Q Open, 2023, **3**, 1–20
https://doi.org/10.1093/qopen/qoad014
Advance access publication date: 5 May 2023
Article

OXFORD

Healthy food traditions? Nutritional quality and food composition of EU geographical indications

Gero Laurenz Höhn[1], Martijn Huysmans [2,*] and Christophe Crombez[3,4]

[1]LICOS Centre for Institutions and Economic Performance, 3000 KU Leuven, Belgium
[2]School of Economics, Utrecht University, School of Economics, Adam Smith Hall, Kriekenpitplein 21-22, 3584 EC Utrecht, the Netherlands
[3]Department of Management, Strategy and Innovation, 3000 KU Leuven, Belgium
[4]The Europe Center, Stanford University, 94305 CA California, USA

*Corresponding author: School of Economics, Utrecht University, School of Economics, Adam Smith Hall, Kriekenpitplein 21-22, 3584 EC Utrecht, the Netherlands; E-mail: m.huysmans@uu.nl

Received: December 1, 2022. **Accepted:** April 27, 2023

Abstract

The EU's 'Farm to Fork' strategy aims to promote healthier diets that include more nutritious and natural foods instead of ultra-processed products. Although several producers of geographical indication (GI) foods such as Parma ham advertise their products as artisanal and healthy, little is known yet about whether GIs can contribute to these ambitions. Therefore, we examine the nutritional quality and food composition of GIs compared to non-GIs. We analyse more than 6,000 cheeses and prepared meats marketed in France. We find that in these food categories GIs are associated with lower nutritional quality based on the Nutri-Score metric. Thus, GI regulations may need to facilitate health-driven product reformulations. On the positive side, we find that GIs in the considered dairy and meat categories tend to be less likely to contain food additives and to be ultra-processed. However, this seems to be truer for Protected Designations of Origin than Protected Geographical Indications. Hence, harmonised additive rules could strengthen the natural character of GIs.

Keywords: Geographical indications, Front-of-pack labelling, Ultra-processed foods, Nutritional quality, Nutri-Score, Food additives.

JEL codes: O34, Q18

1. Introduction

Can century-old food traditions help to ensure a sustainable future? The European Union (EU)'s Green Deal highlights geographical indications (GIs), that is, protected traditional foods, such as Italian Parma ham or Greek Feta cheese, as contributors. GIs safeguard the names of agricultural products that are produced in a specific area. In the EU, regulation 1151/2012 protects GIs with two major origin labels. For Protected Designations of Origin (PDOs) like French Roquefort cheese all production processes must take place in a denominated region. For Protected Geographical Indications (PGIs) like Belgian Ardennes sausage, only the most defining production steps must take place in the denominated region. According to the EU, the local '*terroir*', a combination of natural and human factors, ensures unique quality attributes.

In line with the EAT-Lancet report (Willett et al. 2019), the EU's 'Farm to Fork' (F2F) strategy emphasises the need for healthier diets as part of the transition to sustainable food systems (EC 2020). Under the F2F strategy, GIs are planned to be reinforced and the prospects of some GIs to represent a healthier food choice sound promising (FAO 2021; Vandecandelaere et al. 2021). However, little is known yet about the extent to which the GI sector may contribute as a whole.

The EU highlights GIs as important quality labels. Yet high-quality food need not be healthy. First and foremost, GIs certify the origin and allegedly related quality (Zago and Pick 2004; Menapace and Moschini 2014; Deconinck and Swinnen 2021). The contribution of GIs is especially debatable regarding the EU's sustainability goals because almost 40 per cent of all agri-food GIs registered in the EU are of animal origin, including cheeses and meats that should be consumed more moderately (EC 2020). While certain aspects of some GIs, such as amino acid levels in Parmesan cheese, may have positive health effects (FAO 2021), extant research has not examined the nutritional quality and food composition of GIs on a broader basis.

The overall nutritional quality of GIs represents a highly contentious topic in recent front-of-pack nutritional labelling debates. The Nutri-Score, which translates the nutrition facts table into a single score using traffic-light coding from high to low nutritional quality, represented one of the European Commission's options regarding more informative and harmonised nutritional labelling (WHO 2021). Nutri-Score opponents point out that their traditional foods, that is, GIs in particular, are penalised by the Nutri-Score categories and score unjustifiably low (Borrillo 2021). Thus, our first objective is to analyse whether GIs indeed tend to have worse Nutri-Scores values compared to non-GIs.

Apart from their overall nutritional quality, case studies on GIs suggest that their traditional production methods make them less processed and thus allegedly healthier (FAO 2021; Glogovețan et al. 2022). Therefore, our second objective is to contribute to existing exploratory studies by analysing the presence of food additives and processing degree in GIs and their generic counterparts.

Hence, our contribution is based on a two-fold approach. We also go beyond the scope of previous work that focused on specific products. Such limited scope inhibits more generalisable conclusions regarding the overall potential of GIs to contribute to healthier diets. Thus, we base our quantitative analyses on the extensive French open-access database of Open Food Facts (OFF) (OFF 2021), which grants access to thousands of observations, including more than 1,200 products representing seventy-nine GIs from ten countries.

We find that GIs are associated with worse Nutri-Scores. In contrast, our probit regressions confirm the potential of GIs to represent the more natural alternative containing fewer food additives. However, this finding is only true for PDOs, which are typically more strictly regulated than PGIs. All in all, while GIs may tend to have worse Nutri-Scores, they do seem to be less processed.

2. GIs and Healthy Diets

Obesity represents a major health concern (Ameye and Swinnen 2019). Thus, it is evident that policy-makers must tackle forcefully the issue of unhealthy diets (Tremmel et al. 2017). In that respect, Sogari et al. (2023) highlight that future health policy concerning diets should account for traditional foods. Also, food safety concerns about, for example, additives remain a major issue for consumers in the latest Eurobarometer (EFSA 2019). In general, the health-related aspects of GIs have not been examined on a broader basis. In what follows, we map out our paper's contribution to the two strands of related literature on nutritional quality and processing degree of GIs. While both aspects are distinct from each other, they remain correlated regarding health risks (Julia et al. 2022). Considering both is hence important in terms of health. For example, a recent study found that adults consuming foods with bad Nutri-Scores and particularly a high degree of processing have higher mortality risks (Bonaccio et al. 2022).

2.1 GIs and nutritional quality

Grunert and Aachmann (2016) highlight that consumers tend to associate GI labels with authenticity and high quality. Some consumers apparently regard GIs not only as traditional but also as healthy (Glogovețan et al. 2022; Thøgersen and Nohlen 2022). A consumer survey conducted by AND-International revealed that more consumers perceive GIs to be healthy rather than tasty (AND-International 2020). Hence, it comes as no surprise that many GIs such as Comté, Parmesan and Roquefort cheese, or San Daniele and Parma ham advertise the health benefits of their products, for example, the avoidance of food additives and richness in vitamins (San Daniele 2022). Nonetheless, the aforementioned GI products score low on overall nutritional quality based on the new Nutri-Score (Roquefort 2022), a candidate for a harmonised nutrition label at the EU level.

Breda et al. (2020) call for more informative nutrition labels to enable consumers to choose healthier products. In the EU, food producers are required to report on the package, the energy value, and amounts of sugars, proteins, salts, carbohydrates, fats, and saturates. However, these so-called nutrition facts panels, which are often on the back of packages, do not seem to be as appealing to consumers as more intuitively designed and colour-coded front-of-pack labels (Jones and Richardson 2007; Becker et al. 2015; Nohlen et al. 2022).

According to the International Agency for Research in Cancer (IARC) the Nutri-Score represents such a more appealing alternative (WHO 2021). It summarises the nutrition facts panel into a single score that categorises products with traffic-light coding (Julia and Hercberg 2017): From A (dark green, high nutritional quality) to E (red, low nutritional quality). Research confirms that the Nutri-Score is informative and recognizable to consumers (Egnell et al. 2020; Hagmann and Siegrist 2020; Sarda et al. 2020). A recent consumer experiment in Belgium provides evidence that consumers actually chose foods of better nutritional quality when Eco- and Nutri-Scores are displayed (De Bauw et al. 2021).

The Nutri-Score was first introduced in France (Julia and Hercberg 2017), but has been endorsed by several other EU countries, such as Belgium, Germany, the Netherlands, and Spain (WHO 2021). Major retailers, such as Delhaize and Carrefour in Belgium or Rewe and Edeka in Germany, also started labelling their products with the Nutri-Score (Rewe 2022). Due to its successful implementation in several Member States, it became the preferred option for harmonised labelling outlined in the F2F initiative (WHO 2021). Ultimately, the European Commission will apparently not opt for the Nutri-Score, but it may still propose a very similar colour-coded label (Fortuna 2022).

