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Review

Protected Designation of Origin (PDO), Protected Geographical Indication (PGI) and Traditional Speciality Guaranteed (TSG): A bibiliometric analysis

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ABSTRACT

Despite the importance of the literature on food quality labels in the European Union (PDO, PGI and TSG), our search did not find any review joining the various research topics on this subject. This study aims therefore to consolidate the state of academic research in this field, and so the methodological option was to elaborate a bibliometric analysis resorting to the term co-occurrence technique. Analysis was made of 501 articles on the *ISI Web of Science* database, covering publications up to 2016. The results of the bibliometric analysis allowed identification of four clusters: "Protected Geographical Indication", "Certification of Olive Oil and Cultivars", "Certification of Cheese and Milk" and "Certification and Chemical Composition". Unlike the other clusters, where the PDO label predominates, the "Protected Geographical Indication" cluster covers the study of PGI products, highlighting analysis of consumer behaviour in relation to this type of product. The focus of studies in the "Certification of Olive Oil and Cultivars" cluster and the "Certification of Cheese and Milk" cluster is the development of authentication methods for certified traditional products. In the "Certification and Chemical Composition" cluster, standing out is analysis of the profiles of fatty acids present in this type of product.

1. Introduction

As part of its food quality policy, the European Union (EU) promotes three types of quality labels for agricultural products and foodstuffs: Protected Designation of Origin (PDO), Protected Geographical Indication (PGI) and Traditional Speciality Guaranteed (TSG) (European Commission, 2013). PDO covers agricultural products or foodstuffs that are produced, processed and prepared in a specific geographical area, using recognized know-how. PGI covers agricultural products or foodstuffs closely linked to a geographical area; at least one of the stages of production, processing or preparation occurs in that area, while the raw material used in production can come from another region. Finally, TSG covers agricultural products and foodstuffs that are produced using traditional raw material or traditional production methods, or that have a traditional composition, with no restriction as to the product's geographical origin.

The PDO, PGI and TSG schemes were introduced, not only as a way to support consumers' decisions, but also as a mean of food control (Grunert & Aachmann, 2016; Hajdukiewicz, 2014). European producers are aware of these schemes and consumers are showing renewed interest in traditional food (Almli, Verbeke, Vanhonacker, Næs, & Hersleth, 2011; Grunert & Aachmann, 2016; Guerrero et al., 2010). On one hand, agricultural producers in the EU are increasingly interested in using geographical indications to differentiate their products in international markets, and thereby improve their competitiveness and profitability. On the other, consumers' growing interest in quality and traditional products creates a demand for agricultural products and foodstuffs with specific, identifiable characteristics, particularly those that are linked to their geographical origin and their production method (Hajdukiewicz, 2014).

In 1992, the first European legislation for agricultural products and foodstuffs was adopted, covering PGI and PDO labels. Those legislation was inspired on existing national systems, such as the French AOC (*Appellation d'Origine Contrôlée*) and Italian DOC (*Denominazione d'Origine Controllata*) (European Commission, 2011). The French AOC system is closely linked to the concept of *terroir*, since a *terroir* product is characterised by a specific geographical origin, developed over a long period of interaction with local traditions, the local environment and know-how (Barham, 2003; Hajdukiewicz, 2014). These factors are considered in applying PDO/PGI schemes (Hegnes, 2012).

In 2006, Regulation (EU) N° 509/2006 was adopted, creating a regulatory framework of the TSG label for agricultural products and

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foodstuffs. The latest regulation on agro-food quality certification schemes came into force on 3 January 2013 – Regulation (EU) N° 1151/2012. Applications to use any of those schemes are generally managed by a group of producers, through the national food authority's communication with the European Commission. The Commission analyses applications, in order to guarantee the right to use the respective label. However, Regulation (EU) N° 1151/2012 is not applied to wine products, except for wine vinegar, since those products require specific control rules, according to Regulation (CE) N° 1234/2007. Wine products can benefit from the PDO and PGI labels but not from TSG.

It is of note that currently producers from countries outside the EU can join EU quality certification systems, according to the *World Trade Organization's* rules on international commerce. Since 2006, applications for registration of PDO, PGI and TSG labels by producers in other countries, and objections in relation to applications made individually in other countries, can be made directly to the European Commission. However, the number of international registrations is very low (Hajdukiewicz, 2014).

There is a need to protect high quality products with geographical indications and designations of origin from possible commercial fraud, since such products are related to higher retail price and bring in higher financial benefits to producers in comparison with other similar products (Danezis, Tsagkaris, Brusic, & Georgiou, 2016). Methods for testing authenticity and providing analytical data on traceability require robust analytical techniques that can be used by the various regulatory authorities (Camin et al., 2017). So, it is not surprising that studies about food authentication cover more and more certified traditional products such as cheese (Fontenele, Bastos, dos Santos, Bemquerer, & do Egito, 2017), wine vinegars (Paneque, Morales, Burgos, Ponce, & Callejón, 2017; Ríos-Reina et al., 2017), vegetables (Drivelos, Danezis, Haroutounian, & Georgiou, 2016; Mir-Marqués, Elvira-Sáez, Cervera, Garrigues, & de la Guardia, 2016), meat (Mateus & Russo-Almeida, 2015), lard (Chiesa et al., 2016) or saffron (Cagliani, Culeddu, Chessa, & Consonni, 2015).

Food authentication aims to identify unique markers or groups of markers to characterise the authenticity of food or their potential adulterants/contaminants and use them to resolve authenticity problems (Guerreiro, Barros, Fernandes, Pires, & Bardsley, 2013). The studies about markers of authenticity of high-value added products, such PDO cheeses, analyse important topics like the evaluation of the proteolytic profiles in terms of ripening time and milk admixtures (Guerreiro et al., 2013), or the determination of biochemical, volatile and textural profiles during manufacture and ripening (Bertolino, Dolci, Giordano, Rolle, & Zeppa, 2011). Thus, reliability of food authenticity markers and the evaluation of factors that affect them are crucial to ensure the right decision about a product authenticity or an adulteration.

Despite the importance of PDO, PGI and TSG schemes and the various issues related to those, literature reviews on the subject are lacking (Grunert & Aachmann, 2016). The few existing reviews are about specific topics such as consumer reactions to the use of this type of scheme (Grunert & Aachmann, 2016), the economic perspective (Hajdukiewicz, 2014) or food authentication (Danezis et al., 2016). Considering the continuing lack of a more generic and aggregating review of various research topics on this subject, our aim here is to make a bibliometric analysis of the PDO, PGI and TSG schemes, in order to understand the state of academic research in this field. The analysis will consider articles on the *ISI Web of Science* database, covering publications up to 2016.

This study is structured in various sections. After analysis of statistical data and description of the methodology used, we examine 501 articles included on the *ISI Web of Science* database, considering publication in all areas of research. This is followed by the descriptive analysis of the results and analysis of the main thematic areas, resorting to the bibliometric technique of term co-occurrence. In the last part, after summarizing the main aspects dealt with in this study, we indicate limitations and future lines of research.

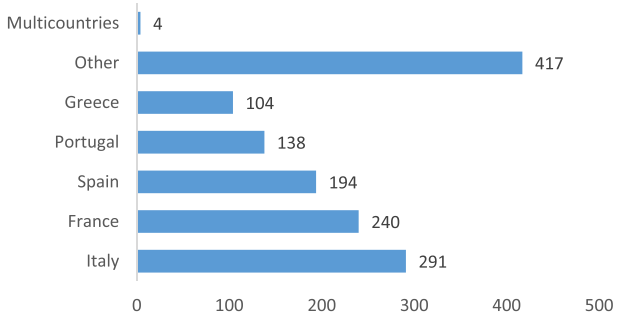

Fig. 1. N° Registrations per country (DOOR Database, 2017).

