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Sustainability in Protected Designations of Origin (PDO) in the European Union: An approach from a Systematic Literature Review

Sustentabilidad en las Denominaciones de Origen Protegidas (DOP) en la Unión Europea. Aproximaciones desde una revisión sistemática de la literatura

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Abstract

Protected Designations of Origin (PDO) safeguard and recognize food products with specific qualities resulting from their origins. This topic has been of recent interest to academics. Nonetheless, research that addresses sustainability in PDOs is still scarce. Thus, this paper aimed to identify the way the link between PDO and sustainability topic has been approached in recent research, especially on geographical spaces with a great history of use and exploitation of PDO figures, such as the European Union (EU). A systematic literature review methodology was selected by applying the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, and by using Scopus, WoS, and Science Direct database between 2005 and 2021. From this screening process, 41 eligible studies were selected, and a qualitative and quantitative analysis was performed on the selected sample to address the following elements: (1) timeline growth on the field of knowledge; (2) food type product analyzed in the research; (3) research's geographical location; (4) methodologies used, and (5) sustainability term's combinations and its link to food type product. The results showed that sustainability in PDO's research in the EU has experienced an upwards trend and is mostly carried out in those countries with the highest volume of PDOs registration, focusing mainly on dairy and oil products. Most of them applied mixed methodologies to assess an interdisciplinary sustainability perspective from its social, economic, and environmental dimension, being sustainable production systems the most common term used in the research.

Keywords: sustainability, Protected Designations of Origin, systematic literature review, European Union, food quality.

Resumen

Las denominaciones de origen protegidas (DOP) salvaguardan y reconocen los productos alimenticios con cualidades específicas derivadas de su origen. Este tema ha sido de reciente interés para los académicos; no obstante, la investigación que aborda la sostenibilidad en las DOP es aún escasa. Por tanto, este trabajo tuvo como objetivo identificar la forma en que se ha abordado el vínculo entre DOP y sostenibilidad en investigaciones recientes, especialmente en espacios geográficos con una gran

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trayectoria en el uso y explotación de DOP, como la Unión Europea (UE). Se seleccionó una metodología de revisión sistemática de la literatura aplicando la metodología *Preferred reporting items for systematic reviews and meta-analyses* (PRISMA) y se utilizó la base de datos de Scopus, WoS y Science Direct entre 2005 y 2021. De este proceso de selección, se escogieron 41 estudios elegibles y se realizó un análisis cualitativo y cuantitativo de la muestra para abordar los siguientes elementos: (1) tendencia temporal en el campo del conocimiento; (2) tipo de producto alimenticio analizado en la investigación; (3) ubicación geográfica de la investigación; (4) metodologías utilizadas; y (5) combinaciones de términos de sostenibilidad y su vínculo con el tipo de producto alimenticio. Los resultados mostraron que la investigación de la sostenibilidad en DOP en la UE presenta una tendencia creciente, y se lleva a cabo principalmente en aquellos países con el mayor volumen de registro de DOP, centrándose en productos lácteos y aceite, y aplicando metodologías mixtas para evaluar desde una perspectiva interdisciplinaria la dimensión social, económica y ambiental de la sostenibilidad, siendo los sistemas de producción sostenibles, el término más utilizado en la investigación.

Palabras clave: sustentabilidad, Denominaciones de Origen Protegidas, revisión sistemática de la literatura, Unión Europea, calidad alimenticia.

1. Introduction

Sustainability, and its most accepted definition nowadays, was first suggested in the Brundtland report in 1987, defining it as the “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations Educational Scientific and Cultural Organization [UNESCO], 2019, p.1).

This concept has become of great relevance in current theoretical and empirical research, especially considering that humanity is facing the loss of agrobiodiversity and a constant eco-systems degradation (Grau López, 2013), which could cause social, economic, and environmental side effects and the destruction of agri-food ecosystems.

This could compromise the availability of territorial embedded food goods, which are those that have an enormous attachment to biocultural heritage and territorial specificities. These food goods are mostly recognized for being protected through institutional figures such as Protected Designations of Origin (PDO onwards) which, in turn, allows a good to be valued considering not only their natural production conditions but also those human and social elements that enrich them with unique features related to a specific geographical area.

Protected Designations of Origin (PDOs) are positioned as the best-known Institutional Protection (IP onwards) figures worldwide for agrifood with a strong territorial linkage. These stamps of origin link the unique characteristics of territory (such as its agronomic, topographic, cultural, and social conditions as well as the transformation processes) around the sowing, cultivation, and elaboration of food products could generate positive outcomes and thus contributing to territorial development (De Pablo Valenciano & Román Sánchez, 2011; Sánchez-Hernández *et al.*, 2017).

IP figures could contribute to a sustainable agri-food system, but because “sustainability of an agricultural system is a time- and space-specific concept” (Krishnankutty *et al.*, 2021, p. 3), an IP implementation (such as PDO) does not automatically imply the achievement of territorial development, mostly because the latter is a multifactorial condition, involving multilevel collective action, requiring adequate systems of territorial governance while articulating agri-food systems and, as mentioned for Owen *et al.* (2020) transiting towards agroecological territories. Furthermore, it is important to mention that, as Lozano (2008) explains, sustainability cannot be understood without considering its three most accepted interrelated dimensions: economic, social, and environmental. All dimensions should be acknowledged while aiming for genuine territorial development, especially if IP figures, focused on agri-food systems based on quality schemes, are the topics in question.

However, despite considering that figures such as PDO, based on the product’s differences from their specificity of origin, could contribute to the economic and environmental development of agri-food systems (Belletti *et al.*, 2015), and given the fact that climate change would undoubtedly have effects in production chains based on products with PDO (Clark & Kerr, 2017) and that PDOs could have effects on environmental sustainability (Bowen & Zapata, 2015), the sustainability approach has tended to be higher and, sometimes, wrongly and exclusively related to environmental issues, hence the need of answering how does the link between PDO and sustainability has been approached in recent research. This becomes especially relevant on those PDOs products whose research on the sustainability topic developed on geographical spaces with a great

history of use and exploitation, such as the European Union (EU onwards).

Therefore, considering the lack of more holistic research on this subject, and to consolidate the state of academic research for the link between sustainability in PDOs, in this study, a systematic literature review (SLR) of the PDOs scheme was performed, considering the EU as the contextual geographical space by applying the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, and by using Scopus, Web of Science (WoS), and Science Direct database between 2005 and 2021 considering publication in all areas of research, in the English language, and executing a screening process to gather papers that included both concepts ‘protected designation of origin’ and ‘sustainability’ as well.

From this first screening process, 41 eligible studies were selected, which became the selected sample ($n = 41$). Then, a qualitative (in-depth content analysis) and quantitative analysis (descriptive statistical) was performed on the selected sample ($n = 41$) to address the following elements: (1) timeline growth on the field of knowledge; (2) food type product analyzed in the research; (3) research’s geographical location; (4) methodologies used on the research, and (5) Sustainability term’s combinations and its link to food type product.

The results showed that sustainability in PDO’s research in the EU, has experienced an upwards trend and is mostly carried out in those countries with the highest volume of PDOs registration, focusing mainly on dairy and oil products, and by applying mixed methodologies to assess multidisciplinary perspectives to study the sustainability’s socioeconomic and environmental dimension, being sustainable production systems the most common term used in the research.

