REVIEW

Nutri-Score – a bibliographic review and analysis of the literature

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Summary
To obtain a solid evidence basis for public policies, it is necessary to thoroughly monitor the respective research and identify potential biases or underresearched areas. This paper maps the research on Nutri-Score (NS), a food labelling and rating system, currently adopted by six European countries. A structured review of the existing literature on the NS using an excerpt of 308 Scopus-listed articles in addition to machine-learning-based clustering of keywords establishes four topical categories within the bulk of the literature, capturing the essence of NS research: NS in comparison to other front-of-package labels, effectiveness of the NS, NS as a measure of food classification, NS and nutritional policy. Additionally, the article delves deeper into the network of researchers involved in NS research, their interlinkages and positions within the network, establishing the presence of three distinctly leading research groups. The discussion is dominated by the group involved with the conception of the NS, which bears a significant potential for bias, as pointed out by other research as well. Underresearched areas include: psychological mechanisms behind responses to the NS, socio-economic particularities and cross-cultural research, use of actual retail data and the use of real-world environments.

Keywords
review; Nutri-Score; bibliographic analysis; researcher network

The Nutri-Score (NS) was first conceived by a working group for the French Ministry of Health and the French Public Health Institute [1], and successfully introduced in French supermarkets in 2017. It is a colour-coded front-of-package label (FOPL) that rates the nutritional quality of food from A (dark green/healthiest) to E (dark red/least healthy). JULIA and HERCBERG [1] introduced the NS to the public and detailed its conceptualisation as well as the perceived functionality. Its general introduction as a FOPL provides one of multiple potential inputs to the European Union's Farm to Fork strategy (F2F), whose ultimate goal is the conception of a harmonised FOPL nutrition label. It is registered with the European Union Intellectual Property Office (EUIPO) and, following its successful introduction in France, was also recommended by the governments of Belgium (2018) [2], Switzerland (2019) [3], Germany (2020) [4], Luxembourg (2020) [5], Spain (2021) [6], and the Netherlands (2024) [7]. Spain, while not openly opposed to the NS, has postponed its mandatory introduction until a decision has been reached on the European level [8]. The NS is currently used on a voluntary basis, with governments advising food producers to adopt it, but the European Commission, in a recent statement, has abandoned its stance on a mandatory introduction across all member countries [9].

In 2022, Italy introduced and adopted the most prevalent alternative to the NS, the NutrInform Battery [10] which does not report nutritional value of a product on a rating scale but by display of the share of a recommended daily intake.

Not all countries have responded positively to the NS. Italy, the Czech Republic, Greece, Latvia, Hungary, Cyprus, and Romania are calling for the approach to FOPL to be reconsidered and a new approach to be conceived [11]. Considering Italy, this surely is related to the broader presence and acceptance of the national NutrInform Battery [12, 13]. Even before the introduction of the NS, four Scandinavian countries introduced their simpler Keyhole label [14], which, however, has

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not been broadly considered in the discussion of the effectiveness of the NS.

The NutrInform Battery, the most prevalent alternative to the NS, deviates from it in reporting numerical information about the nutritional value of the products, whereas the NS only reports a five-value rating scale. Both labels reduce the cognitive burden for consumers and offer added value. However, part of the information reported by the NutrInform Battery has to be displayed on products sold in the European Union already due to the mandatory nutrition declarations [15]. While the NS algorithm is publicly available, it can be assumed that the average consumer is not intimately familiar with it. Thus, compared to the NutrInform Battery, consumers have to base their decisions solely on the label itself and not on the factual information conveyed by it.

Due to the free market for goods and services in the European Union, food products displaying the NS can be found in almost all member countries, including those that display a disapproving stance.

Even though the NS is less than a decade old, a broad range of quantitative and qualitative empirical studies, theoretical discussions, and literature-based debates have already been published. This article contains the results of a detailed literature research, the compilation of a bulk of 308 scientific studies and reports on the NS, following multiple objectives. While structuring the literature revealed that some preliminary reviews of part of the literature exist, no exhaustive study of the existing literature about the NS has yet been published. To obtain a solid evidence basis for public policies, it is, however, deemed necessary to thoroughly monitor the respective research and identify potentials for biases or underresearched areas. The present article aims to close this gap and provide researchers, policymakers, and readers interested in the NS with a review of the current state-of-the-art research on the NS. It offers researchers an insight into the research groups involved in NS research, the main authors to consider and the topical fields already covered by the existing literature. Thereby, it indicates to researchers those areas already well covered by existing research, as well as gaps in the literature.

MATERIALS AND METHODS

Building on the relevant excerpt of the existing literature, the analysis in this study consists of three main parts. The first part is a qualitative content analysis-based review of the articles, structuring them into distinct categories. In the second part of the analysis, the bibliographic characteristics of the articles, particularly the authors involved in NS research and the resulting network of co-authorships, are evaluated. Additionally, the articles‘ publication dates and the journals in which the corpus of articles has been published are considered. In a third part, the regional foci of the articles are considered as well as the keywords of the articles, which are analysed with the help of a machine-learning-based clustering algorithm to determine topical fields of research and integrate those with the results from the first part.