2. Statistical data

According to DOOR database (2017), Southern European countries present the greatest number of PDO, PGI and TSG registrations. Italy and France stand out, having a long tradition of protecting and promoting products nationally, followed by Spain, Portugal and Greece (Fig. 1). PGI is the principal certification scheme, followed by PDO and TSG, although the last named has a low number of registrations (Fig. 2). “Fruit, vegetables and cereals”, and “cheeses”, are the product types with most registrations, although “meat products”, “fresh meat”, and “oils and fats” are also important (Fig. 3).

Regarding wine, Fig. 4 reveals that PDO wines (1291) predominate over PGI wines (459) in the European Union (*E*-BACCHUS, 2017).

3. Methodology

3.1. Data collection

Our research took place in June 2017 and focused on articles on *ISI Web of Science*, including articles up to 2016. In a first phase, documents using in the title, abstract or key words (Topic) one of the following terms: “Protected Designation of Origin”, “Protected Geographical Indication” or “Traditional Speciality Guaranteed” were selected. This search resulted in an initial sample of 577 documents. The review was limited to peer-reviewed published articles, omitting books, book chapters and other non-validated publications, since articles can be considered as validated knowledge and probably have a greater impact in the field (Keupp, Palmié, & Gassmann, 2012). After selection of “Article” and “Review” documents, 527 articles were obtained. Only articles in English were considered, since the spread of scientific knowledge occurs fundamentally through this language, and so the final number of articles obtained was 501.

3.2. Term co-occurrence

After identifying the articles, the bibliometric technique of term co-occurrence will be used. Our unit of analysis is the article, while the

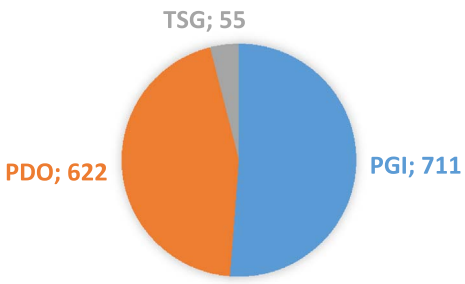

Fig. 2. N° Registrations per certification scheme (DOOR Database, 2017).

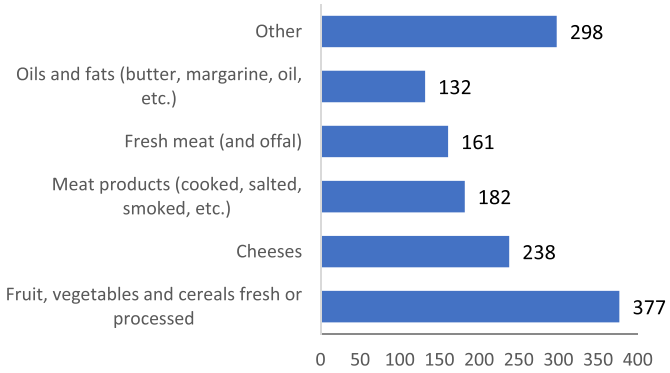

Fig. 3. N° Registrations, by product category (DOOR Database, 2017).

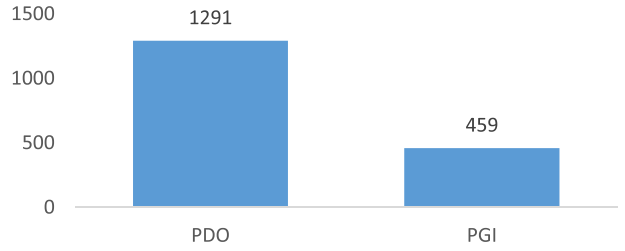

Fig. 4. Registration of PDO and PGI wines in the European Union (*E*-Bacchus, 2017).

variables correspond to the terms included in the titles and abstracts of the 501 articles. Terms were extracted using the VOSViewer program (van Eck & Waltman, 2011), with final production of the respective map with the relationships among the various terms and their association in thematic clusters. With this technique, the distance between two terms is analysed, where a term is understood as a sequence of names in text documents (van Eck & Waltman, 2011). Generally, the stronger the relationship between two terms, the shorter the distance between the terms on the map. Colours indicate the grouping of terms in thematic clusters, with terms in the same colour belonging to the same cluster and tending to be more closely related than terms in different colours. Therefore, terms in the same colour tend to co-occur more frequently than terms in different colours.

The binary counting method was chosen, so that the number of co-occurrences of a term in a single document is not taken into consideration, only identifying the presence or absence of that term in the document. Choosing this method, 13,138 terms were identified. After defining 15 as the minimum number of occurrences, we obtained 143 terms. Of these 143 terms, VOSViewer calculated 60% (value automatically defined by the program) of the most relevant terms, i.e., 86 terms. Finally, we removed the irrelevant terms (Table 1), which left us with 44 terms.

Table 1
List of the 42 irrelevant terms omitted from the bibliometric analysis.

Terms		
Ability	Determination	Month
Amount	Development	Occurrence
Case	Discrimination	Paper
Change	Effect	Place
Chemical	End	Presence
Classification	European Union	Purpose
Combination	Finding	Ratio
Composition	First time	Role
Compound	Food	Season
Concentration	Food product	Significant difference
Content	Impact	Specificity
Country	Importance	Technique
Day	Interest	Variable
Detection	Model	Variation

4. Analysis of results

4.1. Descriptive analysis

In the sample of 501 articles on PDO, PGI and TSG, the first article was published in 1999 (Mannu et al., 1999) and falls into the area of microbiology. This is a topic with a growing number of articles published in recent years, with 83 articles published in 2016. As may be observed in Fig. 5, the PDO label stands out in comparison to PGI and TSG labels. Moreover, Fig. 5 also enhance that TSG is clearly the most understudied issue. Regarding journals, these are led by “Food Chemistry”, although publications connected to analysis of products with an animal origin also stand out, such as the “Journal of Dairy Science” (Table 2).

Southern European countries are simultaneously those with the greatest number of registrations in these certification schemes and those with the greatest number of published articles, particularly Italy, Spain and Portugal (Fig. 6). Italian universities are the organisations producing most research in this area, led by the University of Bari, and although Spanish universities and the INRA (*Institut National de la Recherche Agronomique*) in France also feature in the top 10 organisations with most articles published (Table 3).

The authors with most work on the topic are J. A. Pereira (*Escola Superior Agrária de Bragança*, Portugal) and M. F. Scintu (*AGRIS Sardegna*, Italy), with 10 articles each (Table 4), with J. A. Pereira being the only Portuguese representative in the top 10 authors. This author is also responsible for the study (Pereira et al., 2006) with the greatest number of quotations (100) and co-author of the second most quoted study (Matos et al., 2007) with 85 quotations (Table 5). Both studies focus on analysis of products associated with olive-growing in Portugal, namely table olives and olive oil.

In the top 10 most cited articles, PDO is the only certification label analysed. Concerning methodology, only one article is conceptual (Gonzalvez, Armenta, & de la Guardia, 2009) and the remainder are empirical studies. In this set of nine empirical studies, olive oil is the most common product (Casal, Malheiro, Sendas, Oliveira, & Pereira, 2010; Matos et al., 2007; Rastrelli, Totaro, & De Simone, 2002), also highlighting products such as cheese (Brescia, Monfreda, Buccolieri, & Carrino, 2005; Mallia, Fernández-García, & Olivier Bosset, 2005) and chestnuts (Borges, Gonçalves, de Carvalho, Correia, & Silva, 2008; Borges, Soeiro Carvalho, Reis Correia, & Paula Silva, 2007) with 2 articles each. Southern European countries are analysed most, led by Portugal with five studies (Borges et al., 2008; Casal et al., 2010; Matos et al., 2007; Pereira et al., 2006), while the work by Mallia et al. (2005) is the only one to examine products from various countries. It is of note that six of the ten most quoted articles were published in the last decade (2007–2016), demonstrating the dynamic, non-static character of the literature on PDO, PGI and TSG.

