shelf labels; FBDGs = Food-based dietary guidelines; FOPL = Front-of-Pack label; FSA-NPS = Food Standard Agency-Nutritional Profiling System; FSAm-NPS = modified Food Standard Agency-Nutritional Profiling System; HETI = Healthy trolley index; MTL = multiple traffic light; RCT = randomized controlled trial, SSBs = sugar-sweetened beverages; EREN: l'Equipe de Recherche en Epidémiologie Nutritionelle, Inserm/Inrae/Cnam/Université Sorbonne Paris Nord = developers of Nutri-Score

Graphical abstract



1. Introduction

Front-of-pack labels (FOPLs) are claims that communicate health characteristics of foods. They are intended to provide nutritional information to consumers in a simple manner, with the intention of assisting them in making healthier food choices. As such, the primary goal of a FOPL is to encourage consumers to make healthier food purchases. The efficacy of different FOPLs was recently evaluated in three systematic reviews, including a meta-analysis [1-3]. Overall, the studies did report some beneficial results of FOPLs on food choices and dietary intake. However, the individual studies showed rather heterogeneous results and were based on a limited number of studies. Whereas the Nutri-Score system is currently proposed as the system of choice in seven EU countries, Nutri-Score was not included in these reviews. Our recently published narrative review showed that there is currently insufficient evidence to support the notion that Nutri-Score has an effect on real-life supermarket purchases [4].

The debate surrounding Nutri-Score is polarised. On the one hand, there is the scientific group around the developers of Nutri-Score that have published scientific articles concerning the scientific substantiation and validation of Nutri-Score. These scientists have also published a blog supporting Nutri-Score. This blog is used when lobbying with the aim of getting Nutri-Score accepted as the future mandatory front-of-pack logo in the European Union (https://nutriscore.blog).

The Nutri-Score system, however, is not without scientific controversy. As we have shown in our recent article, Nutri-Score lacks an essential part of its scientific substantiation as there is no evidence yet of a beneficial effect on real-life supermarket purchases [4]. In addition, there is much opposition against the application of the current Nutri-Score among nutrition scientists. An example of this can be seen against the backdrop of the opposition in the Netherlands. In 2019, 180 Dutch nutrition scientists requested the Dutch Ministry of Health not to introduce the Nutri-Score because it is not in line with Dutch food-based-dietary guidelines. This led to the appointment of an international scientific committee to change the algorithm behind the Nutri-Score. Their task was to bring Nutri-Score more in line with food-based dietary guidelines. This committee was chaired by the developers of Nutri-Score with the conclusions published in 2022. Subsequently, the Dutch Health Council, who was also part of this scientific committee, wrote a report on the adaptations made by the European Scientific Committee in charge of upgrading the algorithm (https://www.santepubliquefrance.fr/determinants-de-sante/nutrition-et-activite-physique/documents/rapport-synthese/update-of-the-nutri-score-algorithm-for-beverages.-second-

update-report-from-the-scientific-committee-of-the-nutri-score-v2-2023). The Dutch Health Council concluded that the algorithm still fails to bring the Nutri-Score sufficiently in line with the Dutch food-based dietary guidelines for different food groups. Based on this report, again almost all Dutch nutrition scientists and, in addition, the two Dutch dietitian associations wrote an 'alarming letter' to their Ministry of Health with, again, a request to not introduce the Nutri-Score until the critical points made by the Health Council are resolved (https://voedingsjungle.files.wordpress.com/2022/12/20221211_oproep-aan-van-ooijen-nutriscore-aan-te-passen-voorafgaand-invoering_def.pdf). Nevertheless, the Netherland's Ministry of Health declined the appeal of the Dutch food scientists and decided to introduce the Nutri-Score as a voluntary front-of-pack logo in the Netherlands starting in January 2024. Also, in Poland there is no consensus among nutrition experts about the applicability and efficacy of Nutri-Score. In a recent Poland-wide expert opinion study using a cross-sectional design survey among 75 experts with on average 18 years of experience in the medical and agricultural field similar opinions were concluded as among the Dutch scientists. While more than half of the respondents believed that the Nutri-Score provides an overall assessment of a product's nutritional value and might facilitate quick purchasing decisions, it falls short in helping consumers compose a balanced diet and cannot be applied to all product groups. The experts also expressed concerns about the system's ability to account for a product's degree of processing, full nutritional value and carbon footprint. In conclusion, according to the Polish experts, the Nutri-Score requires significant and deep changes and validation against national guidelines and expert expectations before implementation [5]. In addition, the Nutri-Score system also caused a scientific controversy in Italy (see in particular the position paper of the scientific committee of the Italian government and https://cnbbsv.palazzochigi.it/media/2631/expert-opinion-on-front-of-pack-labels-cnbbsv-2022.pdf). The Italian scientific committee concluded that the studies that associate the adoption of a FOPL with an improvement of health status are very few, mainly applied in virtual settings or to pre-existing cases: none of these are longitudinal and are able to identify a causal link between the adoption of the FOPL and the change in health changes.

In the polarised debate, there is also discussion about bias of the peer-reviewed scientific articles. Recently, Besancon et al. [6] suggested that the food industry is opposed to the Nutri-Score system and, consequently, publishes papers that are unfavourable to Nutri-Score on a preferential basis. However, the authors of that commentary paper did not conduct a comprehensive search of the literature, and moreover, their analysis was limited only to the outcome of the studies (favourable versus unfavourable), without considering the content of the papers or their relevance for the validation of Nutri-Score. The paper by Besancon et al. [6] formed the starting point of the present study.

The paper by Besancon et al. [6] concluded that "a study is 21 times more likely to find unfavourable results about the nutrition label Nutri-Score if the authors declare a conflict of interest or the study is funded by the food industry". This figure was based on the following calculation: 111 out of 134 papers selected were favourable of the Nutri-Score system and of those 111 only 2 included declarations of a conflict of interest or indicated that the authors had received funding from the food industry: 2 / 111 = 1.8%. In addition, out of 23 scientific papers that were unfavourable towards Nutri-Score, in total 9 (9/23 = 39.1 %) included a conflict of interest by the authors or reported that the study had received funding from the food industry. By dividing these figures 39.1% / 1.8% = a suggestive figure of 21 times was achieved.

We do not want to question the quality of individual papers that appeared in peer-reviewed scientific journals, as peer-reviewing is an implicit quality indicator. However, we found out that the table that Besancon et al. [6] added in their supplementary material in their paper is not based on a systematic

scientific search in Pubmed but rather only on the literature list on the website of the developers of Nutri-Score (https://nutriscore.blog/author/logonutriscore/ (accessed July 22nd 2023)). That list on the Nutri-Score blog is far from complete and does not mention all peer-reviewed papers about Nutri-Score and in particular lacks papers unfavourable towards Nutri-Score. In addition, the Besancon et al. paper only looked at outcomes 'favourable' or 'unfavourable', without looking at the content of the papers, nor did they evaluate the relevance of the papers for the validation of Nutri-Score. To address these limitations and to cover all applicable data, we conducted a full and complete PubMed search on Nutri-Score/NutriScore *i.e.,* without deleting any pertinent study. Subsequently, all studies that were relevant for the validation of Nutri-Score were selected and reported in a complete literature table (Table 1). Based on this table, an evaluation is made on the relationship between author affiliation and publication outcome.