Methodology

Literature review – data sourcing and categorisation

The Scopus database (Elsevier, Amsterdam, Netherlands) was used to compile a detailed literature review of relevant scientific articles about the NS. For this purpose, all publications containing the terms “Nutri” and “Score” in the title or abstract were downloaded by the end of December 2024. In the first round, abstracts of the 441 extracted articles were scanned to delete articles not related to the NS. In a second round, the remaining 340 articles were checked in detail to see whether the initial assessment proved correct, leading to the elimination of 32 additional articles. The entire filtering process was carried out manually.

The final body of 308 articles was used in a third step to categorise them. The process of inductive categorisation was carried out by both authors separately to ensure a high degree of validity regarding the categorisation scheme and to perform the categorisation as objectively as possible.

Publication-based author ranking – weighting scheme

To establish two types of rating schemes, first, the authors are ordered by the absolute number of articles they took part in authoring. Ranking authors by absolute frequency of involvement disregards the degree of their involvement in authoring the articles. It can be noted that previous reviews implemented alternative rating schemes [14], so that author ratings according to this second rating may vary slightly across reviews. Consequently, a weighting scheme is implemented where authors are awarded one point for each publication where they are listed as the first author, assuming that the first listed author is the one most relevant to the article’s conception.

Authors are awarded one-third of a point for each publication they authored with at most two co-authors, not being the first author. Finally, for every other publication with a total of more than three authors, they are assigned one tenth of a point.

Co-publication network – construction and network statistics

To illustrate the involved research clusters, a researcher network was generated based on the co-publication activities of all authors involved in NS research.

That is, if illustrated as a graph, an edge between two nodes, i.e. researchers, in the network is formed if they are listed together in an article. If they cooperated on more than one article, the thickness of the edge increased accordingly. Fig. 1 illustrates the resulting network if the approach is applied to the authors listed in the 308 considered publications. To simplify the network, only those researchers are considered, who have published at least one paper with a colleague; thus, no isolated nodes exist in the graph. This elimination process still leaves 772 researchers/nodes.

Based on the network's respective statistics, i.e. the eigenvector and the betweenness centrality measures can be calculated. The eigenvector centrality measures which node is closely connected to other relevant nodes with a high eigenvector centrality. Applied to research networks, it indicates which researchers co-publish often with other relevant researchers. The betweenness centrality measures how frequently a node lies on the shortest path between any other two nodes. It thus reports on the importance of the node in connecting parts of the network. Applied to researcher networks, this centrality indicates those researchers who connect researchers and research groups with each other and are thus the key players in the foundation of the research network per se.

The mathematical calculation of both measures is detailed by GÓMEZ [16].

Timeline of Nutri-Score research

Each article listed reported the date it has been published. This information was summarised on an annual basis to illustrate the temporal development path of research on the NS.

Since the corpus of articles used in this study has been extracted from the Scopus database by the end of 2024, it cannot be assured that the number for 2024 is the final number for that year, since the case of some journals issues listed for 2024 might only be published by early 2025. Thus, the number reported for 2024 current acts as a lower bound on the actual number of publications.

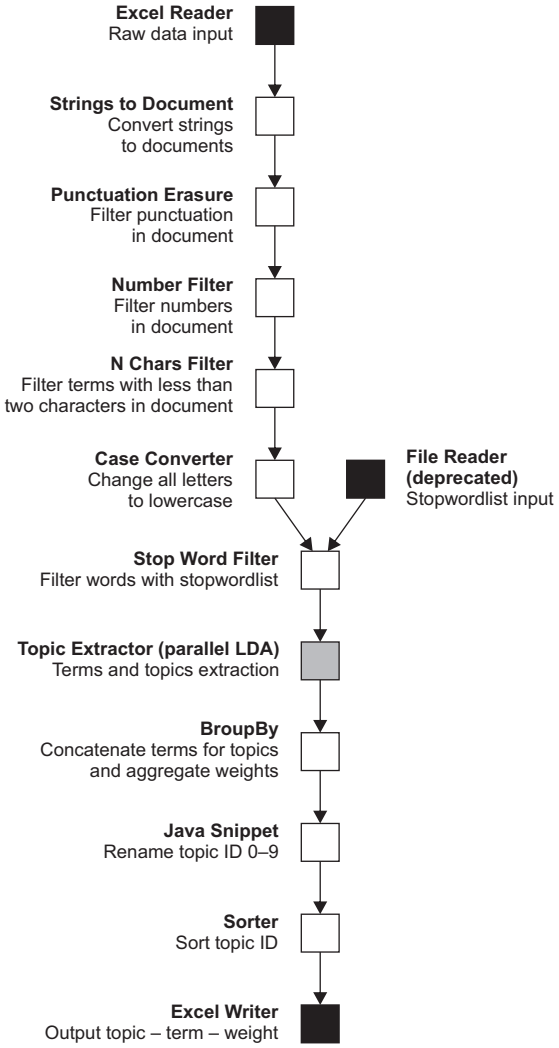

Fig. 1. Implemented KNIME workflow.

LDA – latent Dirichlet allocation.