In Table 6, we can observe the top 10 areas of research in the literature on PDO, PGI and TSG, as well as the most cited study in each area. The main area of research is “Food, Science & Technology”, with more than 300 articles, followed by “Agriculture” and “Chemistry”. In these three research areas, the study by Pereira et al. (2006) is the most quoted, since it addresses a topic transversal to those three areas. All the most quoted studies in each of the 10 research areas are empirical and deal with the PDO label, with Portugal standing out as the most studied country (Cunha, Fernandes, & Oliveira, 2006; Matos et al., 2007; Pereira et al., 2006). In terms of products, cheese is most analysed (Alegría, Szczesny, Mayo, Bardowski, & Kowalczyk, 2012; Bonnet & Simioni, 2001; Hurtaud, Peyraud, Michel, Berthelot, & Delaby, 2009).

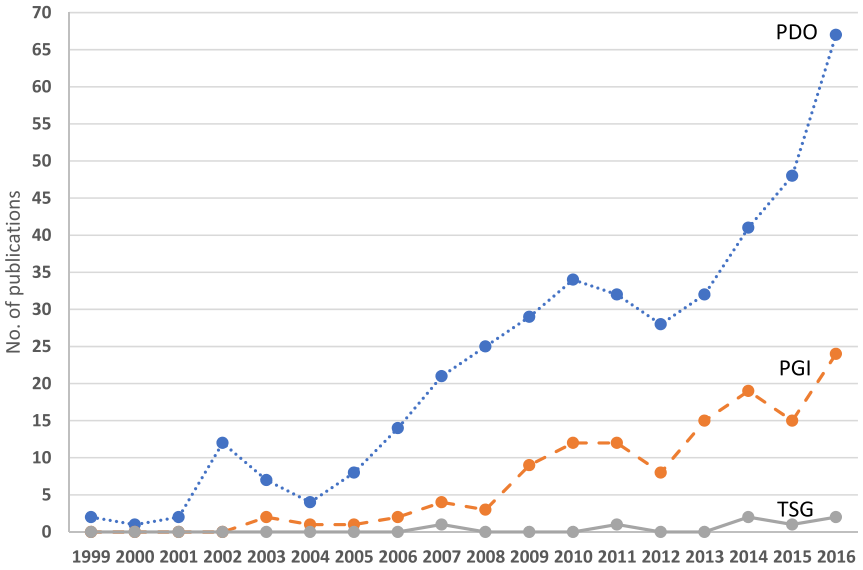

Fig. 5. Evolution of the n° of articles published per year, by label.

Table 2
Top-12 publications.

Publication	N°
Food Chemistry	43
Journal of Dairy Science	20
Journal of Agricultural and Food Chemistry	19
International Dairy Journal	16
Journal of the Science of Food and Agriculture	16
Small Ruminant Research	15
Italian Journal of Food Science	14
Spanish Journal of Agricultural Research	12
British Food Journal	10
Food Control	10
Food Research International	10
Meat Science	10
Other	306
TOTAL	501

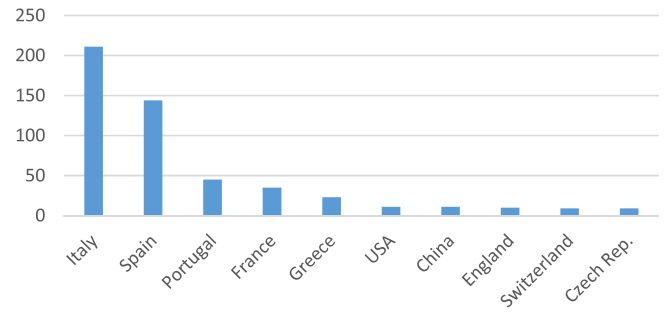

Fig. 6. Top 10 countries with most articles published.

Table 3
Top 10 Organisations with most articles published.

Organisations	Country	N°
University of Bari	Italy	17
University of Milan	Italy	15
University of Bologna	Italy	15
University of Cordoba	Spain	14
University of Zaragoza	Spain	13
CNR	Italy	13
University of Parma	Italy	12
University of Naples Federico II	Italy	12
University of Extremadura	Spain	12
INRA	France	12

Table 4
Top 10 authors with most articles published.

Authors	Country	N°
J. A. Pereira	Portugal	10
M. F. Scintu	Italy	10
M. De la Guardia	Spain	9
L. Xu	China	7
M. Faccia	Italy	6
F. J. P. Elortondo	Spain	6
P. A. Casquero	Italy	6
G. Bittante	Spain	6
M. Albisu	Spain	6
M. Addis	Italy	6

4.2. Thematic analysis

In order to analyse the main thematic streams in the literature on PDO, PGI and TSG, we used the bibliometric technique of co-occurrence of terms included in the titles and abstracts of the 501 articles. The 44 most relevant terms in the literature were extracted using the VOSViewer program, with final production of the respective map with the relationships between the various terms and their association in thematic clusters. Here, four thematic areas were identified in the literature on PDO, PGI and TSG: "Protected Geographical Indication" (cluster 1), "Certification of Olive Oil and Cultivars" (cluster 2), "Certification of Cheese and Milk" (cluster 3) and "Certification and Chemical Composition" (cluster 4) (Fig. 7).

4.2.1. Protected Geographical Indication

In the cluster designated "Protected Geographical Indication", the area arousing greatest interest in the scientific community is the relationship between the consumer and PGI, whereas analysis of PGI meat products is of little relevance.

Table 7 presents the 10 most quoted studies dealing with the PGI-Consumer relationship. The main area of research is "Food, Science & Technology". All the studies use empirical methodology, with Spanish PGI products such as beef (Bardají, Iráizoz, & Rapún, 2009; Sierra et al., 2010) or lamb meat (Sepúlveda, Maza, & Mantecón, 2010) standing out. In addition, fruit and vegetables are also prominent, particularly melons in Spain (Escribano & Lázaro, 2009), chestnuts in Italy (Mangiacotti et al., 2009) and lentils in Greece (Bosmali, Ganopoulos,

Table 5
Top 10 most quoted studies.

Study	Citations	Methodology	Certification	Product	Country
Pereira et al. (2006). Table olives from Portugal: Phenolic compounds, antioxidant potential, and antimicrobial activity. *Journal of Agricultural and Food Chemistry*. 54 (22), 8425–8431	100	Empirical	PDO	Table olives	Portugal
Matos et al. (2007). Chemometric characterization of three varietal olive oils (Cvs. Cobrancosa, Madural and Verdeal Transmontana) extracted from olives with different maturation indices. *Food Chemistry*. 102 (1), 406–414	85	Empirical	PDO	Olive oil	Portugal
Gonzalvez et al. (2009). Trace-element composition and stable-isotope ratio for discrimination of foods with Protected Designation of Origin. *Trac-Trends In Analytical Chemistry*. 28 (11), 1295–1311	76	Conceptual	PDO		
Gonzalvez et al. (2009). Elemental fingerprint of wines from the protected designation of origin Valencia. *Food Chemistry*. 112 (1), 26–34	73	Empirical	PDO	Wine	Spain
Casal et al. (2010). Olive oil stability under deep-frying conditions. *Food And Chemical Toxicology*. 48 (10), 2972–2979	72	Empirical	PDO	Olive oil	Portugal
Borges et al. (2007). Lipid and fatty acid profiles of *Castanea sativa* Mill. Chestnuts of 17 native Portuguese cultivars. *Journal Of Food Composition And Analysis*. 20 (2), 80–89	66	Empirical	PDO	Chestnut	Portugal
Brescia et al. (2005). Characterisation of the geographical origin of buffalo milk and mozzarella cheese by means of analytical and spectroscopic determinations. *Food Chemistry*. 89 (1), 139–147	66	Empirical	PDO	Milk and cheese	Italy
Borges et al. (2008). Nutritional quality of chestnut (*Castanea sativa* Mill.) cultivars from Portugal. *Food Chemistry*. 106 (3), 976–984	65	Empirical	PDO	Chestnut	Portugal
Mallia et al. (2005). Comparison of purge and trap and solid phase microextraction techniques for studying the volatile aroma compounds of three European PDO hard cheeses. *International Dairy Journal*. 15 (6–9), 741–758	65	Empirical	PDO	Cheese	Spain, Italy and Switzerland
Rastrelli et al. (2002). Determination of organophosphorus pesticide residues in Cilento (Campania, Italy) virgin olive oil by capillary gas chromatography. *Food Chemistry*. 79 (3), 303–305	65	Empirical	PDO	Olive oil	Italy

Madesis, & Tsaftaris, 2012).The most cited study (Aprile, Caputo, & Nayga, 2012) concludes that consumers are willing to pay more for PDO products, followed by organic farming label and only after for PGI label. Comparing products with and without PGI, Profeta, Balling, and Roosen (2012) also conclude that consumers are willing to pay more for PGI products, although it is generally women who are more interested in those products (Supeková, Honza, & Kačenová, 2008). In order to increase consumer confidence in PGI products, Bosmali et al. (2012) and Prins et al. (2010) develop methods based on DNA to facilitate identification of such products. In addition, the importance consumers give to "origin" as a quality attribute is one of the main motives for retailers deciding to sell PGI products (Bardají et al., 2009).