2. Materials and Methods

2.1. Literature search

The PubMed database was searched on 22 July 2023 with the keywords [Nutri-Score] and [NutriScore]. In total, 180 papers were identified, of which n=104 addressed some kind of validation of the Nutri-Score system. We are aware that many more papers address nutrient-profiling systems and their validation but we decided to focus explicitly on "Nutri-Score", the subject of this investigation. This is in line with the borders set out in Besancon et al. [5]. Hence, we have included all pertinent papers on "Nutri-Score"; those date from 2016 onwards, the year the term "Nutri-Score" was introduced, unlike earlier names of a preceding similar system.

2.2. Selection of studies

An overview of our complete investigation is summarised in Table 1 and Figure 1 (flow Diagram as per Prisma 2009). To this end, we have copied the Table from Besancon et al. (2023) [6] and added articles that we have found in our full PubMed search, but that were not included in the original Besancon et al. table. These additional papers can be found in blue letters in Table 1 which can be found in the supplementary material.

2.3. Data appreciation

A check in line with the paper of Besancon was carried out on the nomination "favourable" or "unfavourable": when we were in disagreement with Besancon et al. [6] we have written the deviant denomination in red. Furthermore, we have added additional columns into the Table 1, namely:

- [relevant for the validation of Nutri-Score]: yes or no.
- [method] paper methodology: what kind of study (*e.g.* cohort study, RCT, review etc).
- [validation stage] (e.g. validation versus the UK Food Standard Agency nutrient profiling system (FSA-NPS).
- [products] with what products has the study been carried out (if any).
- [real-life] has the studied been carried out in real-life circumstances?: yes or no.
- [additional remarks].

Subsequently, we distributed the validation of Nutri-Score over several categories:

- "alignment with food-based dietary guidelines"
- "discriminatory performance"

- "FSA-NPS health validation"
- "subjective understanding"
- "objective understanding"
- "purchase *intentions*"
- "*real-life* purchases"
- "effects measured on FSA-NPS"
- "reviews"

2.4. Validation versus validation stage

Based on the total overview of studies mentioned in Table 1, we have assigned the 104 relevant papers in terms of their place into the validation stage which can be found in Table 2. This table has been structured in such a way that the lower the row in the table the higher the relevance for the substantiation of the effectiveness of Nutri-Score.

The first three rows are relevant for the theoretical substantiation of the potential health effects of Nutri-Score. "*Alignment with food-based dietary guidelines*" means that the authors conclude that Nutri-Score is sufficiently or not in line with food-based dietary guidelines. "*Discriminatory performance*" means that Nutri-Score sufficiently distributes food items along the different scores (A – B – C – D – E). "*FSA-NPS health validation*" involves studies that apply the algorithm of Nutri-Score (this is the modified Food Standard Agency Nutrient Profiling FSA-NPS [7] score) in epidemiological cohorts demonstrating that a change in the FSA-NPS score is beneficial for different non-communicable diseases and risk factors.

The fourth and fifth row in Table 2 concern subjective and objective understanding. This involves online consumer surveys. "*Subjective understanding*" is defined as the meaning individually attributed to the information on the label by the consumer. Objective understanding happens when the meaning that the consumer attached to the information on the label represents what is intended to be conveyed by the sender. These two concepts are based on the theoretical framework of Grunert and Wills [8]. Examples of subjective understanding are liking and appreciation of Nutri-Score. For "*objective understanding*", three examples of a product are shown in an online survey with different Nutri-Scores and consumers are asked to put products in the right order. When able to do so, these scorings are overly interpreted by the researchers as 'able to rank products according to nutritional quality'.

Most relevant for the efficacy of Nutri-Score is the relation of the score to factual healthier purchases. Some studies are consumer surveys about "*purchase intentions*". In studying the efficacy of Nutri-Score, the most relevant are those studies on the effect of Nutri-Score on "*real-life purchases*" and in the most ideal case on real-life purchases in a complete supermarket assessment. The theoretical effect of Nutri-Score on health is based on the associations between the application of the Nutri-Scores on the label and an "*effect on the FSA-NPS*" (Nutri-Score's algorithm). So, the *golden bullet studies* to determine the efficacy of Nutri-Score are based on the effect of real-life supermarket purchases based on receipts and the effect on the algorithm. Unfortunately, no such study exists. However, there are studies that have calculated the effects of food purchases in online experiments and some in a real-life setting when Nutri-Score is applied only on a small number of products. These studies can be found on the second to last row in Table 2. The lowest row deals with different "*reviews*" covering Nutri-Score.

2.5. Data presentation

All relevant papers from Table 1 are distributed in Table 2 as follows: The amount of article numbers in red are written by authors associated with the developers of Nutri-Score; such authors are either from the EREN institute directly or have published on the topic of nutrient profiles with EREN-based authors. The amount of article numbers in green are written by authors independent of the developers of Nutri-Score; such authors are not from the EREN Institute nor have they published on the topic of nutrient profiles with EREN-based authors. The references in Table 2 are aligned with the references in Table 1.

3. Results

Of the 180 papers found in the complete PubMed search, 104 papers in total were considered as relevant for the validation of Nutri-Score. Subsequently, each paper was identified as either "favourable" or "unfavourable" towards Nutri-Score or received an occasional "neutral" judgement. Our judgement of "favourable" or "unfavourable" was nearly always the same judgement as in the supplement published in the paper by Besancon et al. (2023) [6], so there will be little dispute about the veracity of our findings. When there was no convincing evidence for a judgement of "favourable" we chose for "unfavourable", such as in the case of "insufficient" and similar wordings. This is in line with the position taken in our earlier paper where we found insufficient evidence to support a theoretical health claim for Nutri-Score [4]. No discrimination was made in terms of the quality or size of one paper versus another: all were considered valid as they have gone through peer-review prior to publication. In addition, we included *a few dozen papers* that were not included in the Besancon et al. paper [6]. Here we found out that the table was not based on a PubMed search, but rather on the overview of the Nutri-Score blog (https://nutriscore.blog/author/logonutriscore/) which apparently is an incomplete overview of pertinent studies available.

3.1. Favourable versus unfavourable

Our analysis revealed several interesting observations. Firstly, after selecting all Pubmed-indexed papers of table 1 we found out that the majority of studies on Nutri-Score were conducted by authors who are employed at or connected with its developers and almost all of (n=63) these were favourable towards Nutri-Score [6,7,9-69] and n=4 were unfavourable [12,49,70,71]. In contrast, we found that the majority of studies n=37 that were unfavourable to Nutri-Score [4,5,49,70-103] were conducted by authors who are not employed at or connected with its developers and n=17 were favourable [104-120]. We have also found n=14 papers that were neutral (not favourable nor unfavourable [92,102,121-132]. Subsequently, we have selected all papers that are relevant for different validation stages of Nutri-Score (n=104) according to validation stage in Table 2. Finally, in table 3 we have selected all peer-reviewed papers that were relevant for the validation of Nutri-Score according to the authors that are employed or connected to the developers of Nutri-Score and authors that are not connected to the developers of Nutri-Score. We also have added papers from the Supplement table of Besancon [6] that we have not found in Pubmed searches (n=26). These were mostly opinion papers of articles in other language than English and could not be found in Pubmed.