1.1. Protected Designations of Origin in Europe: a brief contextual data

To define how the link between PDOs and sustainability is attended in research placed on the EU, it is necessary to briefly do an initial analysis of some contextual data.

Considering the importance of protecting food goods linked to the territory, and guaranteeing institutional protection against biopiracy, and potential commercial fraud (Dias & Mendes, 2018), a series of provenance stamps have been established in the EU: Protected Geographic Identifications (PGIs) and Registered Collective Marks of the EU, also known as EU Trademarks (EUTM).

In general terms, within European countries, two protected by law quality schemes are the most common IP figures: the PDOs and PGIs. To be granted, goods for both figures must be agricultural products, originating within the defined area, and their characteristics or properties must be linked to their geographical areas of origin (O’Connor and Company European Lawyers & Consulting Insight, 2007). These protection guidelines find their origins in some existent protection systems such as the French Appellation d’Origine Contrôlée, which is a figure linked to the concept of terroir (Dias & Mendes, 2018) institutionally supported as well on the Paris Convention of 1883, further developed with detail in the Lisbon Agreement of 1958 (O’Connor and Company European Lawyers & Consulting Insight, 2007).

In addition to the granted protections by the legal system of PGIs in the EU, there are other mechanisms through which these products are recognized and further protected on international ground, such as the bilateral agreements signed by the EU with other countries, like Australia and the United States (limited to wines) or Canada, Mexico, Chile, and South Africa.

PDOs are considered much stronger IP figures. For authorities to grant PDOs recognition, it is a requirement that all the inputs used for the final product come from the territory protected by the regulations. By contrast, PGIs are much more flexible as for the authenticity requirements (Moir, 2017). In this way, the scopes of these figures differ in how strict the origin considerations are, and in the different degrees of freedom of production (Dias & Mendes, 2018), which could affect research tendencies considering quality schemes attended and geographical location of the research.

In Europe, it is interesting to note that the first institutional protection under the PDO occurred in 1993 before the European Union Intellectual Property Office (EUIPO, 2020), and the PDO registration rate at EUIPO has remained constant since 1993 (Figure 1), with an annual average of 20 registrations, except for 1996 in which 228 registries were filed up into the system. The increase in the registration of PDO institutional protections in 1996 might be explained by the direct transfer made by local offices of their registers towards the unified institutional protection database of the EU (Moir, 2017) which could partly explain the enormous number and homogeneity of the records, rather than attributing such growth to the positioning or strengthening of the institutional protections figures in the region.

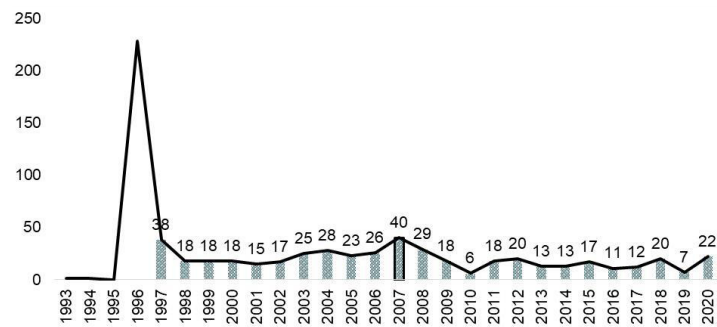


Figure 1. Number of PDOs registered in EUIPO from 1993 to 2020 (EUIPO, 2020).
Figura 1. Número de Denominación de Origen Protegida [DOP] registradas en la Oficina de Propiedad Intelectual de la Unión Europea [EUIPO en inglés] de 1993 a 2020 (EUIPO, 2020).

Note: 2021 data was not available by the time this research was finished.

Figure 1 shows that the second maximum PDOs registration was in 2007, with 40 records at the EUIPO office. After 2007, a significant decrease in registration was recorded, with its lowest in 2010 (6 registrations). Since then, a slight upwards tendency can be seen (having another fall in 2019), yet not at the same levels as before 2007. However, this Figure 1 allows us to infer that this IP tool has had a semi-stable recognition in the population in the region since the trend has remained constant after 2017, even in the face of adverse external conditions in recent years, with an increase in 2020, which could have been partly driven by a series of trade agreement signatures with Eastern countries such as China in 2019, a period in which a trade agreement was signed with the EU that includes the protection of at least 100 goods from the European food industry (European Commission [EC-EU], 2020). It might seem that the logic behind IPs is more motivated by the opening of markets, competitive advantages, and the strategic positioning of agricultural products (Dias & Mendes, 2018) than by reasons of genuine regionalism and the elimination of the merchandising of the authentic (Frigolé, 2014).

Moreover, and as it can be seen in Table 1, in 2020, of the 568 registrations made for PDOs before the EUIPO, the most active countries, with the most constant registration requests, are Italy, France, and Spain which have strengthened their agricultural sectors. On the other hand, in terms of the type of registered products, cheeses occupy first place with 199 registrations, which represents 28% of the total, followed by fresh or processed fruits, vegetables and cereals with 25%, and fats and oils with 18% of the existing registrations. Finally, fresh meats and other products of animal origin make up 13% of the records (EUIPO, 2020).

Table 1. Countries that occupy the first places in PDOs registries in the EU (EUIPO, 2020).
Tabla 1. Países que ocupan los primeros lugares en los registros de DOP en la Unión Europea (EUIPO, 2020).

Country	Number of PDO registries
Italia	173
France	111
Spain	107
Greece	80
Portugal	68
Great Britain	29
Germany	12

It is important to mention that when it comes to PGIs registration, trends change, and shift slightly. For instance, by 2020, Italy holds first place when it comes to IP registries, with 140 PGIs and 173 PDOs, giving a total of 313. Secondly, France reported 159 PGI registries, having a final number of 270 IP (including 111 PDOs); thirdly, Spain had 101 PGI registries summing up a total of 208 total entries. It is interesting to mention that other countries that are not part of the EU, such as China, have registered goods to be protected before EUIPO (2020).

2. Materials and Methods

To analyze the link between sustainability in PDO, a systematic literature review was performed on two stages.

The first stage applied the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, which consisted of a data collection process using Scopus, WoS, and Science Direct database between 2005 and 2021 (first trimester). This first screening process layout 41 eligible studies. With this 41 database (selected sample $n = 41$), a second stage was performed, where a qualitative (in-depth content analysis) and quantitative analysis (descriptive statistical) to address the following elements: (1) Timeline growth of sustainability in PDO's research; (2) Sustainability in PDO's research by food type product; (3) Geographical location of research on sustainability in PDOs; (4) Methodologies approach used on research to study sustainability in PDOs, and (5) Sustainability term's combinations and its link to food type product. It is worth mentioning that systematic literature review methodology allows, by selecting an specific topics and establishing a particular conceptual link, to discover the state of art regarding these thematic relationships. In the same way, these reviews involve a detailed review of particularly and geographically located research, and sometimes focused mainly on specific products or sectors, which provides particular information that, in aggregate, contribute to the inductive approach to generalize knowledge on the topics, in this case, sustainability approach in PDOs investigations.