As for the 10 most quoted studies based on PGI meat products, the majority belong to the research area of "Food, Science & Technology" (Table 8). The study by Berzaghi and Riovanto (2009) is the only conceptual article and analyses the principles and applications of infrared spectroscopy in animal science. Regarding empirical studies, Spain is the most studied country, highlighting PGI lamb, particularly PGI "Lechazo de Castille y Leon" (Miguélez et al., 2008; Miguélez, Zumalacárregui, Osorio, Beteta, & Mateo, 2006). Most of these studies focus on the specificities of physicochemical, nutritional or sensory properties of PGI products.

This cluster also includes studies on the relationship between PGI wines and sensory profile, as well as questions connected to PGI as a way to protect traditional food products.

Table 9 describes some future lines of research in this cluster. Following up previous work, it is still important to develop models to verify the authenticity of PGI products, so as to detect potential fraud that harms products' image in the perspective of consumers (Amenta, Fabroni, Costa, & Rapisarda, 2016). Another line of future research is to compare consumers' willingness to buy PGI/PDO products in urban and rural areas (Likoudis, Sdrali, Costarelli, & Apostolopoulos, 2016). The conception of new marketing strategies for PGI/PDO, associated with various communication media, is also a research area for the future (Luceri, Latusi, & Zerbini, 2016).

4.2.2. *Certification of Olive Oil and Cultivars*

In the thematic cluster designated "Certification of Olive Oil and Cultivars", the area most explored by researchers is the relationship between olive oil and cultivars, while the area least dealt with is the relationship between fruit and cultivars.

In the 10 most cited studies addressing the relationship between olive oil and cultivars, the main area of research is "Food, Science & Technology" (Table 10). All the studies are empirical and deal with the PDO scheme. The majority focus on studying the authentication of PDO olive oils or the olive cultivars used in their production. Southern European countries are most analysed, particularly Italy and Portugal, but no study examines the differences between different countries. In addition, most of these studies do not analyse only one but various PDO olive oils and various cultivars used in their production. Regarding the works done on only one olive oil or one cultivar, the Portuguese olive oil of "PDO Trás-Os-Montes" (Casal et al., 2010; Matos et al., 2007) stands out, as well as the Italian cultivar "Ogliarola" (Pasqualone et al., 2007) and the Spanish cultivar "Cornicabra" (Inarejos-García, Santacatterina, Salvador, Fregapane, & Gómez-Alonso, 2010). However, Tura, Failla, Bassi, Pedò, and Serraiocco (2008) conclude that geographical origin may not be enough to stimulate consumption of a PDO product, if the sensory or nutritional attributes are not also differentiated.

Concerning the 10 most cited studies on the relationship between fruit and cultivars, the main areas of research are "Food, Science & Technology" and "Chemistry" (Table 11).

All the studies are empirical and focus on the PDO scheme. The subject of study in this research is the specificities of the cultivars of various fruits. Portugal is the country most analysed, particularly

Table 6
Top 10 areas of research.

N° Articles	Area of research	Most cited study	Citations	Methodology	Certification	Product	Country
313	Food, Science, Technology	Pereira et al. (2006)	100	Empirical	PDO	Table olives	Portugal
160	Agriculture	Pereira et al. (2006)	100	Empirical	PDO	Table olives	Portugal
135	Chemistry	Pereira et al. (2006)	100	Empirical	PDO	Table olives	Portugal
59	Nutrition Dietetics	Matos et al. (2007)	85	Empirical	PDO	Olive oil	Portugal
24	Biotechnology, Applied Microbiology	Alegría et al. (2012)	55	Empirical	PDO	Cheese	Poland
22	Business Economics	Bonnet and Simioni (2001)	55	Empirical	PDO	Cheese	France
20	Microbiology	Alegría et al. (2012)	55	Empirical	PDO	Cheese	Poland
18	Biochemistry, Molecular Biology	Cunha et al. (2006)	64	Empirical	PDO	Olive oil	Portugal
12	Environmental Sciences, Ecology	Lindkvist & Sánchez (2008)	18	Empirical	PDO	Salted fish and wine	Norway and Spain
11	Veterinary Sciences	Hurtaud et al. (2009)	11	Empirical	PDO	Cheese	France

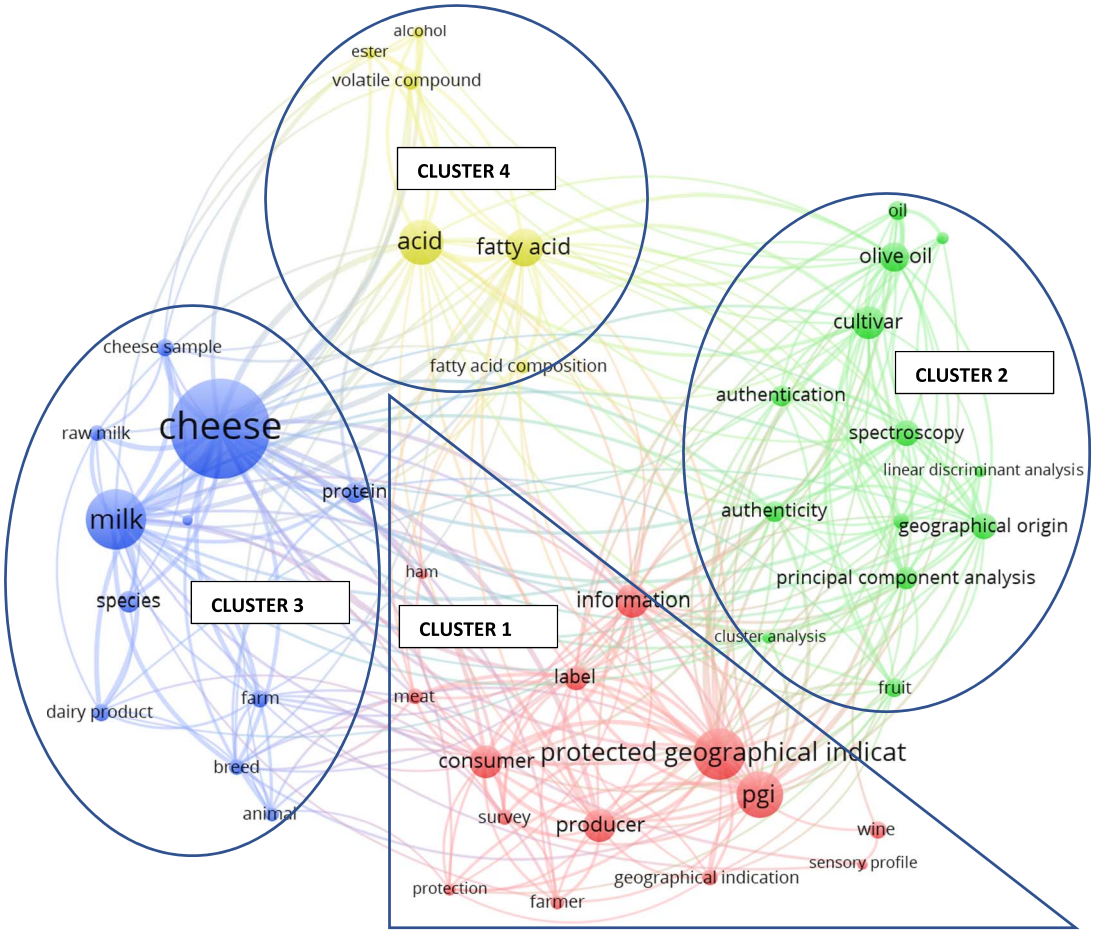

Fig. 7. Networks of term co-occurrence.