However, especially GI producers and southern Member States like Italy and Greece with a high number of GIs (Huysmans and Swinnen 2019) are fiercely trying to prevent the implementation of Nutri-Scores across the EU (Fortuna et al. 2022). In Italy, some retailers were even forced by Italian authorities to abandon the Nutri-Score score label (EFA 2022). The opponents criticise that the Nutri-Score assigns lower nutritional quality to, for example, prepared meats by summarizing the nutrients into a single score without accounting for favourable ingredients such as vitamins and proteins. In addition, it does not consider unhealthy ways of preparation, for example, frying. Finally, as the Nutri-Score is calculated per 100 grams, it may be more comparable across foods, but does not account for portion size.

Nonetheless, although a single score may sound overly simplified, Hagmann and Siegrist (2020) highlight that the Nutri-Score still achieves its goal to inform consumers about nutritional quality. Its algorithm is also used in medical research as a measure of such (Bonaccio et al. 2022). It is important to note that the Nutri-Score should be used to meaningfully compare products within certain categories (e.g. oils) and not across categories. Hence, one should not compare Nutri-Scores of olive oils and soft drinks, but within oils, for example, olive oils compared to palm oils (BEUC 2019). This intended use of the Nutri-Score has often been misunderstood and criticised. For example, the Nutri-Score has been dubbed as an 'attack on Italy' as potatoes designated to become fries had a better score than Italian olive oil (Borrillo 2021).

In terms of health, not much speaks against consuming cheese and meat GIs with bad Nutri-Scores moderately as part of a balanced diet, especially as the Nutri-Score only considers the quantity of certain ingredients and not their specific quality. Regarding the latter, some GIs seem to perform better than non-GIs (FAO 2021). However, dark orange or red Nutri-Score categories could lead consumers to avoid these products. According to GI producers, this avoidance could undermine food heritage—which GIs are meant to protect—as consumers may consume less traditional foods.

In addition, the Nutri-Score should not only incentivise consumers, but also producers to make healthier choices, that is, to reformulate their products and offer healthier alternatives with, for example, lower fat contents. The reformulation aspect represents a major goal of the F2F strategy (EC 2020). Already, major supermarkets like Delhaize and Carrefour in Belgium dedicate websites to 'products with an improved Nutri-Score' (Delhaize 2022). The Nutri-Score may become an even more severe issue for GIs if products of the same category (e.g. hams) offer products with better Nutri-Scores than GIs. For example, in France, many non-GI hams are sold as 'less fat' or 'less salt' alternatives that target health-conscious consumers. Such reformulations may be straightforward to implement for non-GI producers, but not necessarily for GIs that are bound to strict rules.

Opponents of the EU's GI system such as the USA criticise that EU GIs hamper innovation (Osgood and Feng 2018) by 'mummifying' product specifications and hence, impeding reformulations. Gocci and Luetge (2020) point out that by stiffly holding on to traditions, GIs may struggle to meet new market conditions and consumer expectations. This aspect may also be true regarding the rising demand for healthier foods (Sogari et al. 2023).

All in all, despite stiff opposition and backlash from southern Member States such as Greece and Italy as well as GI producers, the bottom line is that a Nutri-Score-like label remains on the Commission's table of options. This fact is mainly driven by the Nutri-Score's easily understandable design as well as an approximate, but overall helpful assessment of nutritional quality based on crucial nutrients. For the above reasons, we examine how GIs compare with generic alternatives in their nutritional quality based on Nutri-Scores.

2.2 GIs and ultra-processed foods

Representative surveys across the EU revealed that traditional foods are *inter alia* defined as naturally processed (Vanhonacker et al. 2010). In contrast, ultra-processed foods are characterized by numerous ingredients that are often exclusively used in industrial production. As a result, ultra-processed foods are often very durable and hyper-tasty (Monteiro et al. 2017, 2019; Adams et al. 2020). These advantages come at a cost because ultra-processed foods have health costs (Adams et al. 2020; FAO 2021; Monteiro and Cannon 2022). Hence, a shift to less processed, more natural products is advocated, and traditional foods such as GIs may represent a healthier alternative (Vanhonacker et al. 2010; Belletti and Marescotti, 2021; FAO 2021).

One of the main characteristics of ultra-processed foods is the use of food additives (Monteiro et al. 2019; Sanchez-siles et al. 2019). The European Food Safety Authority (EFSA) authorises the use of additives (also known as 'E-numbers') below given thresholds. In general, the use of food additives, harmless or potentially harmful, is widespread

(Chazelas et al. 2020). The EU recently banned the use of titanium dioxide (E 171) due to accumulating scientific evidence concerning potential health risks (EFSA 2022). Other potentially adverse additives include nitrites, nitrates, phosphates, and monosodium glutamate (Chazelas et al. 2020, 2021).

A recent re-evaluation of nitrites and nitrates sparked a spirited debate because threshold levels were not changed. Especially for ham, the use of nitrites or nitrates instead of the traditional, sole use of salt is widespread, but concerns about cancer risk and other health hazards remain (ANSES 2022). Hams are a major and economically relevant GI category (Török and Jambor 2016) and prominent GIs such as PDO Parma ham actually ban the use of preservatives like nitrites. However, other GI hams such as Belgian PGI Ardennes ham do not restrict their use at all.[1] While GIs might have the general reputation to be more artisanal and natural products, the use of food additives is not generally forbidden (Galli et al. 2020) and extant research has not yet systematically classified the presence of food additives in GIs. This gap in the literature is surprising as some GIs such as aforementioned Parma ham as well as Parmesan and Comté cheese explicitly ban the use of food additives.

3. Method

3.1 Hypotheses

Based on the literature, we formulate our main hypotheses to test in the context of the considered cheeses and prepared meats.

Higher contents of unfavourable ingredients such as salt and fat lead to higher Nutri-Scores, that is, lower nutritional quality. Some GI specifications even mandate certain salt and fat contents to preserve an authentic and pleasant taste. Thus, our first hypothesis reads

H1: *GIs are associated with lower nutritional quality compared to non-GI products.*

Moreover, ultra-processed foods typically contain food additives. Some commonly used additives are indeed related to adverse health effects (Chazelas et al. 2020, 2021). Several GIs explicitly ban the use of food additives and emphasise accordingly a healthier and more natural character of their products in their advertisements. Consequently, our second hypothesis is

H2: *GIs are less likely to contain additives compared to non-GI products.*

3.2 Data and variables

Following Chazelas et al. (2020), we opted for the open-access and crowdsourced Open Food Facts database that provides data on millions of food and drink products, mainly sold in France and hence, we focus on the latter. However, given the EU Single Market, we expect these products to be representative for the EU as a whole—especially for GIs, which are subject to the same rules throughout the EU.

We downloaded OFF data in November 2021. As about 30 per cent of EU GIs represent cheeses and prepared meats, we focused on the following food categories: cured sausages, cured hams, white hams, cow cheeses, goat cheeses, and sheep cheeses. Also, these categories represent processed products prone to the use of food additives (Chazelas et al. 2020) and tend to fall in bad Nutri-Score categories. OFF provides extensive data on the degree of processing, the presence of food additives, and nutritional quality per product. Our systematic data cleaning process resulted in 6,084 final observations. Online Appendix 1 provides further information on this process and our final data. OFF reports the Nutri-Score for all our observations as a continuous value. Nutri-Scores follow a standard calculation (Julia and Hercberg 2017) that summarises the reported amounts in the nutrition facts panel into a single score per 100 grams of product that falls into a range between −15, that is, best nutritional quality and 40, that is, worst nutritional quality. Nutri-Score values for solid foods from –15 to –1 fall into category A, 0 to 2 into category B, 3 to 10 into category C, 11 to 18 into category D, and 19 to 40 in category E (FOD 2022). For our regressions, we use the continuous dependent variable *Nutri-Score* to test *H1*. This continuous variable is preferred compared to the corresponding Nutri-Score categories (A–E) and hence a categorical variable because the continuous Nutri-Score allows for a more precise assessment of nutritional quality.

Moreover, all our observations are either coded as 'with' or 'without' additives by OFF. We define our second binary dependent variable *contains additives* to test *H2* as follows. *Contains additives* is 1 if additives are present and 0 if additives are absent.