2.1. First Stage: Literature sampling and data collection using PRISMA

The systematic literature review process was carried out between 2005 and 2021 (first trimester) using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Ramírez Vélez *et al.* 2013). To begin with the (1) identification of materials, the authors choose to include only peer-reviewed papers already published in academic journals as the primary source. Thus, the search engines used to obtain the information were academic literature search engines such as Scopus, WoS, and ScienceDirect. The keywords used in all search engines to filter the information were “designation of origin” and “sustainability”, joined by the Boolean operator “and”, to identify papers with both topics. There was no language restriction on the searching process on the databases.

The first step on the PRISMA process involved a data collection using keywords in search engines; the first search identified 125 documents, and after discarding duplicates, the sample remained on 82 (Figure 2).

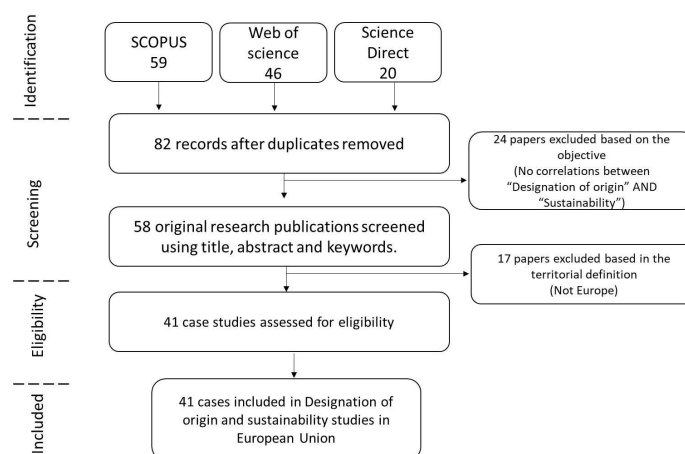


Figure 2. Flow diagram of the data collection process using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Figura 2. Diagrama de flujo del proceso de recopilación de datos utilizando elementos de informe preferidos para revisiones sistemáticas y meta análisis (PRISMA).

Then, step (2) consisted of a screening process by analyzing titles, abstracts, and keywords to gather only those papers that follow the next criteria: research should have contained the terms “sustainability” and “designation of origin” altogether as mentioned before; research should have been accessible as a complete paper in the extensive

form; research should have been written in English, and it should have been published between 2005 and 2021. After removing 24 papers that showed no relation to the matter, a 58 sample was obtained.

Later, a second screening on step (3) was performed to select only those papers whose research areas were located within the EU, which was the selected region of study given its consideration as PDO's birthplace. Therefore, after the latter screening process, a sample of 41 eligible studies was found, which became the selected sample $n = 41$ that was used to perform a qualitative and quantitative analysis as part of the Second Stage.

2.2. Second Stage: Procedure and methods for analyzing selected sample ($n = 41$)

With the database generated with the PRISMA methodology (selected sample $n = 41$), an in-depth review of the research's content was carried out. The authors performed a descriptive statistical analysis to address the following elements:

2.2.1. Timeline growth of sustainability in PDO's research

Based on the selected sample ($n = 41$), the years of publication of each paper were identified and, by using descriptive statistics, the publication trends were graphically plotted and analyzed. Furthermore, this analysis recovered contextual data on the level of PDOs registration made to the EUIPO.

2.2.2. Sustainability in PDO's research by food type product

The next element of analysis consisted of reviewing research papers to categorize them by food type products under PDOs. Therefore, the PDO's products were grouped into the following 9 categories: (1) dairy, (2) oils, (3) wine, (4) fruits, (5) grown food, (6) nuts, (7) bakery, (8) wine & seafood (combined), (9) labels. These categories were constructed after a detailed reading of the 41 original research publications. After considering all the products within the categories, a summary of the food categories was developed to explain in broad terms the objectives of the original research publications. It is important to mention that in this food type category the authors included those products that, on the research, were linked to other IP figures such as PGIs or Traditional Specialty Guaranteed (TSG).

2.2.3. Geographical location of research on sustainability in PDOs

To geospatially localized the first database results, the selected sample ($n = 41$) was categorized by country. Through an in-depth review of the content, the place of study of each of the 41 research papers was specified. The results are presented in statistical cartography where the countries with the highest concentration of studies are shown by color scale. Likewise, a crossing analysis, considering the type of product and geographical location of research was executed.

2.2.4. Methodologies used in research to study sustainability in PDOs

Based on the selected sample ($n = 41$), authors performed an in-depth analysis of the methodology section of each paper, and, based on the information found, a series of categories were proposed to discretize the methodologies and the techniques used in the analysis of PDOs. The categories proposed around the methodologies were: (1) qualitative, (2) quantitative, and (3) mixed methodologies.

2.2.5. Sustainability term's combinations and its link to food type product

With the selected sample ($n = 41$), the use of the term 'sustainability' and the variations within each of the research works was analyzed. The results were gathered by food type and then presented using a graphical network. First, the term 'sustainability' was searched within each research paper, and a database was created to include the combinations of the term. Secondly, the information on the combinations of the term was classified and linked to the categorization of food types. In this way, the combinations of the word sustainability ('binding categories' on the aforementioned), which turned out to be 15, such as sustainable development or sustainable production to name a few, were obtained for the 9 food categories. With the results of this classification, it was possible to

analyze the relationship between food types and the binding sustainability categories and visualized in a graphical network obtained from Cytoscape software version 3.8.0 (US National Institute of General Medical Sciences [NIGMS] & National Resource for Network Biology [NRNB], 2020) which is an open-source software platform for visualizing complex networks and integrating these with any type of attribute data.

3. Results and discussion

The findings around the link between sustainability and PDOs in the EU are presented in two stages. The first stage is constituted by the analyses of the selected sample ($n = 41$) through the elements mentioned before: (1) Timeline growth of sustainability in PDO's research; (2) Sustainability in PDO's research by food type product; (3) Geographical location of research on sustainability in PDOs; (4) Methodologies approach used on research to study sustainability in PDOs, and (5) Sustainability term's combinations and its link to food type product.

3.1. Timeline growth of sustainability in PDO's research

The scientific literature that addresses the intertwining of products with PDOs considering a sustainability approach could be considered recent. Less than two decades ago, in 2005, the first study dedicated to assessing the sustainability topic on the olive oil production (PDO product) in the EU was published (Sanz Cañada & Macías Vázquez, 2005). This study emphasizes a close relationship between environmental welfare and olive traditional production, which generates profits for farmers. Therefore, the relationship between socio-cultural, economic, and environmental elements is important. Five years passed until another research that combined the mentioned two topics was published; the authors also addressed the production of olive oil from a quantitative methodology (Ramos & Santos, 2010). The data presented in the latter paper emphasized that when precipitation decreased in the area, controlled irrigation strategies had to be employed for crops, since olive groves provide economic security for farmers and jobs for the region of Alentejo, Portugal.

In Figure 3 it can be seen that, over the years, the scientific production around the links between sustainability and PDOs in the EU, has shown an upward trend, which reached its peak in 2017 and 2019 with six publications each year. It could be possible to correlate this behavior with the fact that 2015 was considered a “key year for sustainable development” (Elsevier & SciDev.Net, 2015, p. 1). By the end of the same year, the Sustainable Development Goals (SDGs) were approved within the new development agenda promoted by the United Nations Organization (UN). This could mean that sustainability discussion was brought into public discussion, development agendas, public policies, and scientific and academic groups, both at the local and the global levels among countries.