studies on chestnuts and olives. Except for the study by Ramos and Santos (2010), which analyses only the Portuguese olive cultivar "Cordovil", the majority deal with various cultivars. Since the EU has approved registration in recent years of various PDO and PGI products from countries outside the EU, particularly China, the work by Guo, Yue, Yuan, and Wang (2013) stands out, analysing various Chinese apple cultivars for juice. Apart from studies on chestnuts and peaches, all the other fruits analysed are subject to some form of agro-industrial processing, resulting in products such as olive oil, table olives and apple juice. Only the work by Ramos and Santos (2010) relates the type of orchard management, namely irrigation systems, to the quantity and quality of a PDO product.

In this cluster, besides the importance given to authentication of products of certified geographical origin, the use of various statistical methods is of note, such as cluster analysis, principal component analysis and linear discriminant analysis.

Table 12 presents some future lines of research suggested by recent studies. It is still important to study the authenticity of cultivars, despite the greater value attributed nowadays to fruit or vegetables that are not subject to any type of agro-industrial processing, such as fava beans (Drivelos et al., 2016), figs (Ganopoulos et al., 2015) or hazelnuts (Moscetti, Radicetti, Monarca, Cecchini, & Massantini, 2015).

4.2.3. Certification of Cheese and Milk

In the "Certification of Cheese and Milk" cluster, it is the relationship between cheese and milk that arouses most research interest, while the relationship between cheese and animal production is the theme dealt with least.

In the studies most cited focusing on the relationship between cheese and milk, the most important research area is "Food,

Table 7
Top 10 most quoted studies on the Consumer-PGI relationship.

Authors	Citations	Área of research	Methodology	Country	Product	Contribution
Aprile et al. (2012)	40	Business & Economics	Empirical	Italy	Olive oil	Consumers are willing to pay a higher premium price for a PDO product, followed by the organic farming label, a suggestion of quality describing the product as extra virgin oil and then by the PGI label.
Bosmali et al. (2012)	33	Food Science & Technology	Empirical	Greece	Lentils	As the correct identification of lentil varieties is important to ensure quality, safety, authenticity and health properties of food for consumers, High Resolution Melting (HRM) analysis is combined with DNA-based methods in order to facilitate identification of a PGI lentils variety.
Profeta et al. (2012)	17	Food Science & Technology	Empirical	Germany	Beer	Consumers are willing to pay more for a box of beer if the box is labelled with the designation of PGI beer.
Escribano and Lázaro (2009)	11	Agriculture; Plant Sciences	Empirical	Spain	Melon	Propose promoting the cultivation of high quality melon under PGI, in a traditional melon-producing region.
Sierra et al. (2010)	10	Food Science & Technology	Empirical	Spain	Beef	Analyses different biotypes of PGI beef, to determine whether the differences in physicochemical characteristics and tenderization pattern during maturation (3 to 21 days) had an effect on consumers' assessment.
Prins et al. (2010)	10	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	Italy	Spelt	Develops a method to establish the purity of the DNA of a PGI spelt in complex cereal mixtures, in order to increase consumer confidence in PGI products.
Sepúlveda et al. (2010)	8	Food Science & Technology	Empirical	Spain	Lamb meat	Identifies the factors most affecting the purchase of PGI lamb, analysing three groups of consumers characterised by their level of loyalty to the certification label.
Mangiacotti et al. (2009)	6	Chemistry; Nuclear Science & Technology; Physics	Empirical	Italy	Chestnut	Tests the efficacy of the European standard EN 13751, EN 1788, EN 1787 and EN 13708 in detecting irradiated chestnuts, through analysis of PGI chestnuts.
Bardají et al. (2009)	4	Agriculture; Business & Economics; Food Science & Technology	Empirical	Spain	Beef	The quality guarantee provided by PGI, the importance consumers give to “origin” as an attribute of quality, and the quality and conditions provided by the regular supplier, are the main factors motivating a retailer's decision to join the PGI beef supply chain.
Supeková et al. (2008)	4	Food Science & Technology	Empirical	Slovakia	Various	In general, women are more interested than men in food designated as PGI.

Table 8
Top 10 most cited studies dealing with PGI meat products.

Authors	Citations	Área of Research	Methodology	Country	Product	Designation	Contribution
Santos, González-Fernández, Jaime, & Rovira (2003)	34	Food Science & Technology	Empirical	Spain	Blood sausage	Morcilla de Burgos	Examines the physicochemical and sensory properties of a traditional product, in order to support claims for a PGI.
Miguélez et al. (2006)	22	Food Science & Technology	Empirical	Spain	Lamb	Lechazo de Castilla y Leon	Studies various carcass characteristics of PGI suckling lambs, analysing the effects of breed, sex and weight of the carcass.
Berzaghi and Riovanto (2009)	11	Agriculture; Veterinary Sciences	Conceptual				Analyses the principles and applications of near infrared spectroscopy in animal science, namely the distinction of PGI products from other non-traditional products.
Miguélez et al. (2008)	11	Agriculture	Empirical	Spain	Lamb	Lechazo de Castilla y Leon	Studies the quality of PGI suckling lamb and the effects of carcass weight, breed and sex on quality.
Sierra et al. (2010)	10	Food Science & Technology	Empirical	Spain	Beef	Ternera Asturiana	Analysis of different biotypes of PGI beef should be considered for suitable post-mortem management and commercialization of each product.
Sepúlveda et al. (2010)	8	Food Science & Technology	Empirical	Spain	Lamb	Various	Identifies the factors most affecting the purchase of PGI lamb in the main producing region in Spain.
Rinaldi, Chiavaro, Gozzi, & Massini (2011)	7	Food Science & Technology	Empirical	Italy	Sausage	Mortadella Bologna	Investigates the cooking process of PGI sausage for heat and mass transfer.
Ferranti et al., (2014)	6	Food Science & Technology	Empirical	Italy	Bresaola	Bresaola della Valtellina	Identifies bovine muscle derived proteins and peptides surviving digestion, considering the analysis of bresaolas with and without PGI.
Addis, Fiori, Manca, Riu, & Scintu (2013)	5	Agriculture	Empirical	Italy	Lamb	Agnello di Sardegna	Characterises the physicochemical and nutritional properties of PGI lamb.
Bardají et al. (2009)	4	Agriculture; Business & Economics; Food Science & Technology	Empirical	Spain	Beef	Various	Analyses retailers' behaviour in relation to the sale of PGI beef.

Table 9
Future lines of research in the "Protected Geographical Indication" cluster.

Authors	Área of research	Methodology	Country	Product	Contribution	Future lines of research
Amenta et al. (2016)	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	Italy	Lemon	Implements a traceability system to verify the authenticity of PGI lemon production, in order to detect potential fraud.	Proposes application of the classification model developed to more samples of lemons from other regions, so as to improve the model's robustness and precision.
Likoudis et al. (2016)	Business & Economics	Empirical	Greece	Diverse	The factors significantly associated with consumers' willingness to buy PDO / PGI are origin, health claims, a product's label, and sustainable consumer behaviour.	Future studies should include consumers not only from urban but also rural areas.
Luceri et al. (2016)	Food Science & Technology	Empirical	Italy	Diverse	Demonstrates the importance of highlighting the geographical area of PGI or PDO products (through textual or pictorial formats) in print advertisements.	More work is necessary, involving various communication media, for better understanding how the communication strategies of the region of origin influence the brand attitude and the intention to purchase PGI or PDO products.