Publication dates were selected over submission dates since this information is not only uniformly available for every article but also illustrates at which point in time the research results, i.e. the articles, were available to the public.

Outlets of Nutri-Score research

To generate an overview of the different scientific peer-reviewed channels to disseminate research results and discussions on the NS two perspectives were combined. For each article, the journal in which it has been published was available, and conclusively, the respective publisher.

To evaluate how available NS research is to the public for each journal, information is reported

whether they operate on an open access, subscription-based, or hybrid basis.

Finally, reporting the average number of citations for articles published in the respective journal indicates its effectiveness as an outlet channel. Those numbers, however, need to be treated with a certain level of scepticism. To use only a single source of input, only citation numbers reported via Scopus are considered. This has the disadvantage that there is not always a differentiation between no citation numbers being available for an article and zero citations. Thus, these numbers, while also being quite dynamic, can only offer a very rough estimate of a journal's effectiveness as an outlet channel.

Focal points of Nutri-Score research

To determine the regional focus of the articles considered in this review for the empirical studies, the sample origins have been considered and summarised accordingly.

In this regard, it first needs to be considered that not every article contains an empirical study. Second, some articles collect their samples from more than one country and are thus considered multiple times in the respective table. For those studies where a breakdown according to the nationalities that are part of the sample is not possible, or it is not reported in the respective article the reported regional level of agglomeration, e.g. Europe, is considered in the table.

Tab. 1. Inductively determined article categories – status quo end december 2024.

Category	Title	Number of included articles
1	Comparison of the NS with other front-of-package labels	90
2	Effectiveness of the NS	115
2.1	Health impacts or issues	64
2.2	Purchase intention	51
2.2.1	Effects of the NS on the purchase intention	36
2.2.2	Moderators of the impact on the purchase intention	15
3	The NS and food classifications	57
4	The NS and nutrition policy	24
5	Other findings	30
5.1	Scientific studies	10
5.2	Miscellaneous reports	20

NS – Nutri-Score.

Keyword analysis – KNIME workflow

Considering their focus, most of the articles provide self-reported keywords by the authors. These keywords are selected to summarise the content and focus of the article. Most often, journals restrict the number of usable keywords to five or slightly more to get authors to focus on the central aspect of the article. Thus, keywords provide an excellent possibility to study the content of the articles published on the NS in more detail without considering the full article.

Using a Konstanz information miner (KNIME) workflow (KNIME, Zurich, Switzerland) comparable to the one implemented by the study by Kamran and Becker [17], the keywords are clustered into groups using a machine learning approach, implementing natural language processing if they appear in conjunction with each other or similar terms. Fig. 1 provides the scheme of the implemented workflow, illustrating in particular the different functional parts that were used.

RESULTS AND DISCUSSION

Literature review – thematic categorisation and methodological foci

Analysis of the bulk of 308 extracted articles has been carried out following the rules for inductive qualitative content analysis as detailed in the study of Kuckartz and Rädiker [18] in the context of a grounded theory approach. To assure a higher quality of the categorisation, both authors performed the categorisation independently and the presented result is the consensus solution.

The final scheme consists of five categories deduced via the methodological or content-based focus of the respective studies. Tab. 1 summarises the categories, their assigned titles, and the number of included articles. Note that eight articles have been assigned to two categories.

The first category (comparison of the NS with other FOPL, 90 articles), which also consists of almost a third of all studies, contains those studies where the NS is compared to other nutritional FOPLs. Most of the studies in this category are quantitative studies based on surveys or experiments. The second-largest group of articles in this category are literature reviews summarising articles with the goal of eliciting the NS comparative performance concerning other FOPLs.

The second and largest category (effectiveness of the NS, 115 articles) summarises studies on the effectiveness of the NS as a label and the effects it has. It can be divided into two sub-categories:

2.1 (health impacts or issues) and 2.2 (purchase intention).

Articles in the first sub-category 2.1 (64 articles) put a distinct focus on the health aspect, i.e. in how far the NS results in healthier food choices or how it can be used to increase healthiness in the population.

The second sub-category, 2.2 (51 articles), contains articles focusing on the impact of the NS on purchase behaviour. They can be differentiated into studies on the direct effect of the NS 2.2.1 (36 articles) and on those focusing on moderators impacting the effect the NS has on the purchase intention 2.2.2 (15 articles). While a link between the two sub-categories, purchase intention and healthier food choices, is evident, articles assigned to category 2.2, as compared to those of category 2.1, are more general, and the health aspect is not the primary focus of the study. However, some overlaps exist, leading to some articles being assigned to both groups.

The third category (the NS and food classifications) summarises those studies where the NS, as a label indicating food quality, i.e. healthiness, is considered (57 articles). This category slightly intersects category two, i.e. sub-category 2.1, in its focus on the NS as an indicator of healthy foods. Opposed to category 2, and in particular 2.1, the articles in category 3 focus on the NS as a tool of food classification. Thus, the section foremost summarises those articles that discuss the suitability of the NS for different groups of foods. It also subsumes those articles that consider the adoption of the NS by companies and the placement of NS-labelled products in supermarkets.