3.2. Overall observations

Our observations based on the relevant studies mentioned in the overall Table 1 and summarised in Table 2 are as follows:

The majority of studies (7 out of 11) that addressed "*alignment with food-based dietary guidelines"* were supportive of Nutri-Score. Five of these studies were conducted by authors who were employed by or connected with the developers of Nutri-Score. In contrast, four other studies that did not find

favourable results were carried out by scientists not affiliated or connected with the developers of Nutri-Score.

3 out of 6 studies that addressed "*discriminatory performance"* were supportive of Nutri-Score. These studies were conducted by authors who were employed by or connected with the developers of Nutri-Score. Another three unfavourable studies were carried out by researchers not connected with the developers of Nutri-Score.

All studies that addressed "*FSA-NPS health validation"* were supportive of Nutri-Score. From these, 13 out of 19 were conducted by authors who were employed by or connected with the developers of Nutri-Score.

Four studies that addressed "*subjective understanding"* were favourable of Nutri-Score, while another seven were not. Three out of four favourable studies were carried out by groups that are affiliated with the developers of Nutri-Score. Seven studies were unfavourable to Nutri-Score and all of these were conducted by authors who were not employed by or connected with the developers of Nutri-Score.

Nearly all studies (26 out of 28) that addressed "*objective understanding"* were supportive of Nutri-Score. Of these studies, n=19 were conducted by authors who were employed by or connected with the developers of Nutri-Score. Two studies were unfavourable of which one study was caried out by authors not connected to the developers of Nutri-Score. One reference [96] is mentioned as both favourable as unfavourable under *objective understanding* because Nutri-Score was unfavourable for fruit drinks and favourable for bread, cookies and cereals.

Six studies addressed "*purchase intentions"* and five of these were carried out by the group of the developers behind Nutri-Score. In contrast to the authors and developers of the Nutri-Score, we have interpreted 3 out of these 5 studies as unfavourable. Two studies showed a statistically better result of Nutri-Score when compared to the Reference Intake, but the Nutri-Score in these studies did not perform better than no-label [70,71], which should be interpreted as an unfavourable result. One study considered an outcome of $p<0.10$ as significant, whereas we consider $p<0.05$ as significant [82]. Finally, in a study on the effect of purchases on three product groups, Nutri-Score had only a limited effect on one group, namely sweet biscuits, and not on the product groups: breakfast cereals and appetizers [49].

Six studies addressed "*real-life purchases"*. Three of these studies were favourable and three were unfavourable. The two studies carried out by the developers of Nutri-Score were favourable. Three studies that were conducted by authors who were not employed by or connected with the developers of Nutri-Score resulted in unfavourable results. The three very important real-life studies that were unfavourable for Nutri-Score [72,95,100] were not mentioned on the Nutri-Score blog on July 22nd 2023 and, consequently, not in the paper of Besancon.

The team that developed Nutri-Score has also carried out 7 studies on the effect of the application of Nutri-Score in an online supermarket environment "*on the algorithm FSA-NPS*". All resulted in an improvement on the algorithm. However, one study in a whole online supermarket with a complete range was interpreted as a favourable study, albeit that it showed that Nutri-Score did not perform better than no label [71].

Finally, 11 studies involved *reviews* on Nutri-Score which were all carried out independently of the team behind Nutri-Score. Only one review concluded favourably, whereas ten studies were unfavourable.

4. Discussion

Our findings suggest that most studies that have been conducted by authors who are employed by or connected with the developers of Nutri-Score have been supportive of the system. However, the majority of studies that have been conducted by authors who are not employed by or connected with the developers of Nutri-Score have been unfavourable. This has been summarised in Table 3: 52 out of 56 studies by authors that are employed at or connected with its developers conclude towards a "favourable" outcome of their work (= 93%), according to our analysis, whereas according to Besancon et al. [6] and the authors affiliated with the developers of Nutri-Score, all were favourable. In contrast, 30 out of 49 studies by authors that are not employed at or connected with its developers conclude towards an "unfavourable" final conclusion (= 61%). Tables 2 and 3 clearly illustrate that the conclusions of studies and publications on Nutri-Score are subject to publication bias.

The validation of a nutrient profiling system is complex. Also, EFSA could not come to a definite conclusion in two attempts [133,134]. This is due to the fact that for setting a nutrient profiling system, risk assessment and risk management are unavoidably intertwined [135]. The algorithm behind Nutri-Score can also be interpreted as a nutrient profile, albeit one with a limited amount of nutrients. This nutrient profile, which is based on the UK Food Standard Agency Nutrient Profiling System (FSA-NPS) [44], has been adapted twice and forms the basis of the algorithm behind Nutri-Score. The theoretical validation of the beneficial health effects of Nutri-Score is based on an improvement on the algorithm axis by changes in supermarket purchases. This theoretical and, consequently, potential effect has been proven on different non-communicable disease and health risk factors (we refer to the references in Table 2 under FSA-NPS validation). Hence, the only way to prove the efficacy of Nutri-Score is to demonstrate changes in supermarket purchases on the algorithm and not by showing in supermarket sales, that more products with a Nutri-Score A and B have been bought or that less products with D and E have been bought. No such study exists with the application of Nutri-Score on a complete supermarket range. Only one study examined the effects of a black-and-white label on shelf-tags (Electronic Shelf Labels; ESL) in a complete supermarket range [100]. This experiment led to mixed results that cannot predict the effect of Nutri-Score on supermarket purchases. The authors concluded that the impact of ESL on consumer purchases was mixed, as difference-in-differences found were favourable for Nutri-Score B and C products and unfavourable for Nutri-Score D products. The author's conclusion was that shelf labelling on its own is unlikely to significantly influence consumer behaviour. This experiment did not look at the effect of the Nutri-Score on its validation basis in terms of the FSA-NPS [100]. There are some studies that looked at the effect of Nutri-Score on the FSA-NPS carried out by the developers of Nutri-Score in online supermarkets. Some of these studies found favourable results and one study found that no effects of Nutri-Score was observed on the FSA-NPS (Table 2). Also, the negative effects of Nutri-Score can be observed. In a recent study which was carried out independently of the developers of Nutri-Score, the label was applied in a sports and non-sports facility in South Korea and showed a beneficial effect (more purchases of Nutri-Score A and B products) in the sports facility and a negative effect in a non-sports facility. In the non-sports facility, which can be compared to a small supermarket, less Nutri-Score A products and more Nutri-Score B and E products were bought [136]. Overall, it can be concluded that the application of Nutri-Score leads to unpredictable results on sales, sometimes beneficial sometimes negative. So, no final conclusion can be drawn on the efficacy of Nutri-Score.

There are some reports of food authorities supporting Nutri-Score as a front-of-pack logo. For example, the WHO/IARC has published a summary report supporting the science behind Nutri-Score

[137]. However, this report was written by developers of Nutri-Score who were involved in the WHO-IARC report. In addition, different initiatives by the developers of Nutri-Score have been published with support letters from scientists and health associations. The scientific reviews were written by the developers of Nutri-Score and support for the review was requested. More than 400 European scientists publicly support this review as do different health organisations [138], which contrasts with the hundreds of scientists in the Netherlands (and Poland [5]) that oppose the system on scientific grounds https://voedingsjungle.files.wordpress.com/2022/12/20221211_oproep-aan-van-ooijen-nutriscore-aan-te-passen-voorafgaand-invoering_def.pdf. In the review written by the developers of Nutri-Score [138], the literature list is incomplete and has no mention of the most relevant real-life studies that are unfavourable towards Nutri-Score [4,100,136], potentially compromising the supporting scientists. Therefore, we strongly plea for an *independent* scientific evaluation of Nutri-Score by *e.g.* the European Food Safety Authority.

