# Biodiesel from beef tallow: a technological patent mapping

# Biodiesel de sebo bovino: um mapeamento de patente tecnológica

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## ABSTRACT
Beef tallow has become indispensable for the production of biodiesel since the introduction of biofuel manufacturing methods. The objective of this study is to create a technological map of patents that have employed bovine tallow in the manufacturing of biodiesel over the last ten years (2009–2019). The methodological approach was established using a bibliographic survey and a content analysis, in which keywords from the European Patent Office's (Espacenet) and Derwent Innovations Index databases were employed (DII). After a preliminary examination, 34 patents were found, divided into eight patent families, with China being the largest repository of these technologies, suggesting that the companies that promoted the use of beef tallow as a fuel had diversified completely, with no monopoly on technological content for a specific group of institutions.

**Keywords**: biofuel, animal fat, technological development.

## RESUMO
O sebo bovino tornou-se indispensável para a produção de biodiesel desde a introdução dos métodos de fabricação de biocombustíveis. O objetivo deste estudo é criar um mapa tecnológico das patentes que utilizaram o sebo bovino na fabricação de biodiesel nos últimos dez anos (2009-2019). A abordagem metodológica foi estabelecida por meio de levantamento bibliográfico e análise de conteúdo, em que foram utilizadas palavras-chave das bases de dados do European Patent Office (Espacenet) e Derwent Innovations Index (DII). Após um exame preliminar, foram encontradas 34 patentes, divididas em oito famílias de patentes, sendo a China o maior repositório dessas tecnologias, sugerindo que as empresas que promoveram o uso do sebo bovino como combustível se diversificaram

completetamente, sem monopólio de conteúdo tecnológico para um grupo específico de instituições.

**Palavras-chave**: biocombustivel, gordura animal, desenvolvimento tecnológico.

## 1 INTRODUCTION

Biodiesel can be produced from raw materials such as vegetable oils, animal fats, or restaurant fats in a process called "transesterification", which is a chemical reaction that involves the presence of an alcohol and a catalyst. It is safe, biodegradable, and produces less pollutant than petrochemical diesel (Mekala et al., 2014). The choice of raw material, as well as its economic viability, has a significant impact on the quality of biodiesel produced in different regions, accounting for up to 75% of the total cost of production (Adewale et al., 2015).

One of these inputs is beef tallow itself, which in the past was discarded or had little added value. Over the years it has become an important raw material for the production of biodiesel. This is mainly due to two factors: (i) low cost and (ii) high supply in some regions, in addition to non-competition with the food market (Krause, 2008). In Brazil, for example, a leader in the production of biodiesel in South America, tallow has established itself as the second most used raw material, only surpassed by soybean oil (ANP, 2019). This fact is due, among other factors, to the global leadership of Brazilian livestock, which in 2018 reached more than 214.7 million head of bovines available in the country (ABIEC, 2019).

Beef tallow is one of the waste products generated in the slaughterhouse and slaughterhouse industries through the use of the existing greases in these establishments. Typically, this residue is sent to the soap industry, and when there is an excess of this material in the market, it is directed to incinerators or disposed of in an irregular manner in the environment. Therefore, industrial integration is necessary as an alternative means of work and to reduce the accumulation of these residues in the environment. (Costa Neto et al, 2000).

Bovine tallow consists mainly of saturated chain fatty acids, among which oleic acid (47.2%, w/w), palmitic acid (23.8%, w/w) and stearic acid (12.7%, w/w). This sebum saturation characteristic influences two relevant properties of generated biodiesel: oxidative stability and cold filter clogging point (Wyatt et al, 2005; Imahara et al, 2006).

Oxidation is an autocatalytic reaction that gives rise to new products, such as hydroperoxides, dimers, polymers, alcohols, hydrocarbons, and ketones, which can harm the engine and all fuel systems. Bovine tallow, as it has a low concentration of polyunsaturated fatty acids, has better stability when compared to inputs from vegetable oils. On the other hand, in colder environments, this fuel from tallow can solidify, leading to poor performance of engines (Moraes et al, 2008).