Science & Technology" (Table 13). All the studies are empirical and the PDO scheme predominates, except for the work by Scintu and Piredda (2007) which deals with the PGI and PDO schemes. Standing out is the work on the authenticity of PDO cheeses based on determination of the geographical origin of the milk (Brescia et al., 2005; Sacco et al., 2009), and the work analysing the characteristics of PDO cheeses with different ripening stages (Alegría et al., 2012; Delgado, González-Crespo, Cava, García-Parra, & Ramírez, 2010). The study by Mallia et al. (2005) is the only one to analyse the differences between PDO cheeses from different countries but Italy is the country most studied, notably the "Mozzarella di Bufala Campana" cheese (Brescia et al., 2005; Sacco et al., 2009). Although this cheese is made of cow's milk, sheep's milk is more studied. Also standing out is the study by Gómez-Ruiz, Ballesteros, González Viñas, Cabezas, and Martínez-Castro (2002), which analyses the differences in the organoleptic properties of PDO cheeses, made from raw milk (artisanal cheese) or pasteurized milk (industrial cheese).

As for the most quoted studies on the relationship between cheese and animal production, the main research area is "Agriculture" (Table 14). All the studies are empirical, except for the literature review by Pirisi, Comunian, Urgeghe, and Scintu (2011), which analyses the technological, microbiological, chemical and sensory aspects of PDO and PGI cheeses. Most studies focus on the PDO scheme, while the others deal with PGI and PDO schemes. The main country analysed is Italy, with cheese made from cow's milk predominating and no study addressing the differences between countries. The majority examine not only one but various types of PDO and PGI cheese, and studies analysing the importance of PDO and PGI schemes in preserving traditional farming systems stand out (Gaspar, Escribano, Mesías, Escribano, & Pulido, 2011; Scintu & Piredda, 2007; Sturaro et al., 2013). Also highlighted are the studies by Bontempo et al. (2011) and Hurtaud et al. (2009) focusing on the effects of animal feeding systems on the quality of PDO cheese, although the work by Hurtaud et al. (2009) is the only one to analyse the effects of different breeds on the quality of PDO cheese.

Future lines of research in the "Certification of Cheese and Milk" cluster (Table 15) concern more comparative studies, particularly between cheese made from raw milk and pasteurized milk (Turgay, Schaeren, Wechsler, Bütikofer, & Graber, 2016), and between cheese from different geographical origin (Soggiu et al., 2016). More studies are also necessary to develop marketing strategies based on nutritional and organoleptic information about PDO cheeses (Trani, Gambacorta, Loizzo, Cassone, & Faccia, 2016).

4.2.4. Certification and Chemical Composition

In the "Certification and Chemical Composition" cluster, studies are centred on the analysis of various compounds and their chemical families (fatty acid, alcohol and ester), especially the analysis of fatty acids.

In the 10 studies most quoted concerning fatty acids, the main area of research is "Chemistry" (Table 16). Except for the study by Fernández et al. (2006), which is on two certification schemes (TSG and PDO), the others analyse only the PDO scheme. Italy is the country with the greatest number of studies, which focus above all on analysis of PDO olive oil. Besides olive oil, fatty acids are also analysed in other products such as chestnuts (Barreira, Casal, Ferreira, Oliveira, & Pereira, 2009; Borges et al., 2007) and beef (Alfaia et al., 2007) in Portugal, cured ham in Spain (Fernández et al., 2006) and cheese in Italy (Noni & Battelli, 2008). Due to its specificity, the work relating the profile of fatty acids in beef with the slaughter season is also highlighted (Alfaia et al., 2007), as is the fatty acid profile in cheese with the transhumance of dairy cows in different mountain pastures (Noni & Battelli, 2008).

Table 17 presents some future lines of research in the "Certification and Chemical Composition" cluster. Bearing in mind the shortage of studies on the authentication of PDO lard, Chiesa et al. (2016) suggest

Table 10
Top 10 most cited studies on the relationship between Olive Oil and Cultivars.

Authors	Citations	Área of research	Methodology	Certification	Country	Olive Oil	Cultivar	Contribution
Matos et al. (2007)	85	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Portugal	Tras-os-Montes	Diverse	Assesses the usefulness of chemical parameters as a tool to distinguish three cultivars used in producing a PDO olive oil.
Casal et al. (2010)	72	Food Science & Technology; Toxicology	Empirical	PDO	Portugal	Tras-os-Montes	Diverse	Investigates the suitability of different commercial categories of olive oils for domestic frying, among them a PDO olive oil.
Pasqualone et al. (2007)	47	Agriculture; Chemistry; Food Science & Technology	Empirical	PDO	Italy	Collina di Brindisi	Ogliarola	Verify the effectiveness of analysis of microsatellites in verifying the identity of PDO olive oil.
Muzzalupo & Perri (2002)	42	Food Science & Technology	Empirical	PDO	Italy	Diverse	Diverse	Characterises the genetic identity of DNA recoverable of olive oil, in order to facilitate the assessment of its place of origin.
Tura et al. (2008)	38	Agriculture	Empirical	PDO	Italy	Diverse	Diverse	Concludes that geographical origin may not be enough to favour characterisation and consumption of olive oil, if sensory and/or nutritional attributes are not also differentiated.
Inarejos-García et al. (2010)	37	Food Science & Technology	Empirical	PDO	Spain	Montes de Toledo	Cornicabra	Examines the relation between minor component profiles and the quality and sensory perception of a PDO olive oil.
Brescia, Alviti, Liuzzi, & Sacco (2003)	32	Chemistry; Food Science & Technology	Empirical	PDO	Italy	Diverse	Diverse	Based on analysis of olive oils obtained from single varieties, establishes the differences between cultivars in terms of acid, sterol and TAG, determined by chemometrics.
Malheiro et al. (2009)	31	Food Science & Technology; Toxicology	Empirical	PDO	Portugal	Diverse	Diverse	Examines the effect of different microwave heating times on the physical and chemical characteristics of three PDO olive oils.
López-Feria, Cárdenas, García-Mesa, & Valcárcel (2008)	28	Chemistry	Empirical	PDO	Spain	Diverse	Diverse	Describes a headspace-mass spectrometry (HS-MS) coupling, projected for sensory characterisation and classification of extra virgin olive oil, based on PDO and the cultivar.
Korifi, Le Dréau, Molinet, Artaud, & Dupuy (2011)	27	Spectroscopy	Empirical	PDO	France	Diverse	Diverse	Assesses the capability of confocal Raman spectroscopy, combined with chemometric treatments, to determine the composition of olive oils and to authenticate PDO labels.

Table 11
Top 10 most cited studies on the relationship between Fruits and Cultivars.