5. Conclusion

There is insufficient scientific evidence to support the use of Nutri-Score as an effective public health tool. Moreover, the available evidence is limited and biased, and more research is needed to assess the effectiveness of Nutri-Score. We recommend that future research and scientific evaluation on Nutri-Score should be conducted by independent researchers who are not affiliated with the developers of the system. We recommend that the research should also be structured to assess the effectiveness of Nutri-Score in real-world settings.

We hope that our findings will help to inform the debate about the use of Nutri-Score as a public health tool and the role of publication bias in the scientific debate. We believe that it is important to carefully consider the evidence that is available before making decisions about the use of mandatory FOPLs. We conclude that there is no clear consensus on the validity and efficacy of Nutri-Score. More research is needed to assess the system's effectiveness in promoting healthier food choices. If Nutri-Score might be considered as a harmonised front-of-pack logo in the European Union in the future, its scientific substantiation and application should be scrutinised by the EFSA in a similar evaluation as Health Claims.

CRediT authorship contribution statement

S.P.: Conceptualization; Data curation; Formal analysis; Methodology; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing. H.V.: Conceptualization; Data curation; Formal analysis; Methodology; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing.

Declaration of Competing Interest

S.P. is employed at the Dutch Dairy Association. H.V. is an independent consultant at the Food Safety & Nutrition Consultancy (The Netherlands) and holds professorships at the Technical University of Denmark (Denmark) and the University of Ulster (Northern Ireland). Neither author has a past or current collaboration with the Nutri-Score. H.V. is a member of the international board of the Choices International Foundation since 2023. Until 2015, Both S.P. and H.V. were members of the independent scientific committee in the Netherlands supporting the former front-of-pack logo “het

Vinkje". The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The Dutch Dairy Association is involved in the national discussion in the Netherlands about front-of-pack logos by submitting inputs into product reformulations and front-of-pack consultations of the Dutch Ministry of Health, Welfare and Sport.

Data availability

No data was used for the research described in the article other than publicly available literature through PubMed.

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Legends to the Tables

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171. Muzzioli, L.; Penzavecchia, C.; Donini, L.M.; Pinto, A. Reply to Aguenaou et al. Comment on "Muzzioli et al. Are Front-of-Pack Labels a Health Policy Tool? *Nutrients* **2022**, *14*, doi:10.3390/nu14102167.
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173. Riccò, M.; Ranzieri, S.; Balzarini, F.; Vezzosi, L.; Marchesi, F.; Valente, M.; Peruzzi, S. Understanding of the Nutri-Score front-of-pack label by Italian Medical Professionals and its effect on food choices: a web-based study on knowledge, attitudes and practices. *Acta Biomed* **2022**, *93*, e2022042, doi:10.23750/abm.v93i2.11191.
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175. Rodríguez-Martín, N.M.; Córdoba, P.; Sarriá, B.; Verardo, V.; Pedroche, J.; Alcalá-Santiago, Á.; García-Villanova, B.; Molina-Montes, E. Characterizing Meat- and Milk/Dairy-like Vegetarian Foods and Their Counterparts Based on Nutrient Profiling and Food Labels. *Foods* **2023**, *12*, doi:10.3390/foods12061151.

Table 3 Summary of the number of scientific papers that describe favourable and unfavourable outcomes of the Nutri-Score versus whether authors that are or are not employed at or connected with its developers.

	Authors that are or are not employed at or connected with its developers	
	Employed or connected	Not employed or connected
Favourable	52	19
Unfavourable	4	30

These figures are based upon the articles of Table 2 that are labelled as relevant for the validation of Nutri-Score AND are published in peer-reviewed journals. One reference [96] is mentioned in both favourable as unfavourable under *objective understanding* because Nutri-Score was unfavourable for fruit drinks and favourable for bread, cookies and cereals. Therefore, the total amount of relevant references is n=104.

Table 2. Summary and individual allocation of the scientific papers that describe favourable and unfavourable outcomes of the Nutri-Score versus whether authors that are or are not employed at or connected with its developers. Citation numbers in red: the authors are employed at or connected with its developers. Citation numbers in green: the authors are not employed at or connected with its developers. The citation numbers are harmonised with the citations in Table 1.

Validation phase	Relevance	Products	Citation Number	Number of papers
Alignment with food-based dietary guidelines	To prevent consumer confusion, it is important to bring Nutri-Score in line with food-based dietary guidelines.	Food consumption databases	Favourable [7,21,46,117,118,139,140]	5 + 2
			Unfavourable [86,88,99,141]	4
Discriminatory performance	Does Nutri-Score render sufficient discriminatory performance over products within product groups?	Food consumption databases	Favourable [7,21,139]	3
			Unfavourable [85,86,142]	3
FSAm-NPS health validation	Does a better score on the FSAm-NPS have a potential	-	Favourable [9,11,12,17-20,30,34,44,48,51,52,104,105,107,110,114,143]	13 + 6
			Unfavourable	0

	theoretical health effect?			
Subjective understanding	Understanding and liking of logo	-	Favourable [25,53,65,144]	3 + 1
			Unfavourable [74,79,84,90,145-147]	7
Objective understanding	Ability to select the best product among three products of same product group according to Nutri-Score, e.g. breakfast cereals with Nutri-Score A, B, etc	Different three products in product groups	Favourable [13,15,16,23,27-29,31,33,38,41,49,60-63,67,69,96,109,111,115,148-151]*	19 + 7
			Unfavourable [77,96]*	2
Purchase intentions	Effect of Nutri-Score applied in an online supermarket environment		Favourable [36,57]	2
			Unfavourable [49,70,71,82]	3 + 1
Real-life purchases	Effect of Nutri-Score applied in a real-life supermarket or other real-life environments	Complete ranges	Favourable [24,119,120]	1 + 2
			Unfavourable [72,95,100]	3
Effects measured on FSAm-MPS	Effects of Nutri-Score intervention on FSAm-NPS		Favourable [24,35,36,49,57,119]	6
			Unfavourable [71]	1
Reviews	Different reviews about efficacy, validation etc. of Nutri-Score		Favourable [152]	1
			Unfavourable [4,5,73,76,83,93,97,98,102,103]	10

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* One reference [96] is mentioned in both favourable as unfavourable under *objective understanding* because Nutri-Score was unfavourable for fruit drinks and favourable for bread, cookies and cereals.

Table 1. Extended version of the table of Besancon et al. (2023) to which we have included all articles that have been found in our PubMed-search including the ones that were not included in the original table of Besancon et al. (2023). These additional papers are shown in blue letters. In addition, several extra columns with information have been added. Moreover, we have checked the nomination "favourable" or "unfavourable": when in disagreement with Besancon et al. (2023) the deviant denomination is presented in red.