Our main explanatory variable is the dummy variable *GI dummy*. OFF mentions so-called 'label tags' for each product. These tags report labels that the product possesses, for example, the EU organic label or GI labels. Thus, we checked all products in our sample for GI label tags (i.e. PDO/PGI and the equivalent acronyms AOP/IGP in French)) and corresponding protected names of GI products. In total, we have 79 different GIs in our sample accounting for more than 1,200 product observations (see Online Appendix 10 for a list). If the product is a GI, then the variable *GI dummy* takes the value of 1. In addition, we define a categorical variable *GI label* that distinguishes between *PDOs* and *PGIs* to the reference group of *non-GIs*. PDOs typically have stricter product specifications than PGIs and the variable *GI label* accounts for these differences.

We use the OFF food categories to introduce *food category* controls to our models. While 82 per cent of prepared meats include additives, this was only the case for 30 per cent of cheeses in the study of Chazelas et al. (2020). Also, certain food types naturally tend to be ultra-processed (FAO 2021) and to have certain Nutri-Scores. As our approach spans several food categories, we control for unobserved heterogeneity among these types of foods with controls for each *food category*, namely *cow cheese*, *sheep cheese*, and *goat cheese* as well as *cured* (raw) *ham*, *white* (cooked) *ham*, and *cured sausages* (meats are made from pork).

Moreover, the EU has a harmonised regulation on organic production that qualifies products to bear an organic label. Today, organic producers must follow EU regulation 2018/848, which also restricts the use of food additives. Thus, we create the dummy *organic* that takes the value of 1 if the product is organic to control for organic production.

Finally, there exists another national quality certification on the French market, which is not restricted to French products. Products with a so-called 'label rouge' ('red label') also have to follow certain product specifications, which are monitored by INAO, that is, the French National Institute of Origin and Quality. Apart from sensory characteristics, the superior quality guaranteed by the specifications must derive from product image and services as well as production conditions. GI producers can have a label rouge in addition to the GI label (INAO 2022). Thus, we control again for corresponding stricter production rules with the dummy *label rouge* that is 1 if the product bears a label rouge.

3.3 Descriptive statistics

Table 1 states the descriptive statistics of our sample and summarises our defined variables.[2] Our sample provides some interesting insights from a descriptive point of view. In the food categories considered for our study, about 50 per cent of products contain additives. This finding already underscores previous studies that highlight the widespread use and consumption of food additives (Monteiro et al. 2017; Adams et al. 2020; Chazelas et al. 2020, 2021).

The average Nutri-Score of all these processed products is around 15, which corresponds to the category D and indicates an overbalance of unfavourable nutrients in prepared meat and cheese categories.

Table 1. Descriptive statistics of variables.

Variable	*N*	Min.	Max.	Mean	Description
Nutri-Score	6,084	0	30	15	Nutri-Score of product
Contains additives	6,084	0	1	0.51	1 if product contains additives
GI dummy	6,084	0	1	0.20	1 if GI
GI label					
PDO	6,084	0	1	0.16	1 if PDO rather than PGI or non-GI
PGI	6,084	0	1	0.04	1 if PGI rather than PDO or non-GI
non-GI	6,084	0	1	0.80	1 if non-GI rather than PDO or PGI
Organic	6,084	0	1	0.11	1 if organic product
Label rouge	6,084	0	1	0.02	1 if label rouge product
Food category					
White ham	6,084	0	1	0.16	1 if white (cooked) ham
Cured sausage	6,084	0	1	0.19	1 if cured sausage
Cured ham	6,084	0	1	0.09	1 if cured (raw) ham
Cow cheese	6,084	0	1	0.42	1 if cow cheese
Goat cheese	6,084	0	1	0.09	1 if goat cheese
Sheep cheese	6,084	0	1	0.05	1 if sheep cheese

Furthermore, while the share of GI products is considerable with 20 per cent, only 11 per cent of products are organic. This number is far off from the EU's ambitious goal under the F2F strategy to achieve a share of 25 per cent (EC 2020).

While there are GIs in all categories, they are not equally distributed (see Table A3 in Online Appendix 4). While only four white hams include a GI, the majority of sheep cheeses have a GI. Moreover, PDOs and PGIs are not equally represented in each category. While there are almost only PGIs in the category of cured sausages, there are no PGI goat and sheep cheeses in our sample.

The importance of controlling for food categories also becomes clear when looking at descriptive statistics of our dependent variables in Table A4 (Online Appendix 4). For example, while the average Nutri-Score of cow and goat cheeses is about 14 and 13 (D), respectively, the average of sheep cheeses and cured hams is about 17 (D). White hams have the best Nutri-Score on average with a value of around 6 (C) and cured sausages have the worst average Nutri-Score with approximately 23 (E). Also, while approximately one-fourth of cow and goat cheeses contain additives, the same is true for about 90 per cent of white hams and cured sausages in our sample.

4. Statistical Models

We go beyond simple descriptives in our analysis to examine whether the expected tendencies of GIs formulated in our hypotheses are significant across all products in our sample. Despite a possible overall tendency of GIs, there may be differences within specific categories as shown in Table A4 (Online Appendix 4). In a robustness check, we also run category-specific regressions to check whether our main results also hold within certain categories.

First, we estimate the continuous expected *Nutri-Score* based on an OLS regression:

$$Nutri\ Score_i = \alpha + \beta_1 GI_i + \beta_2 organic_i + \ \beta_3 label\ rouge_i + \delta_c + \ \varepsilon_i. \quad (1)$$

With β_1 measuring the expected difference in *Nutri-Score* of a *GI* relative to a non-GI product.[3] β_2 concerns the coefficient of *organic* products and β_3 concerns the coefficient of *label rouge* products. δ_c represents the controls corresponding to the respective *food category*.

Table 2. OLS regressions on Nutri-Score (higher value = lower nutritional quality).

	Model (1)	Model (2)	Model (3)	Model (4)
GI dummy	1.41***			
	(0.12)			
GI label (reference: non-GI)				
PDO		1.15***	1.57***	1.56***
		(0.12)	(0.08)	(0.08)
PGI		2.34***	0.43***	0.42***
		(0.29)	(0.13)	(0.13)
Organic				−0.28**
				(0.11)
Label rouge				0.08
				(0.26)
Food category (reference: white ham)				
Cured sausage			17.16***	17.14***
			(0.15)	(0.15)
Cured ham			10.65***	10.64***
			(0.16)	(0.16)
Cow cheese			7.68***	7.69***
			(0.13)	(0.13)
Goat cheese			6.55***	6.56***
			(0.16)	(0.16)
Sheep cheese			9.61***	9.65***
			(0.19)	(0.19)
Constant	14.74***	14.74***	6.27***	6.30***
	(0.09)	(0.09)	(0.12)	(0.12)
Summary Statistics				
N	6,084	6,084	6,084	6,084
Adj. R^2	0.01	0.01	0.78	0.78
AIC	38787.91	38781.12	29551.07	29548.99

Notes: Robust standard errors in parentheses. $^{*}P < 0.1$, $^{**}P < 0.05$, and $^{***}P < 0.01$.

Finally, we estimate the probability of product i to *contain additives* with the following probit model:

$$p\ (\text{Contains Additives}) = \Phi(\alpha + \beta_1 GI_i + \beta_2 organic_i + \beta_3 label\ rouge_i + \delta_c). \quad (2)$$

In addition, in a robustness check, we use negative binomial regressions to analyse the number of additives included in a product, that is, count data of additives, which is reported for most of our observations by OFF.

Moreover, in another robustness check, we also run probit regressions to check whether GIs are less likely to be *ultra-processed* based on the NOVA classification system (Monteiro et al. 2017).