Authors	Citations	Area of research	Methodology	Certification	Country	Fruit	Cultivar	Contribution
Pereira et al. (2006)	100	Agriculture; Chemistry; Food Science & Technology	Empirical	PDO	Portugal	Table olives	Diverse	Investigates the phenolic compounds composition, antioxidant potential and antimicrobial activity of different table olives, among them a PDO.
Matos et al. (2007)	85	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Portugal	Olives for olive oil	Diverse	Discriminates three cultivars used in producing PDO olive oils, analysing olives collected in the same year crop and from the same orchard, so as to eliminate the geographical and climatic influences.
Barreira et al. (2009)	29	Agriculture; Chemistry; Food Science & Technology	Empirical	PDO	Portugal	Chestnut	Diverse	Analyses the nutritional, fatty acid and triacylglycerol profiles of different PDO chestnut cultivars.
Ramos and Santos (2010)	26	Agriculture; Water Resources	Empirical	PDO	Portugal	Olives for olive oil	Cordovil	Examines the impact of different irrigation scheduling regimes on the quantity and quality of a PDO olive oil from a low density orchard.
Gonçalves et al. (2010)	22	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Portugal	Chestnut	Diverse	Studies the processing effects (roasting and boiling) on the primary and secondary metabolite composition of different PDO chestnut cultivars.
Montero-Prado, Bentayeb, & Nerín (2013)	20	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Spain	Peach	Diverse	Analyses the volatile compounds of four PDO peach cultivars.
Barreira et al. (2012)	9	Food Science & Technology; Toxicology	Empirical	PDO	Portugal	Chestnut	Diverse	Assesses the nutritional, fatty acid, triacylglycerols and tocopherols profiles of different PDO chestnut cultivars.
Guo et al. (2013)	8	Agriculture; Chemistry; Food Science & Technology	Empirical	PDO	China	Apple for juice	Diverse	Characterises and classifies apple juices according to the apple cultivar and geographical origin, based on its polyphenols composition.
Pasqualone et al. (2013)	8	Agriculture; Chemistry; Food Science & Technology	Empirical	PDO	Italy	Table olives	Diverse	Develops a DNA microsatellite-based method to allow the traceability of different PDO table olives.
Peres et al. (2011)	8	Automation & Control Systems; Chemistry; Computer Science; Instruments & Instrumentation; Mathematics	Empical	PDO	Portugal	Table olives	Diverse	Uses artificial neural networks for fruit classification according to the olive cultivar, functioning as a tool to ensure authenticity of varieties.

Table 12
Future lines of research in the "Certification of Olive Oil and Cultivars" cluster.

Authors	Área of research	Methodology	Certification	Country	Product	Contribution	Future lines of research
Drivelos et al. (2016)	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Greece	Fava bean	The trace & rare earth elemental (REE) fingerprint is minimally affected per harvesting year of a PDO fava bean cultivar.	The results of this study can be used in tests with different PDO and PGI food products, so as to derive fingerprints for food authentication that are not, or are minimally, affected by the production period.
Ganopoulos et al. (2015)	Forestry	Empirical	PDO	Greece	Fig	Characterises the genetic resources of a PDO fig cultivar, using microsatellite markers.	The genetic data obtained can be a useful contribution to optimization of management of fig tree germ plasm, conservation programmes and breeding activities.
Moscetti et al. (2015)	Agriculture; Chemistry; Food Science & Technology	Empirical	PDO	Italy	Hazelnut	Investigates the possibility of using near infrared spectroscopy for authentication of a PDO hazelnut cultivar.	The potential use of visible NIR spectroscopy to separate hazelnuts according to their cultivar should become the subject of future research.

Table 13
Top 10 most cited studies on the relationship between Cheese and Milk.

Authors	Citations	Área of research	Methodology	Certification	Country	Cheese	Milk origin	Contribution
Brescia et al. (2005)	66	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Italy	Mozzarella di Bufala Campana	Cow's milk	To ensure the authenticity of PDO cheese, the geographical origin of the milk is determined by analytical and spectroscopic methods.
Mallia et al. (2005)	65	Food Science & Technology	Empirical	PDO	Diverse	Diversos	Diverse	Compares the effectiveness of Solid phase microextraction (SPME) and Purge & Trap (P & T) techniques in extracting the aroma compounds of PDO cheeses.
Delgado et al. (2010)	63	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Spain	Torta del Casar	Sheep's milk	Studies the volatile profile of a PDO cheese in four different stages of ripening, using the SPME-GC–MS method.
Alegría et al. (2012)	55	Biotechnology & Applied Microbiology; Microbiology	Empirical	PDO	Poland	Oscypek	Sheep's milk	Characterises the microbiota that develops and evolves during manufacture and the ripening stages of a PDO cheese.
Pellegrino & Tirelli (2000)	46	Food Science & Technology	Empirical	PDO	Italy	Diverse	Diverse	Uses a sensitive HPLC method to detect hen's egg white lysozyme in PDO cheeses.
Mannu & Paba (2002)	43	Biotechnology & Applied Microbiology; Microbiology	Empirical	DOP	Italy	Pecorino Sardo	Sheep's milk	Analyses the intra-specific genetic diversity in the natural microbial population colonizing an artisanal PDO cheese.
Sacco et al. (2009)	41	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Italy	Mozzarella di Bufala Campana	Cow's milk	Analytical and spectroscopic methods are used to authenticate PDO cheese, so as to compare the geographical origin of milk from the southern Italy and other regions.
Scintu and Piredda (2007)	40	Agriculture	Empirical	PDO & PGI	Italy	Diverse	Diverse	Analyses the importance of typicity and biodiversity in PDO and PGI cheeses.
Gómez-Ruiz et al. (2002)	40	Food Science & Technology	Empirical	PDO	Spain	Manchego	Sheep's milk	Analyses the differences in the organoleptic properties of PDO cheeses made from raw milk (artisanal cheese) or pasteurized milk (industrial cheese).
Bonetta, Bonetta, Carraro, Rantsiou, & Cocolin (2008)	39	Biotechnology & Applied Microbiology; Food Science & Technology; Microbiology	Empirical	PDO	Italy	Robiola di Roccaverano	Goat's milk	Analyses the microbiological characteristics of a PDO cheese.

Table 14
Top 10 most cited studies on the relationship between cheese and animal production.

Authors	Citations	Área of research	Methodology	Certification	Country	Cheese	Animal production	Contribution
Sacco et al. (2009)	41	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Italy	Mozzarella di Bufala Campana	Cow	Considering the importance of the production of cow milk obtained from autochthonous animals bred in local farms, the authenticity of PDO cheese is analysed in an Italian region.
Scintu and Piredda (2007)	40	Agriculture	Empirical	PDO & PGI	Italy	Diverse	Diverse	By using local and traditional resources, the production of PDO and PGI cheese is essential to stimulate biodiversity.
Sturaro et al. (2013)	27	Agriculture	Empirical	PDO	Italy	Diverse	Cow	Analyses the importance of PDO cheese in reducing the economic disadvantage of traditional dairy farms, compared to intensive farming systems.
Devirgiliis, Caravelli, Coppola, Barile, & Perozzi (2008)	27	Food Science & Technology; Microbiology	Empirical	PDO	Italy	Mozzarella di Bufala Campana	Cow	Focus on microbiological and molecular analysis of lactobacilli and other lactic acid bacteria (LABs) isolated from PDO cheeses, with the aim of identifying the genes responsible for resistance to antibiotics.
Bontempo et al. (2011)	23	Food Science & Technology	Empirical	PDO	Italy	Diverse	Cow	Elemental and isotopic characterisation of PDO cheeses, relating it to animal diet and the requirements of PDO certification.
Delgado et al. (2010)	17	Food Science & Technology	Empirical	PDO	Spain	Torta del Casar	Sheep	Studies the proteolysis and texture changes of PDO cheese in four stages of ripening.
Pirisi et al. (2011)	16	Agriculture	Conceptual (Review)	PDO & PGI	Italy	Diverse	Diverse	Analyses the technological, microbiological, chemical and sensory aspects of PDO and PGI cheeses based on sheep and goat's milk.
Gaspar et al. (2011)	14	Agriculture	Empirical	PDO	Spain	Ibores	Goat	Analyses the main characteristics of dairy goat systems, in an area where goat milk production is only possible due to its use in PDO cheese.
Hurtaud et al. (2009)	11	Agriculture; Veterinary Sciences	Empirical	PDO	France	Diverse	Cow	Examines the effects of two feeding systems and two dairy cow breeds on milk yield and composition, physical and sensory properties of PDO cheeses.
Berzaghi and Riovanto (2009)	11	Agriculture; Veterinary Sciences	Empirical	PDO & PGI	Italy	Diverse	Cow	Analyses applications of NIR spectroscopy, among them the discrimination of PDO and PGI products in relation to other non-traditional products.

Table 15
Future lines of research in the "Certification of Cheese and Milk" cluster.