PubMed search dated July 22tnd 2023	Favourable, Neutral, Unfavourable towards Nutri-Score	EREN Involved Only EREN Yes/No Or affiliated papers with EREN team	Conflict of interest according to EREN	Relevant for validation of Nutri-Score	Method	Validation stage	Products	Real life	Remarks
Adriouch, 2016 [11].	F	Yes		Yes	Cohort	FSA-NPS validation			
Adriouch, 2017 [10]	F	Yes		Yes	Cohort	FSA-NPS validation			
Ahn, 2022. [72]	U	No		Yes	Supermarket sales	Supermarket sales	Whole range of supermarket sports and non-sports facilities	Yes	Nutri-Score results in less sales of #Nutri-Score A products and more B and E products in non-sports-facilities. Hence, under natural circumstances Nutri-Score resulted in less healthier choices. However, in sports-facilities with health-conscious customers Nutri-Score resulted in some healthier purchases.
Andreeva, 2019 [12]	F	Yes		Yes	Cohort	FSA-NPS validation			
Andreeva, 2021 [14]	F	Yes		No	Description FOPLs				
Andreeva, 2021 [13]	F	Yes		Yes	RCT Comparison FOPLs online	Objective understanding	3: pizzas, cakes, breakfast cereals		

					questionnaire				
Andreeva, 2022 [15]	F	Yes		Yes	Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		
Andrianasolo, [153]	N	Yes		No	3 health scores evaluated, not the FSAm-NPS				
Angelino, 2023 [106]	F	No		No	Comparison of NutrInform and Nutri-Score with NOVA		Breakfast cereals		
Aguenaou, 2018	F	Yes		No (not found in Pubmed)					Le logo nutritionnel Nutri-Score : un outil au service du consommateur marocain. Aguenaou H et al *Rev Mar Sciences Agron Vet 6, 3, 2018*
Aguenaou, 2021 [16]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3: yoghurts, biscuits and cold cuts		
Artalejo, 2022 [154]	F			No	Editorial: no peer-review				
Baccelloni, 2021 [74]	U	No		Yes	Comparison FOPLs online questionnaire	Subjective understanding and liking			
Batista, 2023 [121]	N	No		No					
Bend, 2022 [102]	N	No	Yes unrestricted grant	Yes	Review – Evaluation validation Nutr-Score	Evaluation validation Nutr-Score			
Besancon, 2023 [6]	N	Yes		No					
Bolhuis, 2022 [155]		No		No					
Bonaccio, 2022 [156]	F	No		Yes	Cohort	FSAm-NPS validation			
Bonaccio, 2022 [107]	N	No		No					

Bossuyt, 2021 [108]	F	No		No	Eye-tracking experiment, healthfulness estimations				
Braesco, 2022 [75]	N	No	Yes	No	Opinion paper				
Braesco, 2023 [76]	U	No	Yes	Yes	Review				Magnitude of effect of Nutri-Score on food purchases is low. Any associated health effects were modelled rather than observed.
Bryngelsson, 2022 [157]		No		No					
Bullón-Vela, 2022 [158]	F	No		Yes	Cohort	FSA-NPS validation			
Castronuovo, 2022 [77]	U	No		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding, purchase intentions	3: yogurt, cookies, cheese spreads		
Chouraqui, 2023 [78]	U	No		No					"The relevance of the N-S for children should be evaluated considering children's high specific requirements, especially in younger children. This is especially necessary for considering fat and iron requirements, whereas protein-rich foods should be better framed."
Crosetto, 2016				No, not found in Pubmed					Réponses des consommateurs à trois systèmes d'étiquetage nutritionnel face avant *Cah Nutr Diet, 51, 3,*

									124-131, 2016
Crosetto, 2017									Modification des achats alimentaires en réponse à cinq logos nutritionnels *Cah Nutr Diet, 52, 129-133 - juin 2017*
Crosetto, 2019 *[159]*				No, not found in Pubmed					
Cui, 2022 [79]	U	No		Yes	Questionnaire about parent's appreciation in the case of five FOPLs	Appreciation and subjective understanding. China	11: chocolate candy, sugar-sweetened beverages, potato chips, baked foods, seasoning sauces, condiments, processed meat, preserved foods, dairy products, nuts and seeds		Of five FOPLs, Nutri-Score ranked lowest on 3 dimensions: Helping to select a healthy diet; giving information needed by parents, and attractiveness.
De Las Heras-Delgado, 2023 [122]	N	No		No					
De Temmerman, 2021 [109]	F	No		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding; purchase intentions	1: ready to eat meals		Purchase intentions for healthier products, not for unhealthy products
Deschamps V et al *BEH, 24-25- 7 juillet 2015*	F	Yes		No	Not available in Pubmed				
Deschasaux, 2017 [17]	F	Yes		Yes	Cohort	FSAm-NPS validation			
Deschasaux, 2018 [18]	F	Yes		Yes	Cohort	FSAm-MPS validation			

Deschasaux, 2020 [19]	F	Yes		Yes	Cohort	FSAm-NPS validation			
Donat-Vargas, 2021 [110]	F	No		Yes	Cohort	FSAm-NPS validation			
Donini, 2023 [80]	U	No		Yes	Review - opinion				
Donnenfeld, 2015 [20].	F	Yes		Yes	Cohort	FSAm-NPS validation			
Dreano-Trecant, 2020 [21]	F	Yes		Yes	Food composition database validation	General alignment FBDGs; discriminatory performance			
Drewnowski, 2022 [123]	N	No	Yes	No	Comparison of different nutrient profiling systems				
Dubois, 2021 [119]	N	No		Yes. Not found in Pubmed, but very relevant	RCT supermarket trial	Purchase intentions. Effects on FSAm-NPS	4: freshly-prepared foods, pastries, bread, canned prepared meals	Yes	The Nutri-Score improved the nutritional quality of labelled foods purchased by a statistically significant, but clinically insignificant 2.5% in the FSA-NPS score. Effect sizes were 17 times smaller on average than those found in comparable laboratory studies.
Ducrot, 2015 [22]	F	Yes		Yes	Comparison FOPLs online questionnaire	Appreciation, awareness			
Ducrot, 2015 [23]	F	Yes		Yes	Comparison FOPLs online questionnaire	Objective understanding	1: ready meals		
Ducrot, 2016 [24]	F	Yes		Yes	RCT Study of online grocery	Purchase intentions of online supermark	Complete range of online	Online	All FOPLs led to a significant improvemen

					shopping experiment	et. Effects on FSAm-NPS	supermarket		t of the FSA-NPS
Ducrot, 2022 [25]	F	Yes		Yes	Comparison FOPLs online questionnaire	Appreciation			
Ebner, 2022 [160]		No		No					
Egnell, 2018 [28]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		
Egnell, 2018 [26]	F	Yes		No	Portion size selection				
Egnell, 2018 [27]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		
Egnell, 2019 [30]	F	Yes		Yes	Cohort	FSAm-NPS validation			
Egnell, 2019 [70]	U	Yes		Yes	Comparison FOPLs of online supermarket	Purchase intentions of online supermarket	Representative sample of a (online) supermarket range of pre-packed products	Online	Same study as #76. Effects calculated on effect on **FSAm-NPS**. No difference between Nutri-Score effect versus other labels was found when calculated for labelled foods only. Nutri-Score scored better than other FOPLs because subjects purchased more non-labelled foods in particular fruits, meat and poultry.
Egnell, 2019	F	Yes		No (not found in Pubmed)					Comparison of front-of-pack labels to help German consumers understand the