In 2020, the scientific publication on the topic started to fell, which could be interpreted as an effect of the current Covid19 related sanitary global crisis that has shackled academic research, as well as many other productive and social sectors. Nonetheless, by the first trimester of 2021 (the moment the database searching process finished), it is noticeable that there is still interest in resuming the topic, and before the middle of 2021, three scientific articles that combine both study topics have already been published.

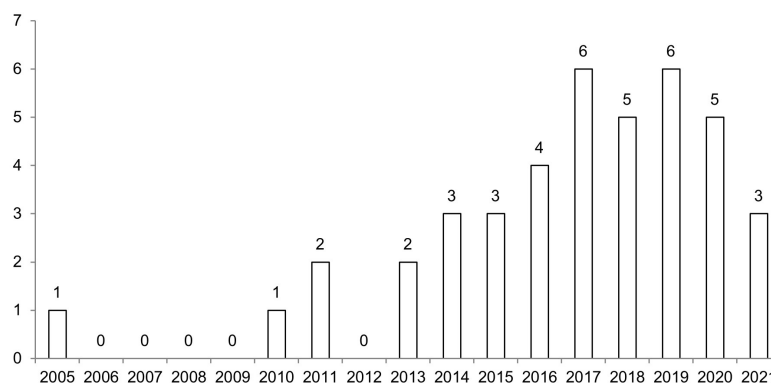


Figure 3. Sustainability approach in PDOs studies: publication trend from 2005-2021 (march), based on selected sample.

Figura 3. Enfoque de sostenibilidad en estudios de DOP: tendencia de publicación de 2005-2021 (marzo), basado en la muestra seleccionada

The behavior of published papers mimics the one in registrations: the volume of PDOs registrations before the EUIPO, which started to decline after 2007, with a maximum drop in 2010, is similar to the research in this topic, which has also presented a downward trend, resulting in zero papers published on the reviewed databases from 2006 to 2009. It is possible to infer that these trends could be partly due to some institutional and political changes in the EU that could affect the PDOs registration and might have impacted too. This might have happened because it was until 2008 that the European Court of Justice recognized PDOs as products related to origin, and it was until 2009 that the international Lisbon Agreement was signed, which seeks to strengthen regulatory processes within the EU, whose effects on interregional trade are not immediate (EC-EU, 2020).

Table 3. Sustainability in PDO’s research by food type, based on selected sample.
Tabla 3. Productos encontrados en la investigación de Sostenibilidad en DOP, basado en la muestra seleccionada.

Dairy (13)	Oils (10)	Grown food (3)
Fontina	Olive oil	Organic food
Dairy systems of Alpine	Olive sector	Agriculture
Tome des Bauges	Olive groves	Nuts (1)
Serra da Estrela cheese	Extra virgin olive oils	Chestnut
Cantal PDO farms	Wine (9)	Bakery (1)
Mountain food products	Wine	Mediterranean bread
Manchego Cheese	Organic wine	Wine & Seafood (1)
Dairy farms	Etna wine	Cod
Parmigiano Reggiano	Grapewines	Label (1)
Sjenica sheep cheese	Mamertino wine	Pdo, pgi and klasa
Grana Padano cheese	Fruits (2)	česká potravina/ czech food, regionální potravina/ regional food, and bio
Mozzarella di Bufala Camp	Arancia di Ribera oranges	
	Maletto strawberry	

It is noteworthy that the most recent studies on sustainability in PDOs, published in 2021, focused on the ‘origin’ label system in the EU, especially from consumer’s perception while acquiring products that, in addition to having a PDO’s label, were produced under sustainable agroecological procedures. In this sense, both Chalupová *et al.* (2021) and Spognardi *et al.* (2021) emphasized that labeling products manufactured under certification of the sustainable or organic process could have a positive effect on the consumption level, as it would generate satisfaction in the customers for purchasing quality organic products that are linked to an origin brand. These studies were carried out among Italian consumers and in the Czech Republic market, so this topic seems to be of interest to different producers in the sector.

3.2.Sustainability in PDO’s research by food type product

To go deeper into each category, a summary of every food type category has been made and each category refers to some of the original authors of the research papers.

3.2.1. Dairy

The studies included in the dairy category used the concept of sustainability to address issues such as feeding pastures for cattle, methodologies to assess environmental impacts, and practices used on farms. There is a strong connec-

tion between environmental circumstances and the social and economic sustainability of the activity. For example, in Bassanino *et al.* (2011) an evaluation of the nutrients (nitrogen and phosphorus) of lowland summer pastures in the Valle d'Aosta region was made. The purpose of this evaluation is to measure nutrients so that when farmers buy fodder for their cattle during the winter, they seek to match the amounts of nutrients from summer pastures to obtain the raw material for the dairy final product. It is observed that the environment and the conservation of summer pastures saved farmers the costs of cattle feeding. Therefore, the conservation of pastures is economically beneficial to the dairy sector because its conservation depends on the savings of inputs such as fodder.

Environmental protection for production is a topic that has been widely discussed in Laurent *et al.* (2017), who addressed it by offering a methodology to assess the impacts that livestock farming might have on the value chain of PDO's cantal cheese production; through a multi-criteria analysis, considering the participation of stakeholders, this paper reviews the activities that could impact on the production of PDO's cantal cheese, by integrating environmental variables such as management of grassland resources, management of farm buildings and landscape, and management of local water and energy resources.

Furthermore, an example of practices that should be applied to advanced towards sustainability in the dairy section De-Pablos-Heredero *et al.* (2018) conducts a study in Spain where, through the proposition of a four-dimension approach of sustainability (economic, technological, organizational, and formative) analyses how does the integration of these dimensions could enhance results by implementing smart farms. The results, after studying 157 farms, indicated that their economic and organizational sustainability was influenced by the return on investment.

3.2.2. Oils

For PDO's oils products, two studies highlighted the importance of integrating sustainability into production and commercial processes. Firstly, Egea and Pérez y Pérez (2016) concluded that governance, environmental care, and collaboration with all the agents involved in the production and commercialization networks, are fundamental to achieve sustainability within the farm sector of olive oil production in Spain. In this study, the social, environmental, and economic scope that sustainability offers as a guide for better resource management is visible. Secondly, in Spain, Millán *et al.* (2018) carried out a study where they make an interweaving with other sustainable activities such as sustainable gastronomic tourism and visits to olive oil production areas, which might contribute to the commercialization of oils produced in the region.

This paper stresses the multifunctionality of the PDO's territory by presenting oleo tourism as a practice in which visitors can enjoy the landscapes of the olive groves while learning about the elaboration process of a PDO's olive. This highlights the conservation of the environment, which, in addition to provide quality products, serves as a tourist attraction appreciated by attendants, leaving extra profits to people engaged in this activity sector.