Finally, the fourth category (the NS and nutrition policy) consists of articles that consider the NS in the context of nutrition policy and its applicability therein (23 articles). As such, it reports an overlap with category 2.1, focusing on the effects the NS has on healthier food choices. Compared to category 2.1, where the articles' focus is on consumer behaviour, articles in category 4 consider governmental nutritional policy and discuss applications of the NS in national nutrition and health policy programs.

The remaining articles that could not be assigned to one of these four categories were assigned to an artificial fifth category (other findings, 30 articles). While there is no dominant thematic structure in the bulk of these articles, they can be divided regarding the type of source. Sub-category 5.1 (scientific studies) contains articles that were published in scientific journals and, in most cases, present the results of scientific methodology-driven studies. Sub-category 5.2 (miscellaneous reports), in comparison, summarises discussions of the NS in popular non-scientific journals that are Scopus-listed but do not focus on scientific analyses and studies. Increasing the scientific rigidity of this review, this last sub-category and its content could also be omitted without far-reaching impacts on the following further analysis and discussion.

From a methodological perspective, it can be summarised that the corpus of studies is 220 empirical quantitative studies as compared to only nine qualitative interview-based studies, two of them mixed-method studies. The remaining 81 are literature reviews or theoretical discussions of the NS and reports on the NS in general or its introduction.

Across the bulk of 220 quantitative studies, only 20 studies consider actual consumer behaviour. Out of these 20 studies, only six implemented real-world experiments in natural supermarket environments. The remainder of the empirical studies from these categories consider only hypothetical situations, measuring purchase intention instead of actual purchase behaviour.

Consequently, while a broad range of articles on the NS have been published, the number of in-depth studies as well as the number of studies conducted under realistic conditions is strongly limited.

The determination of the first four categories will post-factum be corroborated by the exploratory study of the articles' keywords reported in detail at the end of the following section.

Bibliometric analysis

Publication-based author rankings

Based on 308 studies identified in the context of the literature review, more profound analyses were conducted. To elicit the structure of researchers and research groups involved with the NS, first the corpus of articles is scanned to prepare a descriptive overview of the authors most often involved with research on the NS (Tab. 2). The table combines information on the overall quantity of publications about the NS listed in the Scopus database, as well as a weighted ranking, accounting for the number of authors in an article and the author's position in the list of authors.

Tab. 2 lists the top authors regarding the overall number of publications. It summarises all authors with at least ten publications on the NS. Following the previously introduced weighting scheme, a weighted average score is calculated as well. Comparing both ranking, unaltered publication numbers, and weighted publication ranking, mostly the structure remains stable. Only EGNELL,

Tab. 2. Most frequently listed authors (ranking) – status quo end december 2024.

Author	Country of origin	Total number of articles	First author (weight 1)	2-3 co-authors (weight 1/3)	3+ co-authors (weight 1/10)	Weighted score
Hercberg	France	64	9	6	47	15.7
Julia	France	64	6	3	55	12.5
Galán	France	45	4	3	38	8.8
Touvier	France	38	2	2	34	6.1
Kesse-Guyot	France	30	0	0	30	3.0
Egnell	France	26	11	0	15	12.5
Deschasaux	France	18	4	0	14	5.4
Fialon	France	17	6	0	11	7.1
Pettigrew	Australia	17	3	0	14	4.4
Srour	France	13	1	0	12	2.2
Ducrot	France	13	1	0	12	2.2
Mazzů	Italy	12	10	2	0	10.0
Talati	Australia	12	2	0	10	3.0
Drewnowski	USA	11	8	1	2	8.5