									nutritional quality of food products. Ernaehrungs Umschau *international* | 5/2019
Egnell, 2019 [29]	F	Yes		Yes	Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		
Egnell, 2020 [33]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, cereals		
Egnell, 2020 [31]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		
Egnell, 2021 [161]	U	Yes		Yes	RCT Study online grocery shopping experiment	Purchase intentions online supermarket. Effects on FSAm-NPS	Complete range of online supermarket	Online	No significant effects were found for Nutri-Score versus no label on total FSAm-NPS, calories and saturated fatty acids in the shopping cart.
Egnell, 2021 [162]	F	yes		Yes	Post-hoc analysis of online RCT purchase intentions online supermarket. Effects on FSAm-NPS	Purchase intentions online supermarket. Effects on FSAm-NPS	Complete range of online supermarket	Online	Post-hoc analysis of #79, #85 #113. Nutri-Score arm purchased more fresh-fruit and meat.
Egnell, 2021 [34]	F	Yes		Yes	Cohort	FSA-NPS validation			
Egnell, 2022 [36]	F	Yes		Yes	Comparison FOPLs online supermarket	Purchase intentions online supermarket	Representative sample of a (online) supermarket range of pre-packed product	Online	Effects calculated on effect on FSAm-NPS. No difference between the effect of Nutri-Score versus other labels was found when calculated for labelled foods only.

									Nutri-Score scored better than other FOPLs because subjects purchased more non-labelled foods, in particular fruits, meat and poultry.
Eykelenboom, 2022 [163]	F	No		No					Application of Nutri-Score for potential food tax
Fernandez-Alvarez, 2023 [164]		No		No					
Fialon, 2021 [165]	F	Yes	Yes	Yes	Online questionnaire	Objective understanding	1: added fats		
Fialon, 2022 [145]	F	Yes		No (no No-label arm)	Comparison FOPLs online questionnaire	Objective understanding and purchase intention	2: Breakfast products, breakfast cereals,		
Fialon, 2022 [166]	F	Yes		No	Opinion based on 8 interviews				
Fialon, 2023 [167]	F	Yes		No			3: breakfast products, breakfast cereals, added fats		Not relevant for validation, because comparison was made only between two labels. However, no arm with 'No label'>
Finkelstein, 2019 [120]	N	No		Yes	RCT Comparison Nutri-Score and MTL online supermarket	Purchase intentions	Complete online supermarket range	Online	Nutri-Score performed better than no-label. However, MTL reduced the intake of calories of beverages where Nutri-Score did not perform.
Fondevila-Gascon, 2022 [81]	F	No		Yes	Survey	Appreciation			
Fuchs, 2022 [82]	U	No		Yes	RCT Pilot study online grocery	Purchase intentions online	Complete range online	Online	No significant effects were found of

					shopping experiment	supermarket	supermarket		Nutri-Score versus no label in terms of Nutri-Score total, healthy food and unhealthy foods. An effect was found (p=0.068, claimed as statistically significant by the authors) for HETI-score. No effect with p<0.05 has been found on any other outcome. **Authors have decided that a difference of <10% is statistically significant because of limited sample size..**
Galan, 2020 [38]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		
Galan, 2021. [39]	F - opinion	Yes		No	Opinion				
Gassler, 2022	F	No		No (not found in Pubmed)					Towards a differentiated understanding of the effects of Nutri-Score nutrition labelling on healthier food choices *Agribus. July 29, 2022, 39, 1, 28-50*
Godden, 2023 [83]	U	No		Yes					This study shows that FOP labels do not steer all consumers toward healthier choices and may even

									have adverse effects for some.
Goiana-Da-Silva, 2019 [40]	F - opinion	Yes		No	Review / opinion				
Goiana-Da-Silva, 2021 [41]	F	Yes		Yes	Comparison FOPLs online questionnaire	Objective understanding and purchase intention	3: pizzas, cakes, breakfast cereals		
Gómez-Donoso, 2021 [104]	F	No		Yes	Cohort	FSAm-NPS validation			
Hafner, 2021 [142]	U	No		Yes	Alignment Nutri-Score with food composition data	FSA-NPS validation: discriminatory potential foods Nutri-Score			Cross-the-board algorithm does not give good equal distribution of products among Nutri-Scores for some product groups like cheese, flavoured dairy products, cooking oils, juices
Hafner, 2023 [141]	U	No		Yes	Food composition database validation	General alignment FBDGs; discriminatory performance			
He, 2023 [146]	U	No		Yes	Between subjective experiment in 20 countries	Subjective understanding and liking			
Hercberg, 2021 [42]	F	Yes		No	Opinion				
Hercberg, 2022 [168]	F	Yes	No. Paper refers to list of scientists supporting Nutri-Score	No	Narrative review / Opinion				
Hernandez-Nava, 2019 [148]	F	Yes		Yes	Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		

Hock, 2021 [84]	U	No		Yes	RCT Comparison FOPLs online questionnaire	Understanding / application	3: sugar sweetened beverages		
Hoge, 2022 [111]	F	No		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	4: pizzas, breakfast cereals, regular dairy products and appetizers		Favourable results, except for breakfast cereals
Hoteit, 2022 [169]	N	No		No					
Hutton, 2020	U			No, not found in Pubmed					South African Consumer Perception of Five Front-of-Pack Label Formats.l *Journal of Consumer Sciences*, 2020, vol5, 126
Hutton, 2020	F			No, not found in Pubmed	Objective understanding				
Huybers, 2023 [85]	U	No		No					
Jansen, 2021 [112]	F	No		No	RCT online simulated supermarket	Purchase intentions online supermarket.	4: breakfast cereals, muesli bars, crackers, pizzas		
Julia, 2014 [7].	F	Yes		Yes	Food composition database validation	Discriminatory performance product groups			
Julia, 2014 [44]	F	Yes		Yes	Cohort	FSA-NPS validation			
Julia, 2015 [47]	F	Yes		Yes	Cohort	FSA-NPS validation			
Julia, 2015 [46]	F	Yes		Yes	Food composition database validation	Discriminatory performance product groups (cereals)			
Julia, 2015 [140]	N	Yes		Yes	Validation of foods in relation to French				

					food-based dietary guidelines				
Julia, 2016 [52]	F	Yes		Yes	Cohort	FSA-NPS validation			
Julia, 2016 [51]	F	Yes		Yes	Cohort	FSA-NPS validation			
Julia, 2016 [50]	F - opinion	yes		No	Opinion				
Julia, 2015 [48]	F	Yes		Yes	Cohort	FSA-NPS validation			
Julia, 2016	F - opinion	Yes		No	Opinion				La bataille de l'étiquetage nutritionnel. *Rev Prat 66, no 9 (2016) : 943 48.*
Julia, 2016 [49]	N	Yes		Yes	Objective understanding	Purchase intentions of online supermarket. Effects on FSAm-NPS	3: breakfast cereals, sweet biscuits, appetizers		
Julia, 2017	F	Yes		No, not found in Pubmed, not peer-reviewed					El logotipo nutricional NutriScore en los envases de los alimentos puede ser una herramienta útil para los consumidores españoles Rev Esp Nutr Comunitaria 2017; 23(2) Julia et al.
Julia, 2017 [53]	F	Yes		Yes	Comparison FOPLs online questionnaire	Awareness			
Julia, 2017	F	Yes		No (not found in Pubmed)					Perception de différents systèmes d'information nutritionnelle actuellement proposés en France en fonction du statut pondéral Julia C et al *Obes. 12, 1, 2017, 5-15.*