The scientific works discovered, in general, address the techniques and characterization of tallow biodiesel. Cloud point, ease of cold impregnation, power calorific, cetane number, and oxidative stability are analyzed in order to improve the fuel quality. (Tong et al, 2010; Adewale et al, 2015; Pinto et al, 2015).

To create a higher-quality product, beef tallow transterification procedures, alcohol and catalyst selection, optimum working temperature, and biodiesel refining are used. Furthermore, research has indicated that blending biodiesel from beef tallow with biodiesel from vegetable oils, as well as the use of additives, can provide an alternate possibility for improved biofuel characteristics and blends having better oxidative stability. (Pereira et al, 2017).

The production of NOx is a key aspect of biodiesel made from animal fats. When compared to emissions produced by biodiesel generated from soybean oil, bovine tallow has a lower NOx content due to a higher saturation of the carbon chain. Additionally, when compared to mineral origins, this biodiesel has a higher cetane number, resulting in a faster burning of the biological fuel (Cremonez et al, 2015).

Another possibility for biofuel generation is the production of hydrogen by means of gasification of beef tallow. Hydrogen obtained from tallow has been proposed as a low-risk end use for livestock waste and therefore removed from the food chain (Hajjaji e Pons, 2013).

From a structural point of view, fat differs from oils by the degree of saturation of the carbon chain, that is, different animal fat residues may have different characteristics and concentrations of free fatty acids and different saturations. Oil is in the liquid phase due to unsaturated fatty acids (mono and polyunsaturated), while fat such as tallow exists in the solid phase due to the presence of saturated fatty acids. Despite having a greater supply than oil seeds, animal fats are not advantageous when applied directly in the production of biodiesel, due to the low vapor-air mixture, incomplete combustion, and engine deposits (Gürü et al, 2010; Srinivasan e Jambulingam, 2018). Table 1 shows the composition of some fatty acids from animal fat.

Table 1. Fatty acid composition from animal waste

| Fatty acids | Carbon number | Animal fat wastes | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Yellow grease. | Brown grease | Choice white grease | Lard | Tallow | Chicken fat | Fish oil |
| Lauric | C12:0 | - | - | - | - | - | - | 0.14 |
| Myristic | C14:0 | 1.02 | 1.7 | 1.60 | 1.41 | 2.76 | - | 5.77 |
| Palmitic | C16:0 | 14.83 | 23.8 | 22.39 | 25.69 | 25.95 | 22.20 | 16.94 |
| Palmitioleic | C16:1 | 1.50 | 3.1 | 3.40 | 2.82 | 2.84 | 8.40 | 5.42 |
| Stearic | C18:0 | 8.41 | 12.5 | 9.15 | 14.50 | 17.54 | 5.10 | 4.31 |
| Oleic | C18:1 | 47.88 | 42.4 | 44.14 | 40.88 | 41.67 | 42.50 | 19.20 |
| Linoleic | C18:2 | 19.11 | 12.1 | 11.90 | 12.93 | 6.91 | 19.30 | 16.05 |
| Linolenic | C18:3 | 4.68 | 0.8 | - | - | - | 1.00 | 2.82 |
| Arachidic | C20:0 | 2.56 | - | 7.43 | 0.50 | 0.44 | - | - |
| Eicosenoic | C20:1 | - | - | - | 1.34 | 1.88 | - | - |
| Eicosadienoic | C20:2 | - | - | - | - | - | - | - |
| Eicosapentaenoi | C20:5 | - | - | - | - | - | - | 15.55 |
| Docosapentaenoic | C22:5 | - | - | - | - | - | - | 2.45 |
| Docosahexanoic | C22:6 | - | - | - | - | - | - | 11.36 |