5. Results

5.1 Nutritional quality

Table 2 reports estimates of our OLS regressions on *Nutri-Scores*. Model 1 only has a GI dummy as explanatory variable. Model 2 splits out the dummy into PDOs and PGIs. Model 3 adds basic controls and Model 4 adds further controls. As expected, both *PDO* and *PGI* coefficients are positive and significant at the 1 per cent level. Therefore, based on our sample, we can confirm *H1* that *GIs* in the considered cheese and prepared meat categories are

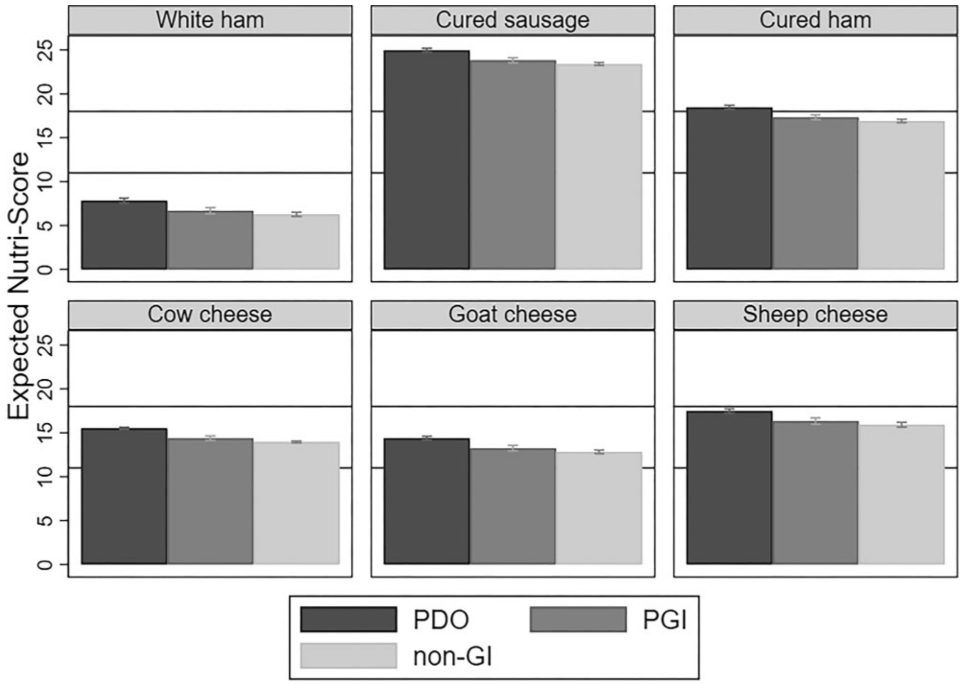

Figure 1. Plot of predictive margins of *GI label* on expected *Nutri-Scores* per food category (Model 4, Table 2). Lines represent the cut-off points from Nutri-Score C to D and D to E (higher is worse).

indeed associated with higher *Nutri-Scores* (i.e. lower nutritional quality). In our full sample, this positive association with values of lower nutritional quality is more pronounced for *PDOs*.

The differences of predicted *Nutri-Scores* of GI products compared to non-GI cheeses and prepared meats are not of a large magnitude since we focus on comparable products (see Fig. 1). Nevertheless, the small but significant differences can lead GIs to fall in a worse category, that is, from D (cut-off value 18) to E.

Note that there are no white hams with a PDO or goat and sheep cheeses with a PGI in our sample (see Table A3, Online Appendix 4). Thus, the corresponding expected Nutri-Scores in Fig. 1 represent an extrapolation, for example, the expected Nutri-Score if a white ham would be a *PDO*. While there is a tendency to score higher for *PDOs* and *PGIs* across all products when controlling for food categories, the expected Nutri-Scores describing extrapolations for specific food categories should still be interpreted with caution. This also applies to extrapolations of predicted probabilities in Fig. 2 estimated by our probit regression, which are described in the next section.

On the whole, our results suggest that across the considered food categories PGIs and PDOs in particular tend to have on average higher Nutri-Scores, which translates into lower nutritional quality.

5.2 Presence of additives

Table 3 reports results concerning our hypothesis *H2*. Model 5 uses a GI dummy and Model 6 splits it out into PDOs and PGIs. The reported average marginal effects of Model 5 and 6 confirm our hypothesis that cheese and prepared meat *GIs* are less likely to contain additives. However, Model 6 reveals that these lower likelihoods of GIs are only statistically

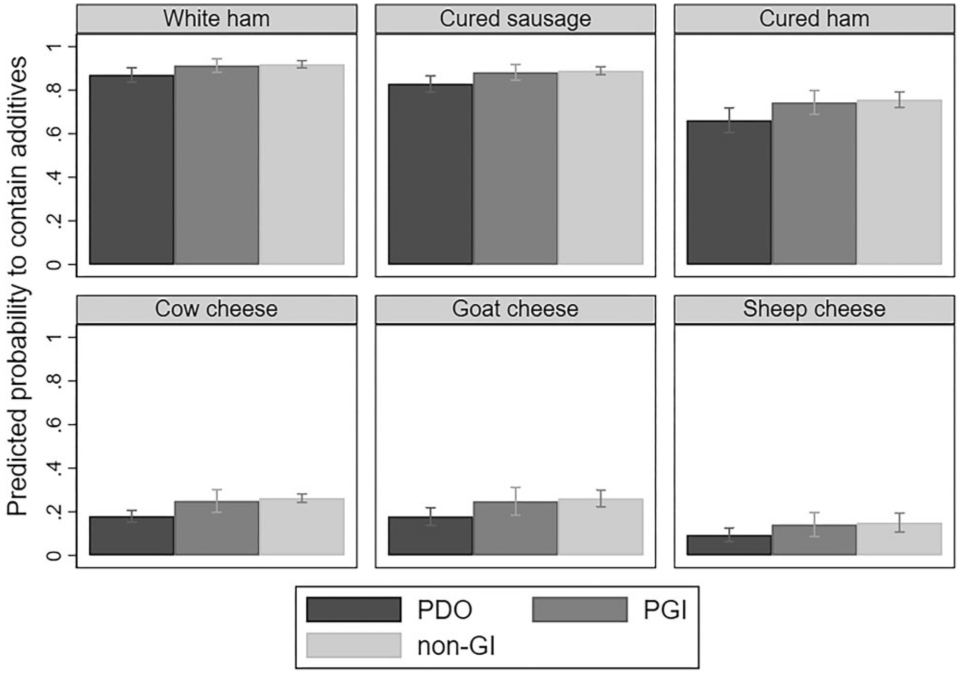

Figure 2. Predicted probabilities to contain additives of GI label per food category (Model 6, Table 3).

significant for *PDOs,* with typically stricter rules than *PGIs*. Overall, a *PDO* product is expected to decrease probability of containing additives by about 7 percentage points compared to a *non-GI* product.

Figure 2 shows that the predicted probabilities to contain additives are around 90 per cent for *non-GI* white hams and sausages, but also lower again for *PDOs* with about 87 per cent and 83 per cent, respectively. The cheese categories have substantially lower predicted probabilities to include additives. But yet again, *PDOs* are expected to have a significantly lower likelihood to contain additives. All predicted probabilities are also in line with Chazelas et al. (2020) where 82 per cent of prepared meats and 30 per cent of cheeses include additives.

All in all, our findings indicate that GIs tend to be less likely to contain food additives. However, this tendency is driven by PDOs with typically stricter production rules that in some cases even explicitly ban the use of additives. Also, note that organic products show an even lower likelihood to contain additives.

6. Robustness Checks

As mentioned earlier, our full-sample regression specifications with controls for food categories model an overall tendency of PDOs and PGIs across categories and not a category-specific one. There can be deviations in specific category contexts and not all categories contain PDOs or PGIs (see also Tables A3 and A4 in Online Appendix 4). Thus, we first analyse prepared meats and cheeses separately. The results of these subsample regressions confirm our main findings (see Online Appendix 6).

Moreover, we also run within-category regressions (see Online Appendix 7). Overall, the results of these regressions do not invalidate our main findings, which is especially true

Table 3. Probit regressions of containing food additives.

	Model (5)	Model (6)
GI dummy	−0.06***	
	(0.01)	
GI label (reference non-GI)		
PDO		−0.07***
		(0.01)
PGI		−0.01
		(0.02)
Organic	−0.21***	−0.21***
	(0.02)	(0.02)
Label Rouge	0.01	0.00
	(0.03)	(0.03)
Food category (reference white ham)		
Cured sausage	−0.03**	−0.03**
	(0.01)	(0.01)
Cured ham	−0.16***	−0.17***
	(0.02)	(0.02)
Cow cheese	−0.66***	−0.66***
	(0.01)	(0.01)
Goat cheese	−0.67***	−0.66***
	(0.02)	(0.02)
Sheep cheese	−0.78***	−0.77***
	(0.02)	(0.02)
Summary Statistics		
N	6,084	6,084
Pseudo R^2	0.37	0.37

Notes: Results reported as average marginal effects (discrete change from base level) instead of coefficients to ease interpretation. Robust standard errors in parentheses. $^*P < 0.1$, $^{**}P < 0.05$, and $^{***}P < 0.01$.

concerning the tendency of GIs to receive worse Nutri-Scores. In the case of additives, only PDO goat cheeses have a higher likelihood to contain additives, which is contrary to the expected lower likelihood of PDOs. However, please note that generally only the categories of cow cheeses and cured hams include a sufficient number of both PDO and PGI observations. This is also a prime reason why we based our main regressions and conclusions on our full sample.