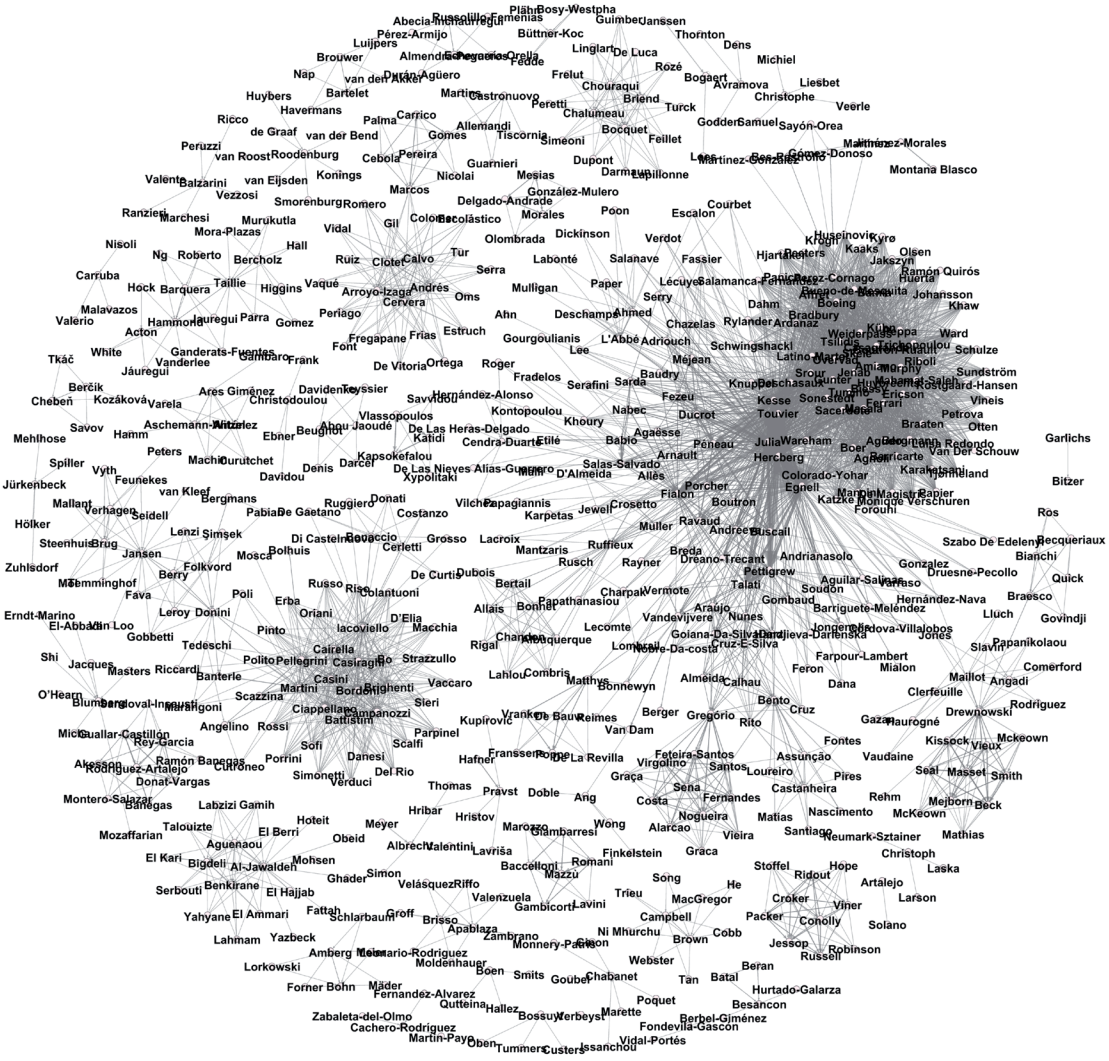

Fig. 2. Researcher network – status quo end december 2024.

Mazzù and Drewnowski report a weighted ranking much better than the one determined by their absolute number of publications; thus, their contribution to NS research might be higher than their overall number of publications may suggest.

Considering the absolute number of publications, the most relevant authors with publications on NS are all affiliated with the Equipe de Recherche en Epidémiologie Nutritionnelle (EREN, Paris, France), the institution that developed the NS and are affiliated with the University Sorbonne Paris-Nord; they form the core of research and development regarding the NS. Almost all of their research regarding the NS is funded by the French government or public institutional bodies, introducing a potential bias, as detailed below. Incidentally, Serge Hercberg and Chantal Julia are also the authors of the introductory article on the NS [1].

In addition, the location of each of the listed authors and their current affiliation are listed. All the French researchers listed are affiliated in one way or another with EREN, while Simone Pettigrew and Zenobia Talati come from Australian institutions focused on health issues. Marco Francesco Mazzù and Adam Drewnowski both have a primarily academic background.

Thus, EREN not only conceptualised the NS but also, considering the research output of its members, provided the single largest share of any institution involved with NS research. As such, Hercberg and Julia each have been involved in almost a quarter of all publications about the NS. There is a significant overlap, with Hercberg and Julia co-authoring 58 out of their 64 articles. Considering these overlaps and co-authorships in more detail and to generate additional insights about the involved authors, not only the top researchers, but all of them, a comprehensive researcher network is constructed in the following section.

Co-publication network

Fig. 2 clearly indicates three major clusters of researchers. The main one in the right part of the figure includes all the French authors listed above in Tab. 2 and is thus centred around the EREN research group, the Sorbonne University, and the Avicenne Bobigny Hospital in Paris. These institutions establish the core of the cluster, as illustrated by the dense area in the top part of the cluster. Since some of its members, first and foremost, Hercberg and Julia, are active in cooperating with other authors and research groups, in the lower part of the cluster, connections to less active research groups are illustrated.

Due to the dominance of this cluster regarding research on the NS its members and their research dominates the perception of the NS as well. Peters and Verhagen [19], using a similarly exhaustive review of the literature, illustrate that they predominantly report positive effects of the NS considering this as a distinct bias in NS research.

In the lower left of the figure, a cluster can be established that links mostly Italian researchers, and in the lower right, a cluster with researchers from Spain can be established. Even though these two clusters are quite established on their own, as seen by the number of connections and their thickness, which indicate the frequency of cooperation, neither cluster is connected to the main cluster centred on the EREN research group.

Other smaller clusters exist as well, a cluster by Chinese researchers on the left of the figure, a cluster with Middle Eastern researchers and links to the World Health Organisation (WHO, Geneva, Switzerland) at the bottom, and another cluster of French researchers on the left, as they comprise researchers from similar origins or institutions.