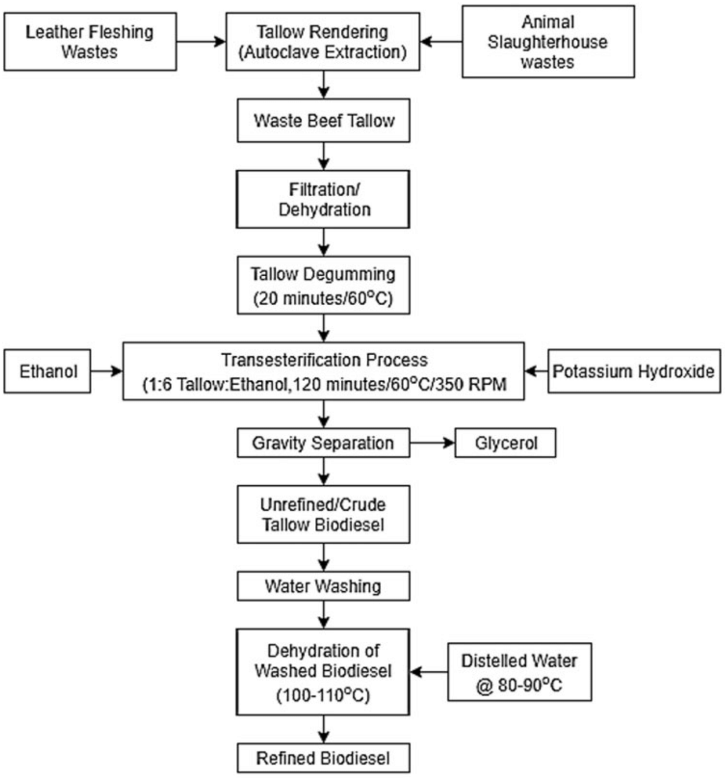
Reference: Adewale et al. (2015)

Animal fat for biodiesel production can be obtained in different ways, including by processing cattle tallow, swine lard or fat from domestic birds such as chickens, turkeys, and other birds. In addition to fish fat and oil, which have been shown to be viable for the production of biodiesel, there are also other lipid fractions that can be extracted from bone and meat meal (Iglesias e Morales, 2012; Adewale et al, 2015). Tallow (from cattle slaughtering processes), lard (from pork fat), chicken fat, fish processing residues, and leather are generally the most studied by several authors (Gürü et al., 2010; Alptekin e Cankci, 2010; Bianchi et al. , 2009; Stojković et al. , 2016; Ezekannagha et al. , 2016; Šánek et al. , 2016; Adewale et al, 2015).

Yellow fat, also known as used cooking oil, is widely available in many commercial establishments and homes in both urban and rural areas, and has a free fatty acid concentration of less than 15%. (Sabudak e Yildiz, 2010). Brown fat or grease refers to materials that have amounts of free fatty acids greater than 15%. It is a residue usually disposed of in compartments of restaurants, homes, or in industries in the food sector, for example (Dias-Felix et al, 2009; Iglesias e Morales, 2012).

Despite the growing demand for animal fat residues, it is common to note that this type of material is expanding and often not fully widespread in many markets in the world.

Figure 1 shows a block diagram with the steps for biodiesel production from animal fat (Srinivasan et al., 2018).




Reference: Srinivasan et al. (2018)

Biofuels are divided into two categories from a technology standpoint: first-generation biofuels and advanced biofuels. Transesterification (with catalyst acid, basic, enzymatic, and heterogeneous) is the traditional manufacturing process for the first generation of biodiesel, but alternative processes such as hybrid processes, hydroesterification, and pyrolysis are also used. This research is crucial in identifying and mapping the current stage of biodiesel technology derived from beef tallow biodiesel, given the existing fuel production scenario and its environmental repercussions. As a result, the objective of this study was to identify the characteristics and evolution of technological abilities using a survey of patents deposited in certain databases over a ten-year period (2009 to 2019).

## 2 MATERIALS AND METHODS

Methodology can be defined as the study of procedures with the objective of getting specific knowledge. In other terms, methodology can be defined as the way of thinking and the practice used in approaching reality. (Minayo, 1998; Demo, 2003).