To continue, we run count data regressions to analyse the number of included additives (see Table 4). Negative binomial regressions were used due to slight overdispersion of the count data (see also Online Appendix 9). In line with our expectations, GIs are more likely to contain less additives in general with statistical significance compared to non-GI products. Again, the overall tendency of PDOs is stronger than the one of PGIs. Nevertheless, both PDOs and PGIs tend to include less food additives.

Another robustness check considers additives themselves. In terms of health, many common food additives such as citric acid (E 330) are considered to be harmless (Chazelas et al. 2020). Therefore, we redefine our dependent variable in a robustness check to contains *adverse additives*. We code the variable as 1 if a product included at least one additive that is related in the literature to adverse health effects. Online Appendix 8 lists these additives and the corresponding results in Table A16. Actually, no PDO product in our sample includes additives related to adverse health effects. This of course confirms *H2*, but we cannot include PDOs in our model specifications due to this perfect prediction. In line with

Table 4. Dependent variable: number of included additives.

	Model (7)	Model (8)
GI dummy	−0.66***	
	(0.06)	
GI label (reference non-GI)		
PDO		−0.89***
		(0.09)
PGI		−0.39***
		(0.08)
Organic	−0.83***	−0.83***
	(0.06)	(0.06)
Label rouge	−0.18***	−0.19***
	(0.05)	(0.05)
Food category (reference white ham)		
Cured sausage	0.14***	0.13***
	(0.03)	(0.03)
Cured ham	−0.36***	−0.38***
	(0.04)	(0.04)
Cow cheese	−1.50***	−1.47***
	(0.05)	(0.05)
Goat cheese	−1.66***	−1.63***
	(0.10)	(0.10)
Sheep cheese	−1.45***	−1.37***
	(0.18)	(0.18)
Constant	0.78***	0.78***
	(0.02)	(0.02)
Summary statistics		
N	6,011	6,011
Pseudo R^2	0.17	0.17

Notes: Robust standard errors in parentheses. $^{*}P < 0.1$, $^{**}P < 0.05$, and $^{***}P < 0.01$.

our previous findings, there is also no statistically significant difference between PGIs and non-GI products regarding the use of adverse additives.

Finally, ultra-processed products are not solely defined by the use of additives. Thus, we conducted a robustness check using the well-established NOVA-classification system that categorises foods according to their overall degree of processing. The results of the corresponding probit regressions confirm our expectation that GIs tend to be less likely to be ultra-processed, which is again driven by PDOs (see Online Appendix 3).

7. Discussion and Limitations

GI research suffers from a lack of comprehensive and readily available data (Török et al. 2020). One of our major contributions is that we base our analysis on a large number of observations and GIs from the Open Food Facts database. Despite its large coverage OFF does not provide information about all available products. Nonetheless, we compare more than seventy GIs to a large number of generic products, which represents a substantially larger scope compared to case studies of single GIs.

It is difficult to make general conclusions in GI research due to the heterogeneity of registered products (Török et al. 2020). We focus on seventy-nine cheeses and prepared meats from ten countries not only because many GIs fall in these categories, but also because additives are common in these categories. In contrast, GI products such as lemons from Sorrento or apples from South-Tyrol fall in NOVA-group 1 of unprocessed or minimally processed foods (Monteiro et al. 2019; Adams et al. 2020). Also, the Nutri-Score does not cover fresh fruits and vegetables, raw meat, or honey (FOD 2022). This is another reason why we focus on processed GI products such as cheeses and prepared meats, which are also controversially discussed in health debates. Consequently, our analysis covers the most relevant GI categories with regard to our research questions.

Moreover, there is heterogeneity not only among GIs, but also generally in the OFF food categories that we consider. Higher Nutri-Scores of PDOs in a cheese category could be due to the fact that GIs may tend to be more ripened and hardened cheeses (e.g. Parmesan cheese) rather than fresh cheeses. While it is important to be aware of within-category variation, these differences do not nullify our overall findings. The OFF categories still represent categories in which consumers search for products.

To continue, food naturalness is a crucial aspect for consumers (Román et al. 2017). Consumers become ever more aware of issues concerning food additives, and classifications like the NOVA system or the Food Naturalness Index of Sanchez-Siles et al. (2019) explicitly account for additive use. This greater awareness also reflects itself in general ambitions to reformulate processed products under the F2F strategy (EC 2020). While consumers may perceive traditional processes and the related GI labels as positive, this positive aspect of GIs may be undermined by the use of food additives. Therefore, the PGI label may lose reputation in particular, especially if additives are used that were publicly debated regarding health hazards.

One limitation of our study is that we cannot control for the dosage of additives. However, the standard paradigm in toxicology 'the dose makes the poison' is being scrutinised by recent studies. The intake of certain additives itself may be harmful despite a low dosage (Chazelas et al. 2020, 2021). Therefore, it is already important to investigate the general presence of additives (Chazelas et al. 2020) as we have done in Models 5 and 6. This importance seems to be especially true for GI products that allegedly represent less processed and more natural alternatives (Vanhonacker et al. 2010; FAO 2021; Glogovețan et al. 2022).

Regarding nutritional quality, prepared meats and cheeses are generally prone to score low in overall nutritional quality, giving producers incentives to improve their nutritional quality. While major supermarkets such as Delhaize in Belgium praise reformulations of hams and cheeses resulting in better Nutri-Scores, GIs are bound to stricter rules that can also stipulate minimum salt or fat contents. However, note that, of course, not all GI specifications negatively affect the nutritional profile. For example, Georgian GI 'Tushuri Guda' cheese commands now a healthier reduced salt content and also Dutch PDO 'Noord-Hollandse Gouda' sets a maximum rather than a minimum salt content (Huysmans and van Noord 2021). Nonetheless, the currently rather small overall difference in Nutri-Scores between GIs and non-GIs in our regressions may increase in the future to the potential disadvantage of GIs. Non-GI producers could strategically reformulate to reach a cut-off value to fall in a better Nutri-Score category, that is, from E to D. While certain GI specifications may ensure superior sensory characteristics (Huysmans and van Noord 2021), this might come at the expense of better Nutri-Scores.

In general, the association of GIs with bad Nutri-Scores may be concerning for GI producers. The current GI regulation does not comprehensively cover nutritional aspects and other sustainability related standards (FAO 2021; Wirth 2016). While certain individual products may have the potential to offer the healthier or more environmentally friendly alternative (Belletti et al. 2015; FAO 2021; Vandecandelaere et al. 2021; Glogovețan et al. 2022), this is mainly based on the respective product specifications and not the overall GI regulation. Thus, EU policy-makers need to carefully contemplate about making the GI label more inclusive by accounting for eco- and health-related issues in the regulation.

Finally, the Nutri-Score considers only the presence and quantity of certain macroelements, but not their specific, qualitative profile. Also, it does not consider the use of food additives nor the content of vitamins, calcium, iron, or other minerals. However, case studies on GIs as well as producer information highlight that GIs are richer in these latter favourable ingredients compared to their generic counterparts (FAO 2021). Higher contents of conjugated linoleic acid in Portuguese GI cheeses and meat suggest better health-related characteristics (Alfaia et al. 2006; Partidário et al. 2008) and Spanish GI hams show higher percentages of healthier unsaturated fatty acids (Fernández et al. 2007). In our study, we could not control for all these various aspects that often require laboratory tests. However, we do account for the use of food additives, which grants primarily PDOs a better standing in terms of health compared to non-GI products. Overall, PDOs tend to avoid additives and do not include additives related to adverse health effects at all in our sample. Future research may investigate on a broader basis the prevalence of other beneficial and/or unfavourable ingredients in GIs compared to non-GIs.

8. Policy Implications

In our analysis, we focus on cheeses and prepared meats, which remain prominent GI products in the media regarding health and labelling debates. Consequently, we formulate food policy recommendations applicable to these product types. However, some may argue that we should not consume GIs of animal origin at all due to comparatively high carbon footprints, health concerns, or animal welfare considerations (Willett et al. 2019). Thus, before we provide our policy implications concerning cheeses and prepared meats, we suggest that fruit and vegetable GIs such as clementines from Calabria or sweet onions from the Cevennes should receive more attention in terms of agri-food promotion campaigns compared to processed GI products.