Authors	Área of research	Methodology	Certification	Country	Contribution	Future lines of research
Turgay et al. (2016)	Food Science & Technology	Empirical	PDO	Switzerland	Focus on fast detection and quantification of four dairy propionic acid bacteria (PAB) in samples of milk used in PDO cheese, resorting to the real-time quantitative polymerase chain reaction.	More studies are necessary on the relationship between concentrations of individual PAB species in the milk used in PDO cheese, and the occurrence of defects in semi-hard, hard and extra-hard cheese varieties made from raw or pasteurized milk.
Soggiu et al. (2016)	Biochemistry & Molecular Biology	Empirical	PDO	Italy	Applies a metaproteomic approach that identifies the functional dynamics of microbial consortia in relation to the number of clostridia spores and lysozyme treatment, using samples of PDO cheese.	More PDO cheese samples of different geographical origin should be selected to confirm the results obtained in this study.
Trani et al. (2016)	Agriculture; Food Science & Technology	Empirical	PDO	Italy	Analyses the chemical and sensory characteristics of a PDO cheese manufactured in spring.	Considering that it is fundamental to provide appropriate nutritional and organoleptic information about PDO cheeses, the results of the study can be used to improve marketing strategies and adjust them to the consumer.

developing their model in additional studies with a greater number of samples. Semmar and Artaud (2015) also propose extending their model of predicting olive oil blend compositions, from fatty acid data, to other olive oil blends made with more than three varieties. Considering the influence of the differences between native and non-native sheep breeds on the quality of PDO cheese, another future line of research to follow is study of ways to add value to native breeds, contributing to their conservation (Claps et al., 2016).

5. Conclusions

This study presents a bibliometric analysis of three EU food quality certification schemes: PDO, PGI and TSG. Although the field has a growing number of articles published in recent years, our search failed to reveal any study addressing the main thematic lines of research. Therefore, by using the bibliometric technique of term co-occurrence, it was possible to group the literature in four thematic clusters: "Protected Geographical Indication", "Certification of Olive Oil and Cultivars", "Certification of Cheese and Milk" and "Certification and Chemical Composition".

Unlike the other clusters, where the PDO scheme predominates, the "Protected Geographical Indication" cluster covers studies on the PGI scheme, highlighting analysis of consumer behaviour in relation to this type of product. Emerging in this cluster are products such as meat and ham, although these terms do not have much relevance in the set of studies analysed. The most quoted study in this cluster concludes that consumers are willing to pay more for PDO products, followed by organic farming label and finally PGI (Aprile et al., 2012).

The focus of studies in the "Certification of Olive Oil and Cultivars" cluster is authentication of olive oil or the olive cultivars used in its production. Besides olives, the cultivars of other fruits such as apple, peach and chestnut are analysed, but occupy little space in the literature on this topic. The "Certification of Cheese and Milk" cluster includes studies based on authentication of the milk used in cheese production, especially Italian ones. The relationship between animal production and cheese quality is little studied. Unlike the other clusters, where the predominant research area is "Food, Science & Technology", studies included in the "Certification and Chemical Composition" cluster are essentially within the "Chemistry" area. In this cluster, analysis of fatty acids, especially in olive oil, stands out.

Empirical methodology is predominant in all clusters, with few conceptual articles. Southern European countries are analysed most, especially Italy, Spain and Portugal. Although fruit and vegetables are the product category with most PDO and PGI registrations, this category is less studied in the literature, as opposed to products such as cheese and olive oil.

6. Limitations and future lines of research

Our study has some limitations. Firstly, it is based only on articles on *ISI Web of Science*. Secondly, the filtering process used may have omitted relevant literature but the rigorous methodological (reproducible) procedure mitigates the fact that excluded articles may include information significantly altering our conclusions. Furthermore, defining a minimum number of term occurrences, in the thematic analysis, prevents the identification of all terms as well as the relationship between them.

Considering the dominance of the PGI and PDO schemes, more studies addressing the TSG certification scheme are necessary. Another future line of research is the conception of new marketing strategies for traditional certified products, associated with various communication media or nutritional and organoleptic information about those products. More studies are also needed abut consumer behaviour in relation not only to PGI but also PDO and TSG products, considering the differences between countries or regions.

Despite the diversity of studies on authentication of PDO and PGI

Table 16
Top 10 most cited studies on analysis of Fatty Acids.

Authors	Citations	Área of research	Methodology	Certification	Country	Product	Contribution
Borges et al. (2007)	66	Chemistry; Food Science & Technology	Empirical	PDO	Portugal	Chestnut	Analyses the lipid and fatty acid profiles in PDO chestnut cultivars.
Fernández et al. (2006)	51	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	TSG & PDO	Spain	Cured ham	Studies TSG and PDO cured ham to assess its nutritional value in relation to fatty acids.
Casale et al. (2012)	43	Chemistry	Empirical	PDO	Italy	Olive oil	Characterises PDO olive oil with non-selective (UV–visible, NIR and MIR spectroscopy) and selective (fatty acid composition) analytical techniques.
Lanteri Armanino, Perri, & Palopoli (2002)	43	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Italy	Olive oil	Studies PDO olive oil through chemometric methods.
Marini, Magrì, Bucci, Balestrieri, & Marini (2006)	37	Automation & Control Systems; Chemistry; Computer Science; Instruments & Instrumentation; Mathematics	Empirical	PDO	Italy	Olive oil	Uses class-modelling techniques in the authentication of PDO olive oils.
Alfaia et al. (2007)	35	Food Science & Technology	Empirical	PDO	Portugal	Beef	Describes the influence of the slaughter season on lipid content, fatty acid composition, conjugated linoleic acid (CLA) isomeric profile and nutritional value of fat in PDO beef.
Brescia et al. (2003)	32	Chemistry; Food Science & Technology	Empirical	PDO	Italy	Olive oil	Classifies the cultivars used in producing PDO olive oil obtained from single varieties, based on differences in acid, sterol and TAG determined by chemometrics
Noni and Battelli (2008)	30	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Italy	Cheese	Analyses the evolution of fatty acids and terpenoids profiles in milk and PDO cheese, affected by the transhumance of cows in different mountain pastures.
Barreira et al. (2009)	29	Agriculture; Chemistry; Food Science & Technology	Empirical	PDO	Portugal	Chestnut	Analyses the nutritional, fatty acid and triacylglycerol profiles of PDO chestnuts.
López-Feria et al. (2008)	28	Chemistry	Empirical	PDO	Spain	Olive oil	Describes headspace-mass spectrometry (HS-MS) coupling, projected for sensory characterisation and classification of extra virgin olive oil based on the PDO and the cultivar.

Table 17
Future lines of research in the "Certification and Chemical Composition" cluster.

Authors	Área of research	Methodology	Certification	Country	Product	Contribution	Future lines of research
Chiesa et al. (2016)	Chemistry; Food Science & Technology; Nutrition & Dietetics	Empirical	PDO	Italy	Lard	Analyses the usefulness of near infrared spectroscopy (NIRS), combined with volatile compounds (VOC) and fatty acids, for authentication of PDO lard.	Additional studies are necessary using a greater number of samples to identify new potential markers in a more complex model.
Claps et al. (2016)	Food Science & Technology	Empirical	PDO	Italy	Cheese	Analyses the differences of native and non-native sheep breed in the quality of a PDO cheese.	More studies are needed to add value to native breeds, contributing to their preservation through sustainable use.
Semmar and Artaud (2015)	Chemistry; Food Science & Technology	Empirical	PDO	France	Olive oil	Develops a new simplex-based approach predicting olive oil blend compositions, from fatty acid data.	Proposes extending the approach used to control other oil blends made from more than three varieties.

products, it is essential to improve the models already developed and create new models applied to other products, given the unique characteristics each of these products presents. In this field, authentication of fruit or vegetable cultivars represents a promising line, since up to now there has been a focus on studying products subject to some type of agro-industrial processing, such as olive oil and cheese. Considering the influence of the differences between autochthonous breeds on the quality of traditional products such as meat or cheese, more studies are also needed to conceive ways of adding value to autochthonous breeds, thereby contributing to their preservation.

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