In this sense, a technique is a set of stages and processes that must be completed in a specific order, laying out the path to be taken. This collection of procedures establishes a path along which the researcher can have faith in the investigation, which is critical for successful outcomes. Furthermore, the method is determined by the classification of the study that one desires to conduct, whereas the type of research determines the methodological processes that must be followed in order to reach the proposed objectives. (Marconi e Lakatos, 2001)

The research was carried out by gathering data from the European Patent Office's (Espacenet) and Derwent Innovations Index's (DII) databases, from which the International Patent Classification (IPC) codes were retrieved. Both databases have a broad scope, with information on inventions and technological development dating back to 1782 (Espacenet) and a chemical structure database that can be used to locate patents with chemical information (DII) stage, keywords like "beef tallow," "animal fat," and "animal waste" were used in the search fields of each electronic platform. To ensure better coverage of the verified results and analyze the possibility for innovation, the Boolean operator "OR" ("or") was included. For the datasets employed in this study, a ten-year span of scientific production was delimited, encompassing the years 2009 to September 2019. At the end of the relevant term, the words "producing biodiesel" was added. The INPI Brazilian patent database was also used in this search using the same Portuguese translated keywords.

The initial evaluation showed 312 deposits registered by Espacenet and 224 deposits registered by DII. The retrieval of the information contained in the patent documents was analyzed individually to verify whether the records found had a specific relationship with the proposed topic of this work (Patents for Biodiesel Production from Beef Tallow). In this way, the analysis obtained 34 records of patents filed, of which only 3 were linked exclusively to the DII patent databases.

The specific research themes investigated were biodiesel production, physical-chemical characteristics, engine performance, atmospheric emissions, and life cycle. For physical-chemical characteristics, the keywords were "characterization of beef tallow biodiesel", "cetane number", "viscosity" and "density" combined with the terms "beef tallow biodiesel" and "blends of beef tallow biodiesel". The keywords "emission beef tallow," "engine beef tallow," "performance motor," and "blends beef tallow emission" were chosen to explore characteristics of engine performance and atmospheric emissions. In order to examine life cycle analyses, patentes were searched using terms like "life cycle beef tallow" and "life cycle animal fat."

## 3 RESULTS AND DISCUSSIONS

The investigation carried out provided an overview of the number of patents related to the theme of biodiesel from beef tallow between the years 2009 and 2019 (see Table 1). In this scenario, eight (8) subclasses of patents related to IPC data will be observed, in which it was identified that a great variability of patents were classified in Section C (Chemistry and Metallurgy). At the same time, it is clear that the codes referring to beef tallow biodiesel, which obtained the largest number of patents (ie, 12 patents), were C11C, whose meaning is expressed in Table 1 below, followed by C10L (ie, 11 patents), C11B (ie, 4 patents), B01J and C12P (ie, 2 patents each), and finally B01D, C07C, and C10G (ie, 1 patent each).

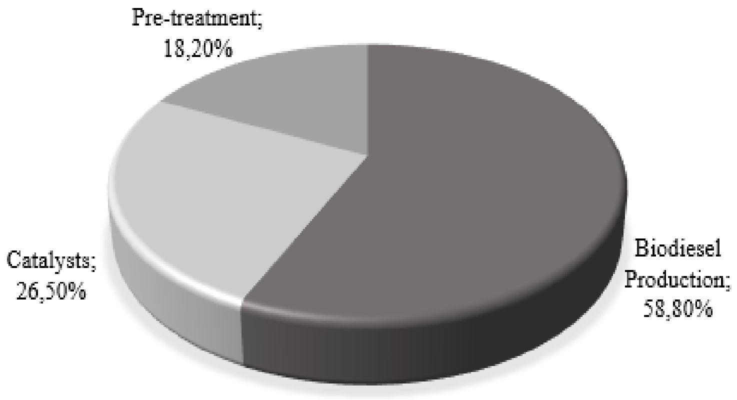
Table1. Evolution of patent codes, 2009-2019