Summarising, the figure illustrates the dominating role the French research network around EREN and, in particular, Hercberg and Julia play in general. It, however, equally well illustrates that there are still a number of local, in part even quite established, research centres that persist and are not yet linked to the grand cluster resulting from the founders of the NS.

Combining the objective underlying Tab. 2 with the insights gained from Fig. 2, based on the researcher network, statistics on the researchers' relevance regarding the rest of the network can be calculated, shifting the perspective from the individualistic relevance of Tab. 2 to a global perspective. In this regard, Tab. 3 reports for the top 10 researchers the eigenvector centrality as well as the betweenness centrality.

Comparing the results of Tab. 2 and Tab. 3, five of the researchers from Tab. 2 are also present regarding the eigenvector centrality and four regarding the betweenness centrality. The statistics thus confirm the leading role of the NS result by its progenitors, Hercberg and Julia, but it cannot be uniformly stated that a large amount of research on the topic results in several high-quality co-authors or is the binding stone across research groups. Nevertheless, the eigenvector centrality underlines the importance of EREN and the affiliated institutions regarding NS research; a high eigenvector centrality strongly correlates with membership in the central cluster. The for-

Tab. 3. Network statistics.

Researcher	Eigenvector centrality
Hercberg	1.0000
Julia	0.9993
Touvier	0.9670
Kesse-Guyot	0.9540
Deschasaux	0.9254
Latino-Martel	0.9028
Srour	0.8977
Amiano	0.8882
Biessy	0.8882
Boutron-Ruault	0.8882

Researcher	Betweenness centrality
Hercberg	1.0000
Julia	0.7041
Drewnowski	0.3936
Jones	0.3214
Gonzalez	0.2409
Vandevijvere	0.2213
Gregório	0.2105
Ruffieux	0.1942
Touvier	0.1854
Kesse-Guyot	0.1681

mation of research clusters like the observed ones reflects decisions of national and European-level nutrition policy and the funding of respective research institutions.

Considering the betweenness centrality scores, the relevance of HERCBERG and JULIA is obvious even from Fig. 2 alone. Even the third position, DREWNOWSKI, only reports a score of 0.39, which illustrates the fast-decreasing relevance of researchers connecting parts of the networks, and the role of the researchers in positions three through ten are no longer visually obvious from Fig. 2. Nevertheless, having HERCBERG and JULIA as references makes the activities of other researchers seem less significant in comparison.

Timeline of Nutri-Score research

To add a final switch in perspective, Tab. 4 summarises in which years the considered articles have been published, illustrating the topic's dynamics over time.

Regarding the publication dates of articles about the NS, two dates need to be considered. First, the NS was introduced in 2017 in France; thus, any study done before 2017 can either be only on FOPL in general or about the imminent introduction of the NS. Thus, all articles published before 2017 are summarised into one group.

Data on the considered articles has been extracted from the Scopus database by the end of 2024. Assuming a small delay before a publication later listed for 2024 is published, not all publications about the NS that came out in 2024 are registered yet. Thus, even though the number of publications has been decreasing since 2022, it can be assumed that the final number of publications for 2024 will at least reach the level of 2023 again. The assumption that research on the NS has reached its zenith, however, cannot conclusively be rejected. Developments, i.e. changes in the stance of the European Union and changes in the NS algorithm, which led to its abandonment by large companies like Danone (Paris, France), might hint at the NS losing its relevance for European nutrition policy. Conversely, since those developments in part were already foreseeable by early 2024 and the publication numbers still did not decline strongly, it might indicate a continuously steady academic interest in the NS.

Tab. 4. Article publication dates – status quo end december 2024.

Years	Number of publications
Before 2017	8
2017	6
2018	12
2019	23
2020	33
2021	50
2022	66
2023	57
2024	53
Sum	308

Outlets of Nutri-Score research

The publications considered in this review have been published in 124 journals of differing quality, Tab. 5 gives an overview of the ten most often used journals, which coincides with listing all journals that report at least 5 articles being published in one of their issues and covers 117 (38.0 %) of all considered articles.

As can be seen from Tab. 5, most of the NS research has been published in open-access journals or in hybrid journals, where often the open-access option has been selected. The strong presence of MDPI (Basel, Switzerland) and Frontiers (Lausanne, Switzerland) in the list and the

Tab. 5. Top 10 journals – status quo end december 2024.

Title of journal	Number of articles	Publisher	Open access	Average number of citations
Nutrients	47	MDPI (Basel, Switzerland)	Yes (paid)	13.17
Food Quality and Preference	13	Elsevier (Amsterdam, Netherlands)	Hybrid	31.15
Appetite	11	Elsevier (Amsterdam, Netherlands)	Hybrid	31.00
Foods	10	MDPI (Basel, Switzerland)	Yes (paid)	8.80
Deutsche Lebensmittel-Rundschau	7	Behr (Hamburg, Germany)	No	–
Frontiers in Nutrition	7	Frontiers (Lausanne, Switzerland)	Yes (paid)	3.86
PLoS One	6	Public Library of Science (San Francisco, California, USA)	Yes (paid)	25.33
International Journal of Behavioral Nutrition and Physical Activity	6	BioMed Central (London, United Kingdom)	Yes (paid)	19.83
Archives of Public Health	5	BioMed Central (London, United Kingdom)	Yes (paid)	20.20
European Food and Feed Law Review	5	Lexxicon (Berlin, Germany)	No	–

debate concerning their adherence to scientific rigor at least needs to be pointed out, in particular since these articles also report a high number of citations, thus shaping a large part of the scientific treatment of the NS as a research topic.