Julia, 2017	F	Yes		No (not found in Pubmed)	Description of Nutri-Score				Nutri- Score: evidence of the effectiveness of the French front-of-pack nutrition label. Ernahrungs Umschau 64(12): 181–187
Julia, 2017	F	Yes		Yes	Report to WHO about validation of Nutri-Score				
Julia, 2018 [54]	F - opinion	Yes		No	Opinion in short correspondence				
Julia, 2018 [55]	N	Yes		No	Opinion paper				
Julia, 2021 [57]	F	Yes		Yes	Quasi-experimental trial, one intervention and control restaurant cafeteria	Purchase intentions . Effects on FSAm-NPS	Complete meal range	Yes	Effect on FSA-NPS in meals of in cafeteria.
Julia, 2021. [56]	N	Yes		No	Explanation FOPLs				
Julia, 2022 [58]	F - opinion	Yes		No	Opinion				
Julia, 2023 [59]	N	Yes		No	Cross-sectional observation				Study used FSAm-NPS to describe nutritional quality of (ultra-processed) foods
Jürkenbeck, 2022 [113]	F	No		No	Comparison FOPLs online questionnaire				
Katidi, 2023 [125]		No		No					
Katidi, 2023 [124]		No		No					
Khoury, 2022 [9]	F	Yes	Yes	Yes	Cohort	FSAm-NPS validation			
Kissock, 2022 [170]	U	No		No	Opinion paper: plea to adjust algorithm				
Konings, 2023 [88]	U	No		No	Food compositio	Alignment with food-based			

					n database validation	dietary guidelines			
Kontopoulou, 2021 [60]	F	Yes		Yes	Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		
Kontopoulou, 2022 [61]	F	Yes		Yes	Post-hoc analysis from 2021 study	Appreciation	3: pizzas, cakes, breakfast cereals		
Lee, 2023 [126]	N	No		No					Comparison of dietary index scores between different front-of-pack logos
Martini,. 2022 [89]	U	No	Yes	No					
Mazzu, 2021 [90]	U	No	Yes	Yes	RCT Comparison FOPLs online questionnaire	Subjective understanding and liking	4: yoghurt, sauces, biscuits, saltines		
Mazzú, 2021 [91]	U	No	Yes	Yes	Comparison FOPLs	Subjective understanding			
Mazzú, 2022 [92]	N	No		No					
Mazzú, 2022 [93]	U	No		Yes	Co-citation analysis				
Mazzú, 2023 [94]		No		No					
Merigot, 2016.	F	Unknown		No, not found in Pubmed					Les effets d'alerte et de promotion des logos nutritionnels sur la face-avant des produits agroalimentaires.l *Décision Marketing, 2016, 83, 29-48*
Mertens, 2022 [127]		No		No	Assessment of nutritional values in European diets according to Nutri-Score algorithm				
Meyerding, 2022 [128]	N	No		No					
Mialon, 2018	F - opinion	Yes		No	Opinion				The policy dystopia

									model adapted to the food industry :the example of the Nutri-Score saga in France. Mialon M et al. *World Nutrition 9, 2: 109 20, 2018*
Millar, 2022 [114]	F	No		Yes	Cohort: cross-sectional analysis	FSA-NPS validation			
Montero-Salazar, 2022 [105]	F	No		No (patients)	Cohort – renal patients				
Mora-Garcia, 2019 [95]	U	No		Yes	Randomized field trial	Efficacy real-life	300 food items	Yes	Using the Nutri-Score led to more protein, more calories and more expenditures (on healthy items only) in purchases. Purchases of 'unhealthy' products did not decrease. **No calculation on effect validated FSA-NPS**
Mora-Plazas, 2022 [96]	U	No		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	1: fruit drinks 4: yogurt, cookies, bread and cereal		Nutri-Score had no effect versus no label in selecting high sugar fruit drinks. Nutri-Score did not help identify products with excess nutrients of concern
Muzzioli, 2022 [103]	U	No		Yes	Narrative review				
Muzzioli, 2022 [171]	N	No		No	Comment				
Nabec, 2019	F	No		No, not found in					

				Pubmed					
Nabec, 2022	F	No		No, not found in Pubmed					The Role of Nutri-Score Front-of-Pack Labels on Children's Food Products in Informing Parents: An Analysis of the Branding Effect Décisions Marketing Volume 106, Issue 2, April 2022, 143-160
Packer, 2021 [149]	F	No		Yes	Comparison FOPLs online questionnaire	Objective understanding	6: pizzas, drinks, cakes, crisps, yogurts, breakfast cereals		
Packer, 2022 [150]	F	No		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	6: pizzas, cakes, breakfast cereals, drinks, crisps, yogurts		
Panczyk, 2023 [5]	U	No		Yes	Expert opinion of Polish scientists about Nutri-Score's application	Expert opinion			Polish experts: Nutri-Score requires significant and detailed changes and validation against national guidelines and expert expectations before implementation.
Paper, 2023 [143]	F	Yes		Yes	Cohort	FSA-NPS validation			
Peters, 2022 [4]	U	No	Yes	Yes	Narrative review	Review exploring effectiveness studies with regards to Nutri-Score in real life		Yes (review)	Conclusion: There is insufficient scientific evidence for substantiation that Nutri-Score has an effect on real purchases in supermarkets

Pettigrew, 2022 [63]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3: : pizzas, cakes, breakfast cereals		
Pettigrew, 2023.[62]	F	Yes		Yes	Post-hoc analysis	Objective understanding	3: pizzas, cakes, breakfast cereals		
Pettigrew, 2023 [63]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3:: pizzas, cakes, breakfast cereals		
Pitt, 2023 [172]	N	No		No	Comparison Keyhole and Nutri-Score				
Poquet, 2019 [144]	F	No		Yes		Subjective understanding	3 foods		
Ricco, 2022 [173]	U	No		No					
Roberto, 2021 [174]	N	No		No	Descriptive paper FOPLs				
Rodriguez-Martin, 2023 [175]		No		No					
Santos, 2020 [115]	F	No		Yes	Comparison FOPLs online questionnaire	Objective understanding and appreciation	5: breakfast cereals, dairy products, canned fish, cookies, breakfast		All FOPLs scored better than no label, traffic light was most preferred by consumers
Sarda, 2020 [65]	F	Yes		Yes	Comparison FOPLs online questionnaire	Awareness			Consumers were asked if they have changed their purchases, but not in what context.
Schlarbaum, 2022 [97]	U	No		No	Nutritional assessment		Ready-to-eat salads		
Septia Irawan, 2022 [129]		No		No					
Shrestha, 2023 [98]	U	No		Yes	Systematic review	Review of efficacy of FOPLs on actual purchases			"this review does not provide a definitive conclusion about the

									effects of FOPL on actual purchases and consumption "
Shin, 2023 [116]	F	No		Yes	RCT online grocery store with warning label and Nutri-Score **with added sugar percentage tag**	Online purchases	Whole supermarket range	Online	Nutri-Score with **added sugar percentage** tag resulted in decreased sugar intake per serving.
Shin, 2023 [130]	N	No		No					
Song, 2021 [152]	F	No		Yes	Systematic review	Impact assessment FOPLs			Colour-coded FOPLs are able to nudge consumers to buy healthier products.
Stiletto, 2022 [78,147]	U	No		Yes	Subjective understanding				Italian consumers interpret Nutri-Score as a healthy indicator, Even if it is signalling an unhealthy choice (D).
Szabo de Edellenyi, 2019 [139]	F	Yes		Yes	Food composition database validation	General alignment FBDGs; discriminatory performance product groups			
Talati, 2019 [67]	F	Yes		Yes	Comparison FOPLs online questionnaire	Subjective understanding, liking	3 pizzas, cakes, breakfast cereals		
Talati, 2019 [66]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Subjective understanding, liking	3 pizzas, cakes, breakfast cereals		
Temple, 2020 [73]	U	No		Yes	Narrative review – comparison FOPLs	Comparison FOPLs			
Ter Borg, 2021 [99]	U	No		Yes	Food-composition database comparison	Alignment with food-based			