3.2.3. Wine

Only in wine research was it possible to distinguish the use of Life-cycle Assessments (LCA) methodology, which could evaluate environmental impacts of PDO's production in a sustainable manner. In some of the research the impacts of the Rioja wine production chain were evaluated (Jiménez *et al.* 2014), and the water footprint was analyzed (Bonamente *et al.*, 2016). At the same time, Bonamente *et al.* (2016) and Jiménez *et al.* (2014) analyzed the energy levels needed to produce Italian Red Wine and Spanish Rioja wine respectively. In the first case, where Italian wine was studied, it was determined that, from an agri-food value chain perspective, the stage that generated the largest carbon footprint was packaging and distribution; on the other hand, the second study on Spanish Rioja wine does not conduct an environmental impact analysis but rather it runs a statistical model to determine the effect that decisions taken by wine producers have on the water footprint. Something to point out regarding this last paper is that its methodology is presented as a simulator to optimize wine production systems.

3.2.4. Fruits

The fruit studies include only two types of food: Maletto strawberries and Navel oranges. Maletto strawberries have a municipal PDO, which has benefited the community with a wider expansion of the business. This study was done by interviewing 13 strawberry farms to gather information on the impact of PDO in economic and technological variables, highlighting the production costs, labor and supplies for growing the fruit, and analyzing it by making comparisons among farms. In the case of water used as an important farm's supply, it is noted that the

production costs and other variables were different between farmers who obtained the water from wells and those who had to buy it. No distinction was made during the analysis that could lead to highlighting the need to protect aquifers for diminishing production costs. Nevertheless, this study does conclude that the least expensive input among their current assets is water and the most expensive is seedlings (Bellia *et al.*, 2015).

In the case of the Arancia di Ribera oranges, the study of Tudisca *et al.* (2014) focused on evaluating the repercussions of PDO registration in terms of profitability and sustainability for orange farms. The author concludes that the variability of production costs of Arancia di Ribera oranges lies in the farmers' management, the entity of land and investment, quality and quantity of fertilization processes, pesticide treatments, mechanical processes, and irrigation. The results, unlike the strawberry case, showed to be economically unsatisfactory although the product was of high quality. According to the study, a detrimental factor to profits was the ineffective PDO promotion policy and the fact that the product has not yet gained recognition by consumers.

3.2.5. Grown food

This category was designed to include processes to obtain certified food. As mentioned at the beginning of this section, there are no specific PDOs within the grown food category, but instead, it focuses on the research that studies the processes for obtaining them. Marescotti *et al.* (2020) addressed the search for IP by considering that PDO certification has economic purposes and gives value to local heritage, but also links to environmental justifications for certification.

In this sense, the author shows that, unlike PDOs, PGIs tend to be a more strongly rooted figure while considering the protection of the local environment. Therefore, the correlation between the evaluation of registration rules and environmental justifications was studied. The conclusions showed that even though there is a slight advance towards a more environmentally friendly legal framework for PDOs and PGI's registration rules, the environmental justifications were meant just to guarantee better competitiveness and to find new markets for the certified products.

In this category, Mili & Martinez-Vega (2019) emphasized that there is increasing pressure for production systems to evolve towards more sustainable practices. For this Spanish case, they observed that sustainability in agriculture should move towards having a greater diversification of economic activities alongside certifications and sustainable practices where the extension of agricultural land is larger, less agricultural area is burned, and carbon stock and sequestration by agricultural ecosystems is more efficient. Lastly, research addressing consumer behavior, and their willingness to pay for agroecological and organic products, was also integrated into this category. Bryła's research (2017) performed a correlation analysis among 1.000 polish food consumers to define that European known quality products, such as those using organic agricultural systems, correlated with consumers' willingness to purchase those products while paying higher prices for them.

3.2.6. Nuts, Bakery and Wine & Seafood

In the category of nut analysis, only one research conducted by Gullino *et al.* (2020) explored the possibilities of maintaining traditional PDO chestnut production landscapes, while conducting a focus group technique. From this exercise, two scenarios were constructed: the first one proposed the possibility of the disappearance of the chestnut stands, and the second implied the transformation of it. The major conclusion of this study was that traditional chestnut cultivation should remain based on a sustainable development model, where chestnut, and its derived products, continued to be processed within the PDO.

In the case of the bakery category, the study included three types of Italian bread: whole grain bread, Carasau, and Altamura, the latter with a PDO certification (De Boni *et al.*, 2019). The ingredients to produce the bread were evaluated, and surveys on experts and consumers were conducted. In addition, economic, socio-cultural, and environmental dimensions of sustainability were evaluated. As a result, the only bread that fulfilled the three dimensions of analysis was the Altamura bread. So that consumers prefer Altamura bread mainly because of its sustainability characteristics which were evaluated with economic attributes such as processing, value creation, value distribution; with socio-cultural attributes such as supply chain relations, rural development, and human health; and with environmental attributes such as biodiversity and resource management. Thus, it was perceived that the surveyed group had prior knowledge of the term sustainability and its implications.

In the case of wine & seafood, a special category was made, even though another category of 'wine' has been previously analyzed. In the study by Sánchez-Hernández (2011) two food value chains were comparati-

vely evaluated, PDO wine from the Castilla region of Spain, and Norwegian cod with international recognition, but without PDO. The main conclusions of the papers were that the PDO system has enhanced the integration of market niches and created profits for wine producers, while the opposite has happened in the cod case.

3.2.7. Labels

In the labeling research in the Czech Republic (Chalupová *et al.*, 2021), the importance of labeling for PDOs was highlighted. The study was conducted using a quantitative methodology and data was obtained through an online survey among food-producing companies that had proved successful while applying food quality and origin labels. This study reinforces the idea that the main motive of producers to apply for quality and origin labeling tends to be the search for economic benefits, prestige, and a better position in the market. However, the respondents considered that the expectations of using this type of label were higher than the obtained results, nonetheless, the marketing and communication strategies around the labels have boosted the participation of producers in events organized by the labeling authorities.

3.3. Geographical location of research on sustainability in PDOs

Not all the reviewed papers pointed out a specific country or place. Therefore, it was important to map the geographical location of research on sustainability in PDOs. It was found that in the EU, Italy has the largest number of PDOs and PGIs registrations (EUIPO, 2020). This could explain why the mapping of studies carried out, as it can be seen in Figure 4, showed a greater concentration of research on sustainability in PDO's in this country (Italy 15), followed by third-place on PDOs registration being Spain with 10 research as well, one of them including Norwegian case study. It is noteworthy to mention that, in cases where a country was not specified in the research, it was decided not to locate it on the map, but it was mentioned in the analysis.

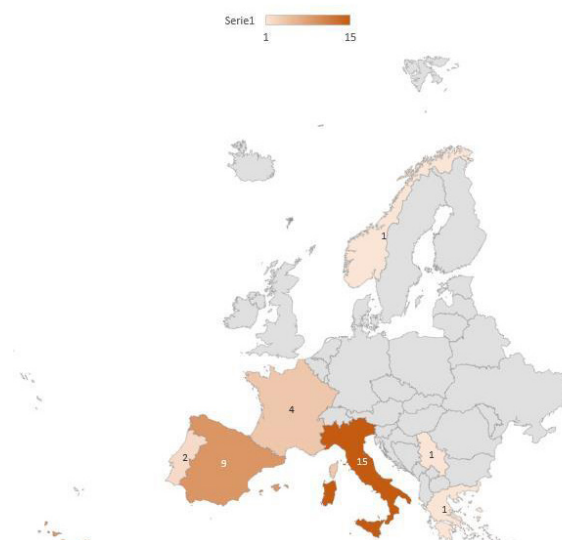


Figure 4. Geographical distributions of PDO and PGI studies linked with sustainability ($n = 41$), based on selected sample.