Otherwise, it can be commended that most of the research has been published open access so that it is broadly available to academia as well as to the media interested in the topic, an aspect seen by the Deutsche Lebensmittel-Rundschau (Hamburg, Germany) reporting the third-highest number of articles.

Since citations can be used as a quality proxy for articles, it can be noted that while most articles are published in open access, this does not necessarily lead to more citations of the articles.

Regarding citations, it can be added that the most often cited article of Ducrot et al. [20] reports 139 citations, and the next two, Dubois et al. [21], Temple [22], are cited 98 or 87 times, respectively. Since the study of Dubois et al. [21] is the broadest, reporting the results of an empirical study with more than one million participants covering multiple European countries, and the study by Ducrot et al. [20] is a pre-adoption study on the effectiveness of the NS in France, their relevance for the scientific community and follow-up research is well-founded. Additionally, considering that the study of Ducrot et al. [20] has already been published in 2016, the high number of citations is not surprising.

Due to the problem, introduced above, with Scopus citation numbers as well as their dynamic nature, a detailed analysis thereof, incorporating the articles' age, will not be part of this study.

Focal points of Nutri-Score research

Tab. 6 summarises the regional foci of the studies. This allows for identification of those locations that are already well researched and those where gaps in the literature persist. The table provides a full list of all countries in which studies have been conducted about the NS, disregarding whether they have already introduced the NS themselves or not.

A total of 42 countries and Europe as a whole are represented in the table, generating the image of an international representation. Looking closer, however, reveals that out of the 261 national samples (2 samples are listed as European), 222 (84.4 % of the total) were drawn from countries inside Europe, and out of these, 196 (74.5 % of the total) were drawn from member states of the European Union. It can be stressed again that multiple studies implemented samples drawn from multiple countries.

France, the initiator of the NS [1], registers by far the largest number of samples, which coincides with Tab. 2, i.e. the most prominent authors being from France, considering the NS in a French context. Nevertheless, it is remarkable that only 152 studies (57.8 %) focus on countries that have already adopted the NS, and the remaining more than 40 % are focused on countries without NS experience. In this regard, Italy plays a special role since the majority of studies of category 1 consider comparisons between the NS and Italy's NutrInform Battery.

The Portuguese government has not yet opted in favour of a general introduction of the NS, but manufacturers can freely decide whether to introduce the label [23]. Food manufacturers such as Nestlé (Vevey, Switzerland), Auchan (Croix,

Tab. 6. Regional focus of studies – status quo end december 2024.

Country	Number of articles
Implemented Nutri-Score	
France	53
Germany	26
Spain	25
Netherlands	21
Belgium	16
Switzerland	11
Not implemented Nutri-Score	
Italy	20
United Kingdom	10
Portugal	11
Australia	7
Europe	2
Canada	6
Norway	4
Brazil	3
Slovakia	3
Mexico	3
Colombia	3
Poland	3
Bulgaria	2
Singapore	2
Slovenia	2
China	2
Denmark	2
Finland	2
Chile	2
Argentina	2
Ireland	2
Hungary	2
India	2
New Zealand	1
Serbia	1
Ghana	1
Latvia	1
Lithuania	1
Czech Republic	1
Estonia	1
Lebanon	1
Morocco	1
South Korea	1
Romania	1
South Africa	1
Luxembourg	1
Saudi Arabia	1

France) and Danone (Paris, France) have decided to introduce the NS, which is why the NS also appears on other European markets [24]. Whereas in 2024, due to changes in the NS algorithm, Danone has withdrawn from using the NS on its products.

Considering that multiple studies exist on Latin American or African countries, where the majority currently have no comprehensive nutritional policy in place, even though foreign products with FOPLs might already be commonplace, this shows the perceived potential inherent to FOPLs like the NS.

Keyword analysis

A total of 236 articles with keywords reported 1 083 keywords that were available for the analysis, thus on average 4.6 keywords per article were given by the authors.

Extracting different cluster numbers, between three and 100, leads to the conclusion that a four-cluster solution is the most comprehensive and can still be suitably interpreted based on the keywords assigned to represent each of the proposed cluster solutions. To find a fitting title for each of the four clusters, between three and ten of the terms most strongly associated with each of the clusters have been extracted as well.

Summarising, the four clusters extracted from the keywords can be termed as follows:

- labelling and nutritional quality;
- labelling and food choices;
- comparison of nutrition ratings;
- labelling and nutrition policy / industry guidelines.

Comparing the results of the keyword analysis with the results of the qualitative content analysis detailed in the section on the literature review reveals a strong overlap. While the category 5 (other findings, Tab. 1) does not have a clear focus and consists almost entirely of articles that did not report keywords, it is not surprising that it is not covered by the results of the keyword analysis. Thus, the machine-learning-based clustering yielded the same topical fields as the qualitative content analysis, supporting the claim that those four fields capture the essence of the last nine years of research on the NS. Research on the NS also indicates that the authors' self-reported keywords describe and position the respective articles well.