Moreover, the sales value for GI fruits, vegetables, and cereals is increasing. The sales value grew by 97 per cent from 2010 to 2017 and represented 8 per cent of the total sales value of agri-food GIs in 2017. In comparison, cheeses and prepared meat products had a joint share of more than 50 per cent (AND-International 2019). Thus, policy-makers should stimulate new applications of fruit and vegetable GIs and support producers in marketing. A total of 41 per cent of new GI registrations since 2020 were fruits, vegetables, and cereals compared to 12 per cent of cheeses and prepared meats. A continuously growing number of registrations of fruit and vegetable GIs may enable the GI sector to contribute more to healthier diets.

In what follows, we suggest concrete starting points for policy proposals concerning cheese and prepared meat GIs as well as related nutritional labelling. Individual GI specifications can already be amended under Article 53 of the current GI regulation 1151/2012. For example, Mozzarella changed its maximum curd temperature from 36°C to 39°C (Huysmans and van Noord 2021). As a matter of fact, about one-fifth of all food GIs have undergone at least one amendment and processed GI products were amended about 40 per cent more often compared to unprocessed ones (Quiñones Ruiz et al. 2018).

First, we suggest that current GI specifications should become more flexible in terms of, for example, minimum salt or fat contents. The FAO report advocates for GI amendments and suggests that in specific contexts such as Chinese 'furu' (fermented tofu) GIs with lower salt content may be allowed to account for better nutritional quality (FAO 2021). Our findings on the association of GIs with lower Nutri-Scores strengthen this point. While for traditionalists this may represent a sacrilege, GI producer organisations should consider allowing less salt and fat in their GIs. Several non-GI producers already started reformulating their products, which also results in better Nutri-Scores.

A perfect example of GI reformulation is the recent application for an amendment of the famous Italian ham 'Prosciutto di San Daniele'.[4] With explicit reference to the World Health Organization goals, the consortium of San Daniele ham intends to allow its producers to lower salt contents. Moreover, the consortium emphasises that this lower salt content does not jeopardise the authentic organoleptic characteristics, which is what purists could fear.

The amendment has not been implemented yet because the reformulation was classified as a major amendment by the European Commission. To allow for easier and faster reformulation, a practical policy implication would be to treat such health-related amendments as minor instead.

Secondly, our results indicate that overall, PDOs tend to be less likely to contain additives and to be ultra-processed. In order to strengthen consistency across different GIs, harmonised additive rules should be considered. Restrictions regarding additives should not compromise GIs, but underscore one of the major regulatory goals, that is, to preserve traditional production techniques. Also, systematically avoiding the use of additives would strengthen the natural character of GIs, which sometimes struggle in finding the right balance between artisanal and industrialised production (Gangjee 2017).

In addition, GI amendments that concern the restriction of certain food additives to make the final product more natural should also be classified as minor. A recent example is the amendment to the specification of PGI 'Mortadella di Bologna', which was intended to guarantee a simpler and more natural recipe. The minor amendment was approved in June 2022 and added an explicit ban on polyphosphates as well as processing aids and other substances that affect the product's colour. Moreover, natural flavourings are now restricted to a maximum of 0.3 per cent.

Finally, a Nutri-Score-like label seems likely to become the Commission's proposal for harmonised labelling, but its ultimate form remains uncertain. While EFSA emphasised the need for healthier food choices, it did not give a clear label recommendation, leaving policymakers with uncertainty (Turck et al. 2022). Therefore, a possible adjustment of the Nutri-Score could be to reward products that are free from (adverse) additives, which may be a step towards current opponents. For example, the Italian EU official Roberto Berutti fears that with the Nutri-Score also ultra-processed foods will be labelled as 'green' A-/B-label choices (Fortuna 2021). The NOVA system already considers additives and additives must be listed in ingredient lists. Thus, a revised Nutri-Score may account for additives as well with relatively little effort.

In July 2022, the steering committee of the Nutri-Score approved future changes to the Nutri-Score metric (MSP 2022). These changes are likely to improve the scores of certain hard cheeses with limited amounts of salt, which can be seen as a step towards several GI producers. However, while the Nutri-Score algorithm may improve, it still does not account for the presence of additives or vitamin levels. Nevertheless, the recent decision underscores that the Nutri-Score metric is still developing and may be revised even further as suggested above.

9. Conclusion

For the first time, we examined quantitatively nutritional quality and food composition of EU GIs in cheese and prepared meat categories with the help of extensive data on Nutri-Scores, additive presence, and NOVA-groups derived from the French Open Food Facts database.

Our OLS regressions indicate that both PGIs and PDOs are currently associated with higher (i.e. worse) Nutri-Scores. In the future, rigid traditional product specifications may impede reformulations, which could advantage non-GI products further.

In general, note that our analysis only considers the presence of ingredients summarised by the Nutri-Score, but not their specific quality profile. While the analysed GIs overall tend to receive worse Nutri-Scores, this does not mean that GIs are unhealthier *per se*.

In that respect, our probit results confirm previous indications in the literature that GIs are less likely to be ultra-processed and to contain additives. However, these findings are driven by PDOs. Overall, PGIs do not show a significant difference concerning ultra-processing and additive use compared to non-GI products. Hence, the general heterogeneity of GI products (Török et al. 2020) also reflects itself in our differing results regarding PDOs and PGIs.

Our findings have several policy implications concerning GI cheeses and prepared meats. First, GI specifications should become more flexible in terms of reformulations concerning, for example, minimum salt and fat contents. Secondly, harmonised rules on food additive use could be considered in the GI regulation. Thirdly, the Nutri-Score itself is already recommended by seven EU Member States and a Nutri-Score-like label remains one of the options for a new mandatory EU-wide nutrition label. However, the Nutri-Score's highly debated limitations in assessing nutritional quality complicate decision-making. In order to bring proponents and opponents of the Nutri-Score closer, the underlying metric may be enhanced by accounting for the use of food additives and/or the content of vitamins as well as other beneficial nutrients.

All in all, whether GIs can actually contribute to healthier diets remains ambiguous. Our findings suggest a potential of some GIs regarding food processing and additive use, but not in terms of nutritional quality based on the Nutri-Score metric. Therefore, we hope to provide new starting points for researchers and practitioners to scrutinise further the possibilities of GIs in dairy and meat as well as other categories to contribute to a healthier future.

Acknowledgments

We would like to thank two anonymous reviewers for their constructive feedback. Moreover, we thank seminar participants at KU Leuven and Utrecht University as well as participants of the 22nd PhD symposium of the Belgian Association of Agricultural Economists (BAAE) for discussions and comments on earlier drafts. In particular, we want to thank Hannah Ameye for expert advice on nutrition as well as Johan Swinnen and Giulia Meloni for their useful suggestions. Moreover, we thank Emilie Vandecandelaere and Alexandra Ognov for their pertinent comments. Finally, we would like to thank the helpful team of the Open Food Facts website (https://world.openfoodfacts.org/contact) for useful information and suggestions regarding their open-access data. All shortcomings remain our own.

Funding

This research was supported by KU Leuven-Long term structural funding (Methusalem funding) by the Flemish Government.

Conflict of interest

There are no conflicts of interest to declare.

Data availability statement

The datasets were derived from sources in the public domain: Open Food Facts (available on: https://world.openfoodfacts.org/) and eAmbrosia (available on: https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/geographical-indications-register/). The data and replication code are available in the online supplementary material.

Supplementary material

The supplementary material is available at *Q Open* online.

End Notes

1 All basic information about certain GI product specifications in this article is derived from the EU's eAmbrosia database (EC 2022).

2 The correlation matrix of all our independent variables can be consulted in Online Appendix 2.
3 In line with our hypotheses, our initial specifications are based on the *GI dummy*. Note that in our final model specifications, we distinguish between *PDOs* and *PGIs* in a categorical variable called *GI label* with the reference group of *non-GI* products to account for potential differences between the two EU GI labels.
4 In the Official Journal of the European Union, C 139, 29 March 2022.