Figura 4. Distribuciones geográficas de los estudios de DOP e Indicaciones Geográficas (PGI en inglés) vinculados a la sostenibilidad ($n = 41$), basado en la muestra seleccionada.

In this geographical analysis it was found that in some cases papers were developed using the EU as a central region of analysis, and as region it was studied in 6 papers, followed by those 4 studies that took place in France, Portugal with 2 papers, and Greece, Czech Republic, Polish and Serbia with only one research performed in each country. By combining the geographic location of the research and the food type categorization, it was observed that the country and the category with the highest representation within the selected sample ($n = 41$) is Italy and dairy products (as can be seen in Figure 5), followed in second place by Spain and Oils.

In general, these results show that research on sustainability in PDOs is mostly carried out in those countries with the highest volume of PDOs institutional registration and with the highest PDO productive activity

and experience. Besides, this geographical distribution reflects that protection schemes, such as the PDOs, are still emerging figures, particularly in commercial stages and within the research realm, especially in Eastern European countries that are part of the EU.

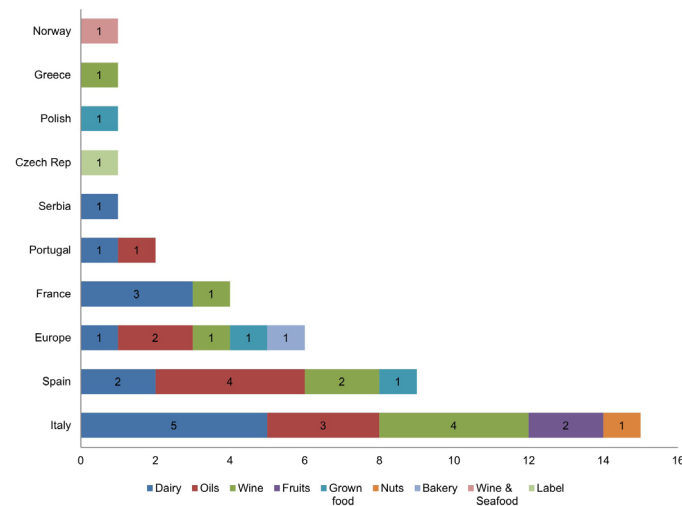


Figure 5. PDO's research by country and food type product, based on selected sample.

Figura 5. Investigación de la DOP por país y tipo de producto alimenticio, basado en la muestra seleccionada.

It should be noted that, although Europe is shown within the research category, this region only concentrates a very small part of the studies (6 of them), the rest of them are localized to a specific country. Furthermore, although Italy concentrates the largest number of studies, it does not include all food categories (having just 5 out of 9) since grown food, bakery, wine & seafood, and labels are not represented in this country.

Finally, the countries with the lowest quantity and diversity of studies are Norway, Greece, Polish, Czech Republic, and Serbia, as all five of them covered only one type of food each. However, it is interesting to note that the Czech and Norwegian studies provide food categories not covered in the other European countries, such as labels and wine & seafood. These two types of food provide diversity to the sample, allowing for a wider range of analyses.

3.4. Methodologies approaches used to study sustainability in PDOs

After analyzing the selected sample ($n = 41$), Figure 6 shows the distribution among the different approaches: qualitative, quantitative, or a mixture of both (labeled as mixed). As it can be seen, most researchers used a combination of methodologies, being the most common mixed methodologies (both quantitative and qualitative) that complement each other. This latter is congruent with the inclusion of one of the main axes of sustainability, which is the interdisciplinary perspective for the understanding of socio-agroecosystems.

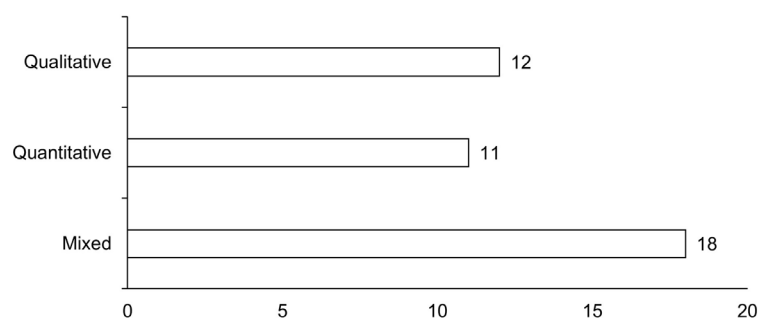


Figure 6. Used methodology among 41 selected articles.

Figura 6. Metodología utilizada en los 41 artículos seleccionados.

Note: The analysis was carried out between three categories: Qualitative, Quantitative, and Mixed.

To deeply understand how sustainability problems were addressed on the selected sample, a subclassification for each methodology was proposed: E.g. ‘Qualitative methodologies’ included methodological techniques such as fieldwork and participatory observation, expert opinions, interviews (that considered structured, semi-structured, and in-depth interviews), surveys (paper surveys, online surveys, including focus groups), database analysis, content-coding and text analysis (blind analysis) and case study. The ‘other’ category was created for methodologies that were not often used and were mentioned mostly once, like stepwise design, exploratory approach, systematic analysis, or sensory test. Results can be seen in Figure 7 and Figure 8, comprehending all reviewed researched articles.

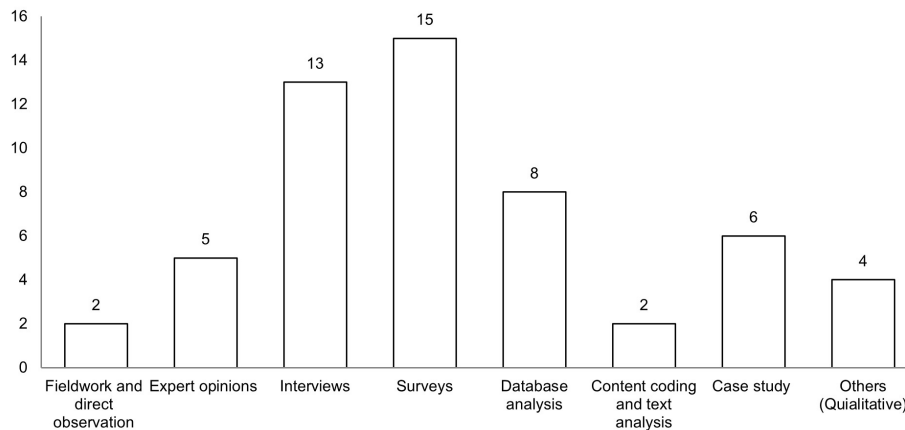


Figure 7. Qualitative methodologies to address sustainability in PDOs, based on descriptive statistics of the article data set.

Figura 7. Técnicas de metodología cualitativa para estudiar la sostenibilidad en las DOP, a partir de las estadísticas descriptivas del conjunto de artículos consultados.