| Code | Description |
|---|---|
| C11C | Fatty acids obtained from fats, oils, or waxes; candles; fats, oils, or fatty acids obtained by chemical modification of fats, oils, or fatty acids |
| C10L | Fuels not otherwise provided for; natural gas; synthetic natural gas obtained by processes not covered by subclasses C10G or C10K; liquefied petroleum gas; use of additives to fuels or fires; fire-lighters |
| C11B | Producing, e.g. by pressing raw materials or by extraction from waste materials, refining or preserving fats, fatty substances, e.g. lanolin, fatty oils or waxes, essential oils; perfumes. |
| B01J | Chemical or physical processes, e.g. catalysis or colloid chemistry; their relevant apparatus |
| C12P | Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture |
| B01D | Separation (separating solids from solids by wet methods B03B, B03D, by pneumatic jigs or tables B03B, by other dry methods B07; magnetic or electrostatic separation of solid materials from solid materials or fluids, separation by high-voltage electric fields B03C; centrifuges B04B; vortex apparatus b04c; presses per se for squeezing-out liquid from liquid-containing material B30B 9/02). |
| C07C | Acyclic or carbocyclic compounds (macromolecular compounds C08; production of organic compounds by electrolysis or electrophoresis C25B 3/00, C25B 7/00). |
| B10G | Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g. by destructive hydrogenation, oligomerisation, polymerisation (cracking to hydrogen or synthesis gas C01B; cracking or pyrolysis of hydrocarbon gases to individual hydrocarbons or mixtures thereof of definite or specified constitution C07C; cracking to cokes C10B); recovery of hydrocarbon oils from oil-shale, oil-sand, or gases; refining mixtures mainly consisting of hydrocarbons; reforming of naphtha; mineral waxes. |

Source: (INPI, 2019)

Due to the great variability of the subclasses, the patent summaries were analyzed to classify the segments for the production of biodiesel from beef tallow. The database of DII data provides a very detailed field on the basis of consultation data with detailed information on the product, such as possible benefits and the use of the patent. After this stage, it was observed that the 34 records found related to catalysts (26.5%), pre-treatment devices (18.2%) and the production of biodiesel using animal fat and other raw materials (58.8%), as shown in Figure 1.

Figure 1: Origin of patents for the production of biodiesel from tallow Source: (Espacenet , 2019; DII, 2019)




As for the annual evolution of the filings of these patents, the year with the largest number of patents registered was 2009, corresponding to 23.5% (8). The years that did not show a significant increase always had a number of publications that reached a maximum of four in any given year. Table 2 shows the evolution of the number of patents related to the production of biodiesel from beef tallow in the period from 2009 to 2019.

Table 2. Annual evolution of patents on bovine tallow biofuels

| Year | Number of patents | Year | Number of patents |
|---|---|---|---|
| 2019 | 1 | 2013 | 3 |
| 2018 | 3 | 2012 | 4 |
| 2017 | - | 2011 | 3 |
| 2016 | 3 | 2010 | 2 |
| 2015 | 3 | 2009 | 8 |
| 2014 | 4 | | |
| Total | 34 registries | | |

Source: (Espacenet , 2019; DII, 2019)

When it comes to the organizations that patent the largest amounts of tallow biodiesel in the world, especially those in Asia, especially China, the 34 records come from different individual deposits, at least 6 from universities. In Table 3, the main depositors and cesionaries of identified patents are listed.