CONCLUSIONS

Research options

Regarding potential future studies, the most intuitive approach would be to continue similar to the existing studies and establish the suitability of NS for national nutrition policy in other European Union member countries. The Austrian government, as opposed to the Portuguese government, without any empirical backing, has not yet fully adopted and advocated the NS, but it gives manufacturers the option of voluntarily introducing it.

Even though isolated studies with a focus on Latin America, Asia, or Africa exist, a broader coverage of studies on these areas and the potential of the NS, or more generally, FOPLs as a tool of nutritional policy, could provide especially policymakers in these regions with valuable and much-needed insights.

All quantitative studies reported follow a decent level of scientific rigour; however, only a limited number consider that reactions to the NS might differ regarding socio-demographic factors. More detailed studies in this regard would provide governments with better targeting options for their nutritional policies and companies with better options to understand the repercussions of the decision to use the NS on their products.

Among the 308 studies considered in this review, most of which implement quantitative studies, the seven qualitative studies seem to be exceptions. The advantage of qualitative studies as compared to quantitative studies is that motivations and intentions can be studied in much better detail than in purely quantitative studies. Looking at the bulk of the literature, it shows that considerably little discussion takes place about why the NS leads to certain behaviour patterns or why it is preferred to and more effective than other FOPLs. All of the studies listed in categories 1 and 2 (Tab. 1), as introduced in the course of the literature review, refrain from tackling this issue, and the seven existing qualitative studies do not consider this issue either. To answer these questions, a more qualitative research design would be required, as well as a stronger focus on a theoretical background founded on psychological consumer behaviour. From a policy perspective, the NS can be considered a form of nudging to motivate consumers to shop for healthier products. This argument is already broadly discussed in the literature. However, a detailed theoretical discussion of the NS in the context of behavioural economics, including respective experimental results, is yet to be provided.

Turning from the consumer to the producer perspective on consumer behaviour, an issue that yet remains unstudied is the determination of the subjective price of the NS seal. Multiple studies have established that the NS has positive or negative impacts on consumers‘ willingness-to-buy and, thus, their willingness-to-pay. Therefore, the NS carries a price, which for a good rating will be a premium for the company, whereas for a bad rating, it will be a burden for it. While this insight can already be gathered from the existing literature, no study has considered choice experiments to actually determine the perceived price of different NS ratings or the display of the NS per se.

While in the context of this study, a machine-learning approach has been used to determine clusters of keywords and thus deduce the most studied research topics, this approach could be expanded. Not every article reports keywords, and even those that do might be limited by the regulations set forth by the respective journals. Thus, it might prove worthwhile to enhance and expand the keyword analysis by considering the articles' full titles as well. Further insights on the articles' scope, objectives, and results can also be gained by subjecting their abstracts or even the whole article to an automated classification or an in-depth sentiment analysis.

Summary and limitations

This review showed that since the introduction of the NS in France in 2017, a wide range of studies, partial reviews, and reports have been conducted and written. The majority of these studies have been conducted in countries where the NS is being used and where the governments have officially adopted it.

The four topical fields determined via the keyword clustering and the categories determined in the inductive literature analysis illustrate the scope of NS research. In combination with the discussion of the preceding section, this offers researchers the opportunity to determine those areas across the breadth of literature where gaps still persist. The review revealed that research on the NS currently is focused primarily on outcomes, i.e. consumer behaviours and reactions. The psychological and behavioristic backgrounds of why and how the NS fulfils its objective are only rudimentarily treated. Broadening the research paradigm, the NS is distinctly placed within the field of product design and product packaging; its discussion in this regard, however, was reduced mainly to a comparison with other FOPLs.

An analysis of the involved researchers and the resulting co-authoring network provides

researchers new to the topic with critical information about the main figures, i.e. as well their relevance among peers, in NS research and indicates the predominant research paradigms. This information might indicate potential biases present in NS research as proposed by PETERS and VERHAGEN [19].

The discussion of relevant journals adds to this information by illustrating the most prevalent outlets of research in this. The strong presence of MDPI and Frontiers owned journals, both perceived as questionable publishers, containing more than one quarter of all considered articles, additionally points out the need to consider research results on the NS more critically.

Regarding the limitations of this study, it needs to be stressed that only those articles listed in the Scopus database have been considered in the course of its conduction. In a future study the inclusion of articles listed in the Web of Science (Clarivate, Philadelphia, Pennsylvania, USA) or additional literature databases, might enhance the analysis, allowing as well for an additional way of rating or weighing articles.

The researcher network depicted in Fig. 2 displays only relations between co-authors. Thus, it only indirectly allows for a deduction of institutions involved in NS research. Expanding this type of analysis and adding information about funding for the institutions involved might reveal additional potential biases in NS research. A large share of articles published open access indicates that the researchers most certainly received funding. A detailed analysis of these funding sources would furthermore add to an understanding of potential biases in the research landscape.

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