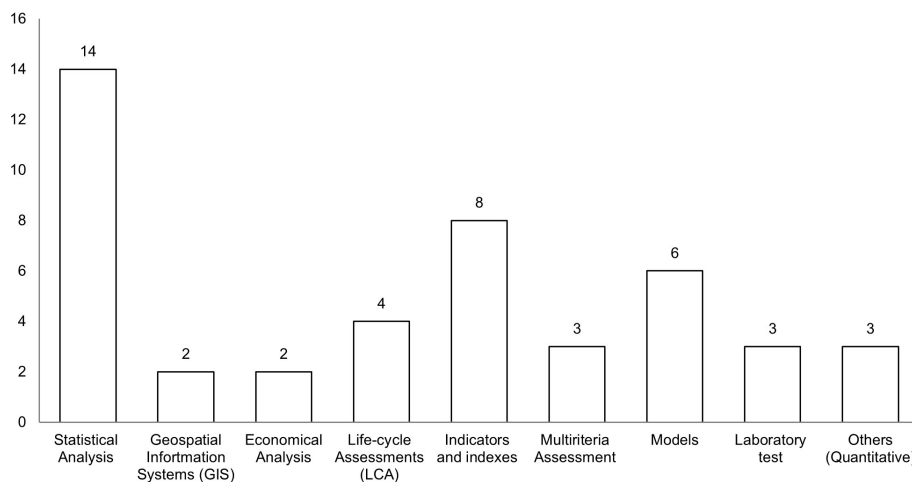


Figure 8. Quantitative methodology to address sustainability in PDOs, based on descriptive statistics of the article data set.

Figura 8. Técnicas de metodología cuantitativa para estudiar la sostenibilidad en las DOP, a partir de las estadísticas descriptivas del conjunto de artículos consultados.

As it can be seen in Figure 7 most recurrent techniques for qualitative methodology were interviews and surveys, which, in combination, represented more than 50% of used methodological approaches. This is different when it comes to ‘Quantitative methodologies. Figure 8 shows a wider variety of tools, although most researchers used statistical analysis, followed by both creation and integration of indexes and indicators to evaluate any dimension of their sustainability problems. In third place, with 6 mentions, the creation or application of mathematical and probabilistic models was the most used approach. The category ‘others’ for quantitative

included tools that were mentioned once, such as food value chains (seen as a methodological tool instead of as an analytical approach), Farm-gate balance (FGB), water and carbon footprint assessment. On this matter, although carbon footprint relies on the same logic behind life-cycle assessment (LCA) it has specific ‘impact’ elements that distinguish it from LCA (Blonk Consultants, 2020).

There is no common or defined profile when it comes to the type of methodologies, both qualitative and quantitative, merged and used to study a sustainability subject in PDOs, but it seems that researchers use at least two of them. Figure 9 illustrates how many tools usually converge when addressing sustainability in PDO papers.

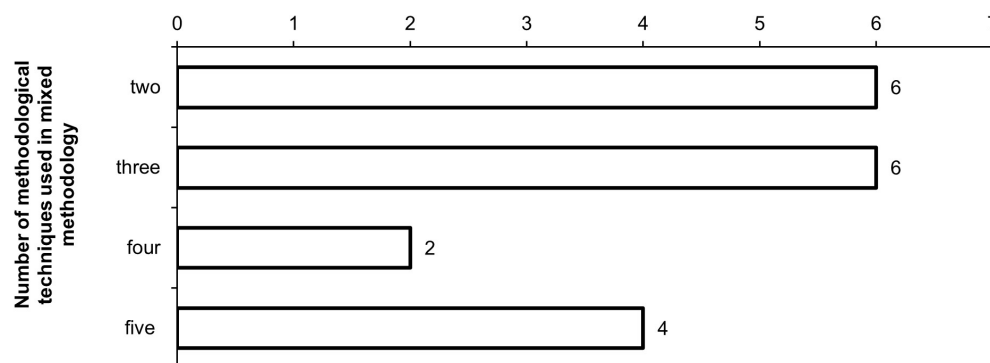


Figure 9. Number of tools used in ‘mixed’ methodology to study sustainability in PDOs, based on descriptive statistics of the article data set.

Figura 9. Número de herramientas utilizadas en la metodología ‘mixta’ para estudiar la sostenibilidad en las DOP, a partir de las estadísticas descriptivas del conjunto de artículos consultados.

On the ‘Mixed’ methodologies, surveys are also the most used technique (11 out of 18 research) and in 54% of the times, surveys were enriched with statistical analysis, which is the most used quantitative methodological technique followed by statistical, predictive, conceptual, or structural models. Of particular interest is that research that has managed to integrate statistical analyzes, surveys, and even interviews or expert opinions, has been focused on analyzing the potential of tourist activities and the use of agri-food landscapes from a sustainable perspective (territorial multifunctionality), especially in territories under institutional protections. At the same time, surveys have been a resource used to analyze agri-food system stakeholders and consumer’s perception, followed by its subsequent statistical treatment by multinomial regression that could help to build a prospective analysis and future scenario (De Boni *et al.*, 2019).

In the same way, collecting information through surveys, and its subsequent statistical treatment is a commonly used resource in research where the aim is to assess the effect of agri-food activities over the environment by using proxy indicators, such as climate change or agronomic adaptation, thus building probabilistic estimates for the identification of prospective scenarios (Resco *et al.*, 2016).

Methodological mixed approaches, when considering the type of product, are hugely common on dairy, oil, and wine products (over 70% of reviewed works). Results indicated that 5 out of 7 studies that merged more than 4 different methodological techniques are related to dairy cases. This might be due, in part, to the fact that the dairy production analysis usually occurs in traditional production systems with specific agri-environmental conditions, and which require, given the limitations of their territory, an analysis of the sustainability of agri-food landscapes, as well as to elucidate around critical points management throughout production processes, energy use, or even regulatory and institutional frameworks that might affect these forms of production under PDO protection (Bassanino *et al.*, 2011; Coelho *et al.*, 2017).

3.5. Sustainability term’s combinations and its link to food type product

The term sustainability was one of the criteria for including scientific research in the selected sample and is a fundamental element for this study. Hence, to explore how the term sustainability is used, a search of the term, and its combinations to other concepts, was performed and then its usage was with the categories of food type. The first step was to identify in the sample the combinations of the term sustainability. From this process, 15

‘binding categories’ were proposed with the found combinations. Secondly, a match between sustainability combinations (‘binding categories’) and the 9 food types was obtained. As mentioned before, the food types are (1) dairy, (2) oils, (3) wines, (4) fruits, (5) grown food, (6) nuts, (7) bakery, (8) wine & seafood, and (9) labels. On the other hand, the binding categories are sustainable agriculture, sustainable behavior (consumption), sustainable concept or theoretical approach, sustainable development, sustainable farms, sustainable food, sustainable image (company image), sustainable indicator, sustainable labels, sustainable management, sustainable policy, sustainable production systems, sustainable prospective scenarios, sustainable quality models or process, and sustainable supply chain.

To analyze the results, a graphical network was generated (Figure 10) depicting the 9 food types and the 15 binding categories. Each link shows the number of times the binding category was found in the food type research.