References

Adams J., Hofman K., Moubarac J. C. and Thow A. M. (2020) 'Public health response to ultra-processed food and drinks', *BMJ*, 369: m2391.
Alfaia C. M. M., Ribeiro V. S. S., Lourenço M. R. A., Quaresma M. A. G., Martins S. I. V., Portugal A. P. V., Fontes C. M. G. A., Bessa R. J. B., Castro M. L. F. and Prates J. A. M. (2006) 'Fatty acid composition, conjugated linoleic acid isomers and cholesterol in beef from crossbred bullocks intensively produced and from Alentejana purebred bullocks reared according to Carnalentejana-PDO specifications', *Meat Science*, 72: 425–36.
Ameye H. and Swinnen J. (2019) 'Obesity, income and gender: the changing global relationship', *Global Food Security*, 23: 267–81.
AND-International. (2019) *Economic value of EU quality schemes, geographical indications and traditional specialities guaranteed. Publications Office of the European Union*. https://op.europa.eu/en/publication-detail/-/publication/a7281794-7ebe-11ea-aea8-01aa75ed71a1, accessed 8 August 2022. DOI: 10.2762/396490
AND-International. (2020) *Evaluation support study on Geographical Indications and Traditional Specialities Guaranteed protected in the EU. Publications Office of the European Union*. https://data.europa.eu/doi/10.2762/891024, accessed 8 August 2022. DOI: 10.2762/708630
ANSES. (2022) 'Reducing dietary exposure to nitrites and nitrates'. https://www.anses.fr/en/content/reducing-dietary-exposure-nitrites-and-nitrates, accessed 28 July 2022.
Becker M. W., Bello N. M., Sundar R. P., Peltier C. and Bix L. (2015) 'Front of pack labels enhance attention to nutrition information in novel and commercial brands', *Food Policy*, 56: 76–86.
Belletti G. and Marescotti A. (2021) *Evaluating Geographical Indications—Guide to Tailor Evaluations for the Development and Improvement of Geographical Indications*. Rome: FAO. DOI: 10.4060/cb6511en
Belletti G., Marescotti A., Sanz-ca J. and Vakoufaris H. (2015) 'Linking protection of geographical indications to the environment: evidence from the european union olive-oil sector', *Land Use Policy*, 48: 94–106.
Bonaccio M., Di Castelnuovo A., Ruggiero E., Costanzo S., Grosso G., De Curtis A., Cerletti C., Donati M. B., de Gaetano G. and Iacoviello L. (2022) 'Joint Association of food nutritional profile by Nutri-score front-of-pack label and ultra-processed food intake with mortality: Moli-Sani prospective cohort study', *BMJ*, 378: e070688.
Borrillo M. (2021) 'Nutriscore, patatine fritte più salutari dell'olio. Patuanelli: Italia contraria'. *Corriere della Sera*. https://www.corriere.it/economia/consumi/21_novembre_15/nutriscore-patatine-fritte-piu-salutari-dell-olio-patuanelli-italia-contraria-743ece18-4605-11ec-9a24-28e7c2e627b2.shtml, accessed 16 August 2022.
Breda J., Castro L. S. N., Whiting S., Williams J., Jewell J., Engesveen K. and Wickramasinghe K. (2020) 'Towards better nutrition in Europe: evaluating progress and defining future directions', *Food Policy*, 96: 101887.
Chazelas E., Deschasaux M., Srour B., Kesse-Guyot E., Julia C., Alles B., Druesne-Pecollo N., Galan P., Hercberg S., Latino-Martel P., Essedik Y., Szabo F., Slamich P., Gigandet S. and Touvier M. (2020) 'Food additives: distribution and co-occurrence in 126,000 food products of the French market', *Scientific Reports*, 10: 1–15.
Chazelas E., Druesne-Pecollo N., Esseddik Y., de Edelenyi F. S., Agaesse C., De Sa A., Lutchia R., Rebouillat P., Srour B., Debras C., Wendeu-Fyet G., Huybrechts I., Pierre F., Coumoul X., Julia C., Kesse-Guyot E., Allès B., Galan P., Hercberg S., Deschasaux-Tanguy M. and Touvier M. (2021) 'Exposure to food additive mixtures in 106,000 french adults from the NutriNet-Santé Cohort', *Scientific Reports*, 11: 1–21.
Deconinck K. and Swinnen J. (2021) 'The size of terroir: a theoretical note on economics and politics of geographical indications', *Journal of Agricultural Economics*, 72: 321–8.

De Bauw M., Matthys C., Poppe V., Franssens S. and Vranken L. (2021) 'A combined nutri-score and "Eco-Score" approach for more nutritious and more environmentally friendly food choices? Evidence from a consumer experiment in Belgium', *Food Quality and Preference*, 93: 104276.

Delhaize. (2022) 'Producten met een verbeterde Nutri-Score'. https://www.delhaize.be/nl/nutriscore-update, accessed 28 July 2022.

Egnell M., Galan P., Farpour-Lambert N. J., Talati Z., Pettigrew S., Hercberg S. and Julia C. (2020) 'Compared to other front-of-pack nutrition labels, the nutri-score emerged as the most efficient to inform swiss consumers on the nutritional quality of food products', *PLoS ONE*, 15: 1–18.

European Food Agency (EFA). (2022) 'Nutri-Score banned by Italian anti-trust authority'. https://www.efanews.eu/item/26073-nutri-score-banned-by-italian-anti-trust-authority.html, accessed 15 August 2022.

European Commission (EC). (2022) 'eAmbrosia: The EU geographical indications register'. https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/geographical-indications-register/, accessed 21 August 2022.

European Food Safety Authority (EFSA). (2019) 'Eurobarometer on food safety in the EU'. https://www.efsa.europa.eu/en/corporate/pub/eurobarometer19, accessed 23 March 2023.

European Food Safety Authority (EFSA). (2022) 'Titanium dioxide: E171 no longer considered safe when used as a food additive'. https://www.efsa.europa.eu/en/news/titanium-dioxide-e171-no-longer-considered-safe-when-used-food-additive, accessed 8 August 2022.

European Commission (EC). (2020) 'Farm to fork strategy'. https://ec.europa.eu/food/sites/food/files/safety/docs/f2f_action-plan_2020_strategy-info_en.pdf, accessed 17 May 2021.

Federale Overheidsdienst (FOD). (2022) 'Nutri-Score frequently asked questions'. https://www.health.belgium.be/nl/node/36098, accessed 28 July 2022.

Fernández M., Ordóñez J. A., Cambero I., Santos C., Pin C. and Hoz de la L. (2007) 'Fatty acid compositions of selected varieties of spanish dry ham related to their nutritional implications', *Food Chemistry*, 101: 107–12.

Food and Agriculture Organization of the United Nations (FAO). (2021) *The Nutrition and Health Potential of Geographical Indication Foods*. Rome. DOI: 10.4060/cb3913en

Fortuna G. (2021) 'Nutri-Score food labelling plan is not panacea, EU official says'. *EURACTIV*. https://www.euractiv.com/section/agriculture-food/news/nutri-score-food-labelling-plan-is-not-panacea-eu-official-says/, accessed 30 November 2022.

Fortuna G. (2022) 'Agrifood brief: Mediterranean (back)fire'. *EURACTIV*. https://www.euractiv.com/section/agriculture-food/news/agrifood-brief-mediterranean-backfire/, accessed 30 November 2022.

Fortuna G., Dahm J. and Foote N. (2022) 'Agrifood Brief: The last score that broke the label's back'. *EURACTIV*. https://www.euractiv.com/section/agriculture-food/news/agrifood-brief-the-last-score-that-broke-the-labels-back/, accessed 30 November 2022.

Galli F., Prosperi P., Favilli E., D'Amico S., Bartolini F. and Brunori G. (2020) 'How can policy processes remove barriers to sustainable food systems in Europe? Contributing to a policy framework for agri-food transitions', *Food Policy*, 96: 101871.

Gangjee D. S. (2017) 'Proving provenance? geographical indications certification and its ambiguities', *World Development*, 98: 12–24.

Glogoveţan A. I., Dabija D. C., Fiore M. and Pocol C. B. (2022) 'Consumer perception and understanding of European Union Quality Schemes: a systematic literature review', *Sustainability*, 14: 1–16.

Gocci A. and Luetge C. (2020) 'The synergy of tradition and innovation leading to sustainable geographical indication products: a literature review', *Journal of Management and Sustainability*, 10: 152.

Grunert K. G. and Aachmann K. (2016) 'Consumer reactions to the use of EU quality labels on food products: a review of the literature', *Food Control*, 59: 178–87.

Hagmann D. and Siegrist M. (2020) 'Nutri-score, multiple traffic light and incomplete nutrition labelling on food packages: effects on consumers' accuracy in identifying healthier snack options', *Food Quality and Preference*, 83: 103894.

Huysmans M. and van Noord D. (2021) *The market for lemons from Sorrento and Gouda from Holland: Do geographical indications certify origin and quality?* U.S.E. Working Paper Series No. 21-08. https://www.uu.nl/sites/default/files/REBO-USE-WP 21-08.pdf, accessed 8 August 2022.

Huysmans M. and Swinnen J. (2019) 'No terroir in the cold? A note on the geography of geographical indications', *Journal of Agricultural Economics*, 70: 550–9.

INAO. (2022) 'Label Rouge (Red Label)'. https://www.inao.gouv.fr/eng/Official-signs-identifying-quality-and-origin/Label-Rouge-Red-Label, accessed 28 July 2022.