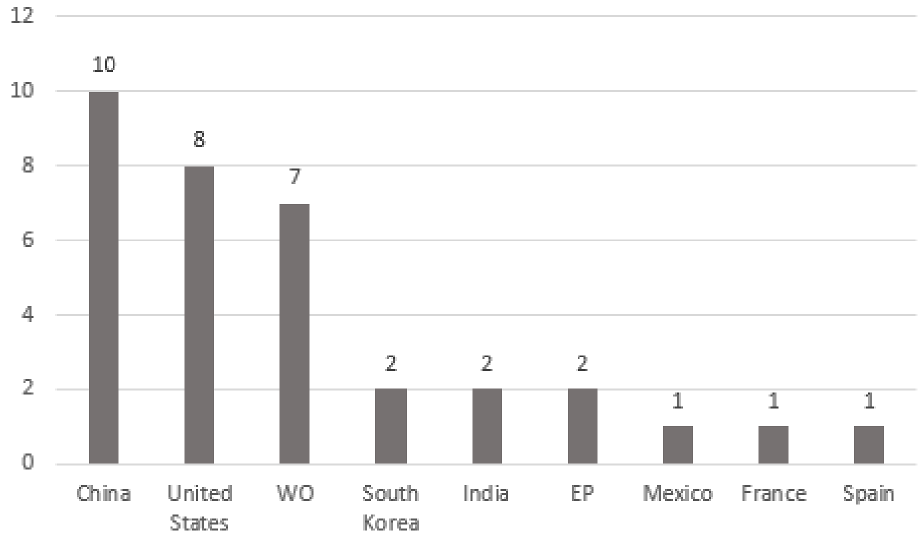
Table 3. Main bovine tallow biodiesel deposit organizations (2009-2019)

| Code | Organizations / Institutions |
|---|---|
| C11C | Univ. Shandong Suzhou, JIAH-I, Dalian Institute of Chemical Physics, Univ. China Petroleum, Inner Mongolia Tian Shou Tech, Huainan Quanrun Environment Protection, La fleur, Qingdao Fresh Bio-Energy Technology Development Co, Chakraborty R., Ind. Management SA, A.S.E.R. Srl y Arisdyne Systems. |
| C10L | Univ. Nevada, Univ. Zlin Batas, Lavella P., Endicott Biofuels, Carre Pons, Patil R.C., Univ. Auburn, Escobar M. A. O., Univ. Huaqiao, Imperial Petroleum y Blue Sun Energy. |
| C11B | Zhengzhou Huilv Technology, Neste Oil Oyj, Alfa Laval Corp. y Cavitation Technologies. |
| B01J | Olva Technologies Sarl y Council ScI & Ind. |
| C12P | Inner Mongolia Zhongxiruan Technology y Trans Bio-Diesel |
| B01D, C07C, C10G | Menlo Energy Management, Korea Inst. Energy y DurimKorea |

Source: (Espacenet, 2019; DII, 2019)

In Figure 2, we list the countries where patent applications have been filed for the production of biodiesel from beef tallow through the investigated databases. It is worth noting that during the investigations, an invention could be deposited in one of the poorest countries. In this sense, it is observed that China obtained the highest patent application, followed by the United States and the United States by the World Intellectual Property Organization (WO). This leader in the number of China's patents does not reflect the leadership in the production of biodiesel worldwide. According to the data published by the Renewables Global Status Report (2018), the largest producers of biodiesel in 2018 were the United States, Brazil, Indonesia, Germany, and Argentina.

Figure 2: shows the countries where patent applications for biodiesel synthesis from beef tallow have been researched using the investigated databases.




Abbreviations: WO (World Intellectual Property Organization), EP (European Patent Organization). Source: (Espacenet , 2019; DII, 2019)