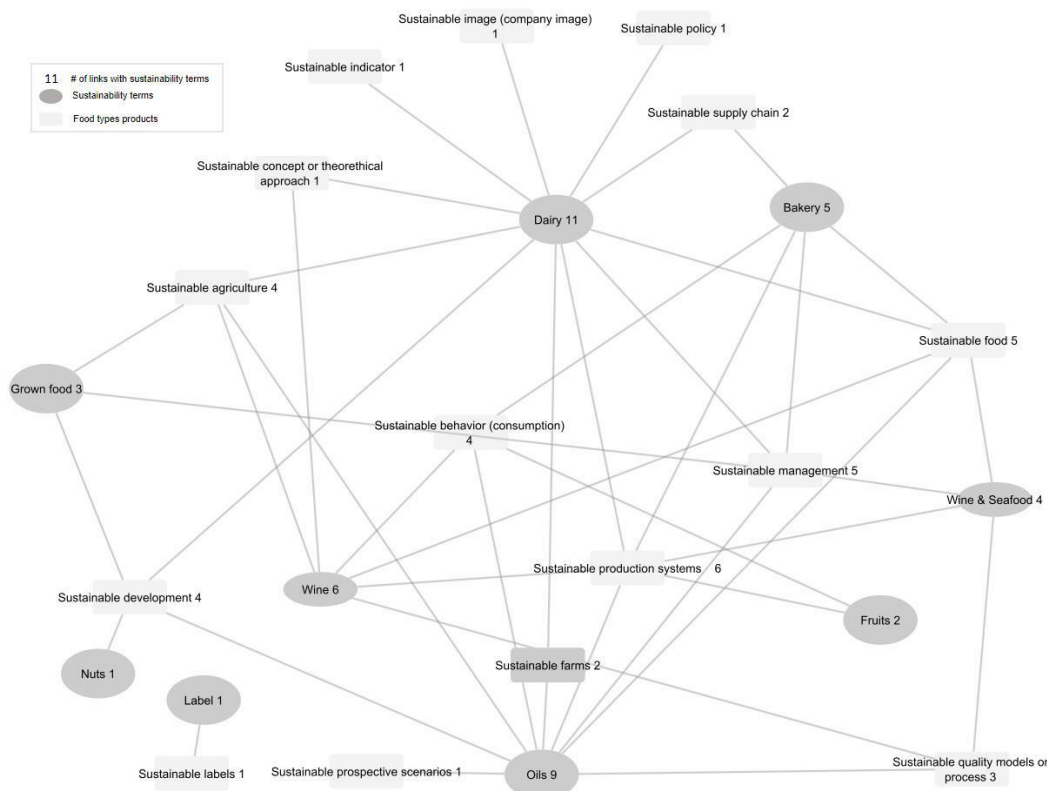


Figure 10. Sustainability terms graphical network on PDOs research by food type product, based on descriptive statistics of the article database by using Cytoscape.

Figura 10. Red gráfica de términos de sostenibilidad en la investigación de DOP por tipo de producto. alimenticio, a partir de las estadísticas descriptivas del conjunto de artículos consultados mediante el uso de Cytoscape.

In Figure 10, the 9 food types are distinguished by gray circles and vary in size according to the number of connections they have with the 15 ‘binding categories’. The food type with the most connections to the ‘binding categories’ is dairy because of the number of papers included on the analysis of sustainability in PDOs. At the same time, dairy has the most links with the 15 ‘binding categories’ (11 out of 15). In second place oil related research is located (that has 9 linkages with the other ‘binding categories’), while wine has 6 connections, bakery has 5 links, wine & seafood have 4, fruits category has 2, grown food with 3, and label and nuts have just 1 connection to ‘binding categories’, respectively.

On the other hand, the 15 ‘binding categories’ are displayed by name: sustainable production systems have the most linkages (6 of them), followed by sustainable management (5), sustainable food (5), sustainable agriculture (4), sustainable behavior (consumption) (4), sustainable development (4), sustainable quality models or process and sustainable supply chain (3), sustainable concept or theoretical approach (2), sustainable farms (2), sustainable image (company image) (1), sustainable indicator (1), sustainable labels (1), sustainable policy (1) and sustainable prospective scenarios (1). This proved that, while discussing research on PDOs,

there is not a single sustainability point of view. Although there is conceptual agreement on the matter among researchers, a series of sub-themes arises from sustainability, especially while considering that the most used binding category was sustainable production system because it integrates complete value chains and complex agri-food systems perspective.

4. Conclusions

Although the EU is the region with the most ancient practices around the PDOs, the inclusion of the economic, social or environmental perspective in an integrated manner (as dimensions of sustainability) is recent. It is possible to perceive that in PDOs research a trend to include economical elements has arisen, which is not surprising since the PDOs are figures designed mostly for commercial promotion of added value goods, as well as protection against practices such as biopiracy in local and global markets.

The results of this analysis reflected that the largest number of PDOs registrations in the EUIPO were done in the same places where the majority of research was performed. The most analyzed products were dairy derivatives such as cheeses, while a second place was occupied by oils, leaving processed fruits, vegetables and cereals in third place. All of this could give us hints to understand that there is a direct, and positive, relationship between the interests of PDOs agri-food productive sectors, which materializes these concerns in forms of PDOs registration in the European offices, with the interest of academic research. This direct relationship could be considered as a virtuous circle because the greater the PDOs productive activity, the larger the available information on the matter, and, if research and information and technology transfer on the topic increase, especially from a sustainability perspective, better performance of these activities could be expected.

On the temporary trend, this research found that there has been an increased tendency in researching sustainability in PDOs, which could occur because global institutional frameworks, under which the EU operates by sharing regional public policies. This might have effects on the locality in such a way that the mere signing of agreements, such as the Lisbon agreement in 2009, show positive effects in the increasing interest in products with designation of origin because there is strong pressure to environmental protection established in the normative requirements of the EU community agrarian policy (CAP). This institutional framework controls part of the income or stimuli for agricultural producers that comply with rigorous environmental measures and agroecological practices, although on this CAP there is still a gap regarding the sustainability concept integration.

This is especially reflected in the case of cheeses since it might be considered an activity that it's not only agricultural but also related to livestock, involving a series of complex processes and rigorous quality systems. In this sense, research has incorporated sustainability elements by using environmental analysis around the quality of pastures, landscapes quality, nutrient content in agricultural soils for livestock use, water and energy management, and by proposing a technological dimension in sustainability subjected to improve the performance of smart agricultural farms.

While discussing the type of products found in this research, it is not surprising that oils and wines, two products with a great productive tradition in the EU region, show great weight in sustainability studies, especially since they have focused on long term resource management by integrating the multifunctionality of territory based on gastronomic practices and agri-food tourism, which could become an important factor for local development, contributing to consumer awareness regarding PDOs, and showing economic benefits in the sector.

On the other hand, the methodological analysis allowed us to rescue a series of tools used in the research of PDOs sustainability. The diversity of these instruments and the constant use of mixed methodologies might be because the sustainability approach requires the inclusion of different disciplines to attend to the economic, social, and environmental dimensions of each issue. Thus, it is not surprising that the methodologies used at various tools to gather enough PDOs information to deliver interdisciplinary analyzes. This is relevant because analytical frameworks to address sustainability must be built from the integration of different databases, and codable and non-codable information, which is still an unfinished task for researchers.

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Contributor Roles

- Laura Elena Martínez-Salvador: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, validation, writing – original draft, writing – review & editing.
- Alejandra Reyes-Jaime: data curation, formal analysis, investigation, methodology, validation, writing – original draft.

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