Jones G. and Richardson M. (2007) 'An objective examination of consumer perception of nutrition information based on healthiness ratings and eye movements', *Public Health Nutrition*, 10: 238–44

Julia C. and Hercberg S. (2017) 'Development of a new front-of-pack nutrition label in France: The five-colour Nutri-Score', *Public Health Panorama*, 3: 712–25.

Julia C., Baudry J., Fialon M., Hercberg S., Galan P., Srour B., Andreeva V. A., Touvier M. and Kesse-Guyot E. (2023) 'Respective contribution of ultra-processing and nutritional quality of foods to the overall diet quality: results from the NutriNet-Santé Study', *European Journal of Nutrition*. 62, 157–64.

Menapace L. and Moschini G. C. (2014) 'Strength of protection for geographical indications: promotion incentives and welfare effects', *American Journal of Agricultural Economics*, 96: 1030–48.

Ministère de la Santé et de la Prévention (MSP). (2022) 'Gouvernance transnationale du Nutri-score : les 7 pays engagés adoptent un algorithme amélioré pour les aliments'. https://solidarites-sante.gouv.fr/actualites/presse/communiques-de-presse/article/gouvernance-transnationale-du-nutri-score-les-7-pays-engages-adoptent-un?utm_source=POLITICO.EU&utm_campaign=f9941d3f09-EMAIL_CAMPAIGN_2022_08_01_05_00&utm_medium=email&utm_, accessed 8 August 2022.

Monteiro C. A., Cannon G., Moubarac J., Levy R. B., Louzada M. L. C. and Jaime P. C. (2018) 'The UN decade of nutrition, the NOVA Food Classification and the Trouble with Ultra-processing', *Public Health Nutrition*, 21: 5–17.

Monteiro C. A., Cannon G., Levy R. B., Moubarac J., Louzada M. L. C., Rauber F., Khandpur N., Cediel G., Neri D., Martinez-Steele E., Baraldi L. G. and Jaime P. C. (2019) 'Ultra-processed foods: What they are and how to identify them', *Public Health Nutrition*, 22: 936–41.

Monteiro C. A. and Cannon G. (2022) 'The trouble with ultra-processed foods', *BMJ*, 378: o1972 DOI:

Nohlen H. U., Bakogianni I., Grammatikaki E., Ciriolo E., Pantazi M., Dias J., Salesse F., Moz Christofoletti M. A., Wollgast J., Bruns H., Dessart F., Marandola G. and van Bavel R. (2022) *Front-of-Pack Nutrition Labelling Schemes: An Update of the Evidence*. Publications Office of the European Union, Luxembourg. DOI: 10.2760/932354

Open Food Facts (OFF). (2021) 'Open Food Facts'. https://world.openfoodfacts.org/, accessed 30 November 2021.

Osgood I. and Feng Y. (2018) 'Intellectual property provisions and support for US trade agreements', *The Review of International Organizations*, 13: 421–55.

Partidário A. M., Ribeiro J. C. S. and Prates J. A. M. (2008) 'Fatty acid composition and nutritional value of fat in three PDO Ewe's Milk Portuguese Cheeses', *Dairy Science and Technology*, 88: 683–94.

Quiñones Ruiz F. X., Forster H., Penker M., Belletti G., Marescotti A., Scaramuzzi S., Broscha K., Braito M. and Altenbuchner C. (2018) 'How are food geographical indications evolving?—An analysis of EU GI amendments', *British Food Journal*, 120: 1876–87.

Rewe. (2022) 'Nutri-Score'. https://www.rewe.de/ernaehrung/nutri-score/, accessed 28 July 2022.

Román S., Sánchez-Siles L. M. and Siegrist M. (2017) 'The importance of food naturalness for consumers: results of a systematic review', *Trends in Food Science & Technology*, 67: 44–57.

Roquefort. (2022) 'Roquefortsansnutriscore'. https://www.roquefort.fr/nutri-score/, accessed 28 July 2022.

Sanchez-siles L. M., Michel F., Román S., Jose M., Philipsen B., Haro J. F., Bodenstab S. and Siegrist M. (2019) 'The Food Naturalness Index (FNI): An integrative tool to measure the degree of food naturalness', *Trends in Food Science & Technology*, 91: 681–90.

San Daniele. (2022) 'San Daniele is healthy'. https://prosciuttosandaniele.it/en/the-ham/san-daniele-is-healthy/, accessed 28 July 2022.

Sarda B., Julia C., Serry A. J. and Ducrot P. (2020) 'Appropriation of the front-of-pack nutrition label nutri-score across the French population: evolution of awareness, support, and purchasing behaviors between 2018 and 2019', *Nutrients*, 12: 1–12.

Sogari G., Pucci T., Caputo V. and Van Loo E. J. (2023) 'The Theory of Planned Behaviour and Healthy Diet: Examining the Mediating Effect of Traditional Food', *Food Quality and Preference*, 104: 104709.

The European Consumer Organisation (BEUC). (2019) 'Five Nutri-Score myths busted'. https://www.beuc.eu/factsheets/five-nutri-score-myths-busted, accessed 27 July 2022.

Thøgersen J. and Nohlen H. U. (2022) *Consumer Understanding of Origin Labeling on Food Packaging and Its Impact on Consumer Product Evaluation and Choices: A Systematic Literature Review.* Ciriolo, E (ed.). Publications Office of the European Union: Luxembourg. DOI: 10.2760/336778

Török Á. and Jambor A. (2016) 'Determinants of the revealed comparative advantages: the case of the European Ham Trade', *Agricultural Economics (Zemědělská ekonomika)*, 62: 471–82.

Török Á., Jantyik L., Maró Z. M. and Moir H. V. J. (2020) 'Understanding the real-world impact of geographical indications: a critical review of the empirical economic literature', *Sustainability*, 12: 9434.

Tremmel M., Gerdtham U., Nilsson P. M. and Saha S. (2017) 'Economic burden of obesity: a systematic literature review', *International Journal of Environmental Research and Public Health*, 14: 435.

Turck D., Bohn T., Castenmiller J., de Henauw S., Hirsch-Ernst K. I., Knutsen H. K., Maciuk A., Mangelsdorf I., McArdle H. J., Naska A., Peláez C., Pentieva K., Thies F., Tsabouri S., Vinceti M., Bresson J.-L. and Siani A. (2022) 'Scientific advice related to nutrient profiling for the development of harmonised mandatory Front-of-Pack nutrition labelling and the setting of nutrient profiles for restricting nutrition and health claims on foods', *EFSA Journal*, 20: 7259.

Vanhonacker F., Verbeke W., Guerrero L., Claret A., Contel M., Scalvedi L., Żakowska-Biemans S., Gutkowska K., Sulmont-Rossé C., Raude J., Granli B. S. and Hersleth M. (2010) 'How European consumers define the concept of traditional food: evidence from a survey in six countries', *Agribusiness*, 26: 453–76.

Vandecandelaere E., Samper L. F., Rey A., Daza A., Mejía P., Tartanac F. and Vittori M. (2021) 'The geographical indication pathway to sustainability: a framework to assess and monitor the contributions of geographical indications to sustainability through a participatory process', *Sustainability*, 13: 1–20.

WHO. (2021) 'Nutri-Score: Harmonized and mandatory front-of-pack nutrition label urgently needed at the European Union level and beyond'. https://www.iarc.who.int/news-events/nutri-score/, accessed 16 August 2022.

Willett W., Rockström J., Loken B., Springmann M., Lang T., Vermeulen S., Garnett T., Tilman D., DeClerck F., Wood A., Jonell M., Clark M., Gordon L. J., Fanzo J., Hawkes C., Zurayk R., Rivera J. A., De Vries W., Majele Sibanda L., Afshin A., Chaudhary A., Herrero M., Augustina R., Branca F., Lartey A., Fan S., Crona B., Fox E., Bignet V., Troell M., Lindhal T., Singh Sudhvir, Cornell S. E., Reddy S. K., Narain S., Nishtar S. and Murray C. J. L. (2019) 'Food in the Anthropocene: The EAT—Lancet Commission on healthy diets from sustainable food systems', *The Lancet*, 393: 447–92.

Wirth D. A. (2016) 'Geographical indications, food safety, and sustainability: conflicts and synergies', *Bio-based and Applied Economics*, 5: 135–51.

Zago A. M. and Pick D. (2004) 'Labeling policies in food markets: private incentives, public intervention, and welfare effects', *Journal of Agricultural and Resource Economics*, 29: 150–65.