						dietary guidelines			
Touvier, 2022 [68]	F - opinion	Yes		No	Opinion				
Valenzuela, 2022 [131]	N	No		No					
Van Dam, 2022 [132]		No		No					
Van den Akker, 2022 [151]	F	No		Yes	Lab-in-field experiment	Objective understanding	1: Breakfast cereals		
Van Tongeren, 2020 [86]	U	No		Yes		Discriminatory performance	4: Cheese, ready meals, soups, sauces		
Vandevijvere, 2020 [69]	F	Yes		Yes	RCT Comparison FOPLs online questionnaire	Objective understanding	3: pizzas, cakes, breakfast cereals		
Vandevijvere, 2021 [100]	U	No		Yes	Difference-in differences comparison of purchases in real supermarkets	Real purchases	Whole supermarket range	Yes	Application of black and white Nutri-Scores on shelf tags. Mixed and unpredictable results.
Vlassopoulos, 2022 [117]	F	No		Yes	Food composition database validation	General alignment FBDGs			
Vlaasopoulos, 2022 [118]	F	No		Yes	Food composition	Validation FSA-NPS in relation to food-based dietary guidelines			
Wlodarek, 2022 [101]	U	No	Yes	Yes	Review				Review addresses potential negative side effects of Nutri-Score

Abbreviations: FBDGs Food-based dietary guidelines; FOPL Front-of-Pack label; FSA-NPS Food Standard Agency-Nutritional Profiling System; FSAm-NPS modified Food Standard Agency-Nutritional Profiling System; HETI Healthy trolley index; MTL multiple traffic light; RCT randomized controlled trial, SSBs sugar-sweetened beveragesEREN: l'Equipe de Recherche en Epidémiologie Nutritionelle (***EREN***) Inserm/Inrae/Cnam/Université Sorbonne Paris Nord = developers of Nutri-Score

Red letters: We are in disagreement with the favourable or unfavourable denomination of Besancon.

Blue letters: Articles found in PubMed that are not mentioned in the table by Besancon nor on the Nutri-Score blog of the EREN-team.

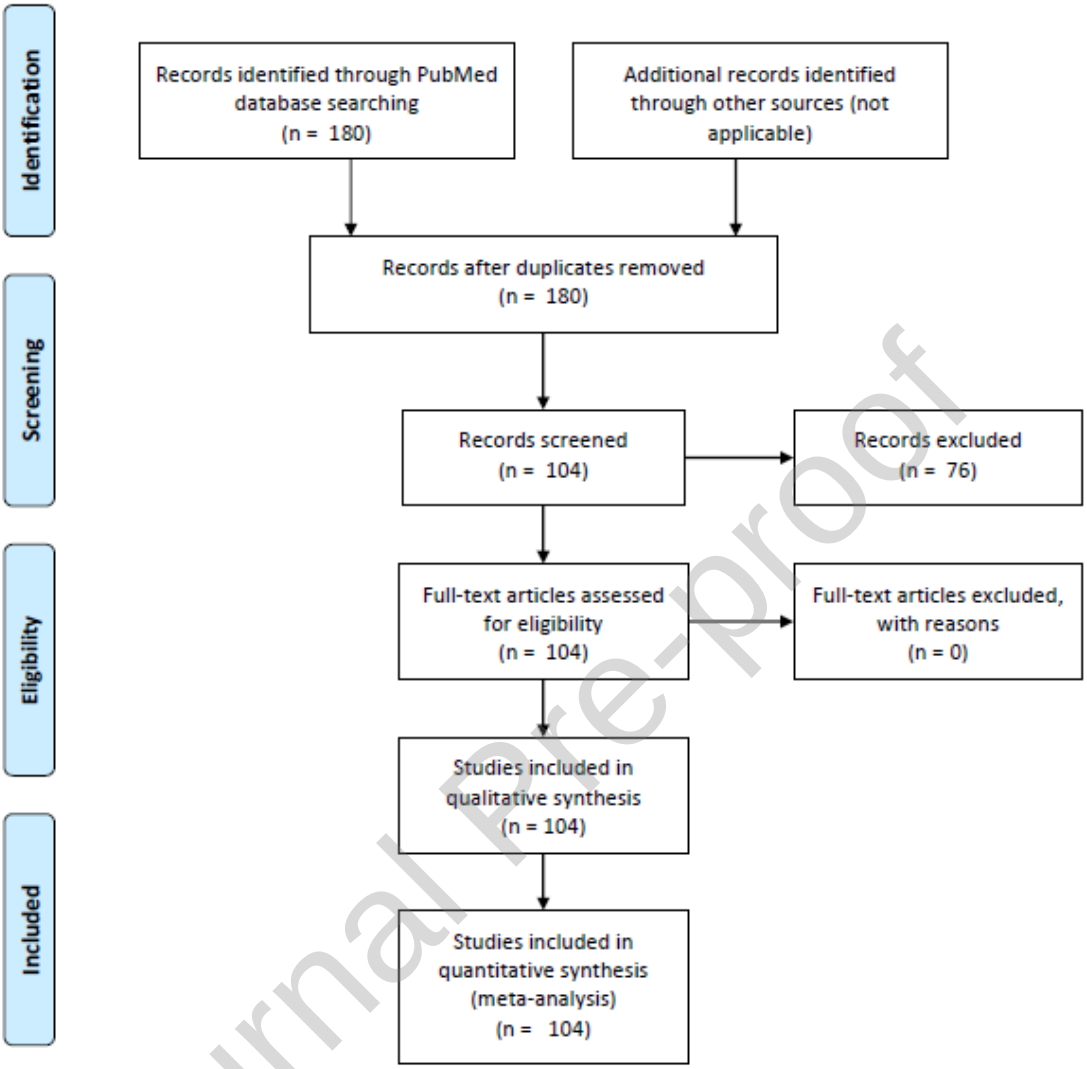

Figure 1. Prisma Flow Diagram for review Nutri-Score search based on Pubmed search d.d. July 22nd 2023.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

S.P. is employed at the Dutch Dairy Association. H.V. is an independent consultant at the Food Safety & Nutrition Consultancy (The Netherlands) and holds professorships at the Technical University of Denmark (Denmark) and the University of Ulster (Northern Ireland). Neither author has a past or current collaboration with the Nutri-Score. H.V. is a member of the international board of the Choices International Foundation since 2023. Until 2015, Both S.P. and H.V. were members of the independent scientific committee in the Netherlands supporting the former front-of-pack logo “het Vinkje”. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The Dutch Dairy Association is involved in the national discussion in the Netherlands about front-of-pack logos by submitting inputs into product reformulations and front-of-pack consultations of the Dutch Ministry of Health, Welfare and Sport.