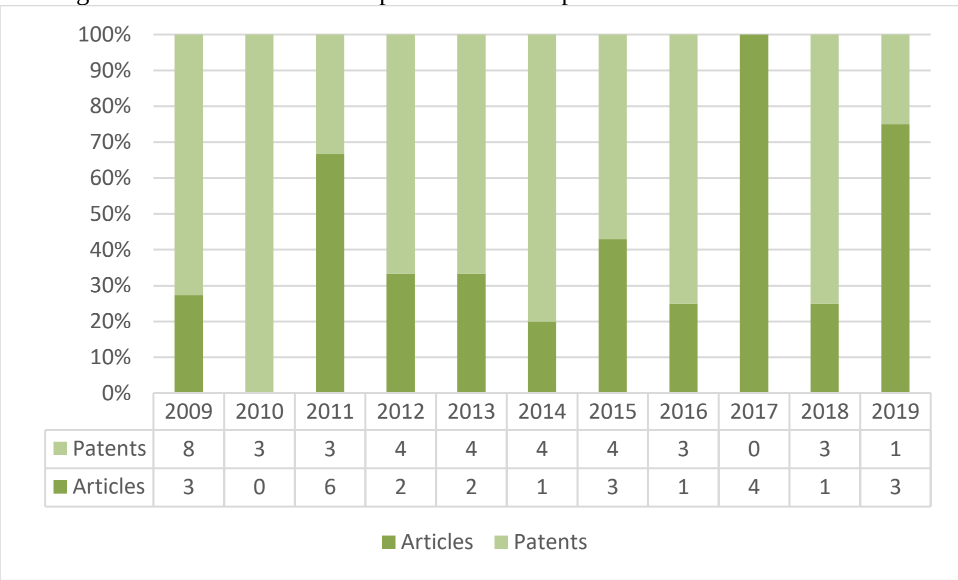
Regarding the Brazilian INPI patent database and according to the research methodology presented in this work, 3 patent applications were found in the pre-defined search period. Recently, a search was conducted in December 2021, and two new Brazilian patents were recovered from the INPI. The information found can be seen in Table 10. The Brazilian patents filed with the INPI have a range of different technologies for the production of biodiesel, with few records on the technology for the production of biodiesel from tallow.

Table 10. Patents filed in the INPI database

| Patent number | Year | Depositor's name | Title |
|---|---|---|---|
| BR1020150036140A2 | 2015 | Federal University of Vales do Jequitinhonha e Mucuri (UFVJM) | Modification of bovine fatty residues using *Stapylococcus xylosus* strains: Raw material for biodiesel |
| BR120130111755A2 | 2013 | Tsingua University (China) | Process for preparing biodiesel from renewable fat with lipase as a catalyst and in-line dehydration |
| PI1005000-0 | 2010 | Curimbaba Mining | Virgin or used vegetable fats and/or animal fats and biodiesel thus obtained |
| BR 10 2018 005358 2 | 2018 | State University of Ponta Grossa | *Luehea divaricata* natural antioxidant additive for use in biodiesel and biodiesel containing *luehea divaricata* natural additive |
| BR 10 2017 026454 8 | 2017 | State University of Ponta Grossa | Natural antioxidant additive based on cobrin (*Tabernaemontana catharinensis*) for use in biodiesel, and biodiesel containing natural cobrin additive |

In more recent years (2017 and 2018), patent subjects have dealt with the use of natural antioxidant additives in biodiesel formulation. For a comparative performance analysis, Figure 3 shows the evolution of the number of patents filed and the scientific papers on beef tallow biodiesel production in the period 2009–Sept/2019.

Figure 3: Annual evolution of publications and patents on beef tallow biodiesel.




It is clearly noted that, in the defined period of the research, there was a distance in the relationship between scientific production and technological production, at least with reference to the number of patent cases filed.

## 4 CONCLUSION

The present work presented an analysis of the technological development aimed at the production of biodiesel from bovine tallow, rescuing 8 families of public patents divided into a total of 34 registrations between the years 2009 and 2019. There was a great variability in the subclasses used to classify them, and the C11C subclass, with 12 patents, presented the largest number of patent families. The research also showed three main topics covered, namely: catalysts, pretreatment, and biodiesel production from tallow, the latter corresponding to 58.8% (20 patents) of the content reviewed.

The year 2009 was the period that presented the highest number of registered patents. However, the growth trend was not followed in the following years, and on the contrary, it decreased or even was canceled, as it happened in 2017. The fall in the number of patents could be related to the fact that many regions have difficulties in the beef tallow production chain, with insufficient technological development to use this raw material.

China was the main country to use technological applications related to biodiesel from bovine tallow, with at least 10 registered patents. It is also observed that the companies or universities that promoted the use of bovine tallow as fuel have diversified completely, without a monopoly on the content of the technologies for a specific group of institutions.

This research is constituted as an analysis tool since it indicates that the technologies that are being developed for a raw material that a few years ago was used in an inappropriate way for the environment. Therefore, a deeper mapping of other technologies is necessary to minimize the physico-chemical limitations of beef tallow and generate biodiesel of better purity and quality.

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