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MAPPING TECHNOLOGICAL INFORMATION IN PATENT DOCUMENTS: USE OF COFFEE GROUNDS IN BIOFUEL PRODUCTION

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Abstract— The study aimed to map technological information contained in patent documents related to the use of coffee grounds as a raw material in the production of biofuels. The methodology has consisted of searching for patent documents in Derwent Innovations Index, National Institute of Industrial Property (INPI) and LATIPAT-ESPACENET, using keywords and codes of International Patent Classification (IPC) and Cooperative Patent Classification (CPC), previously identified in the bibliographic and patent review. The results indicated concentration of technologies in class C10L-005 in solid state; reveal South Korea, Japan and the US as markets in which there is greater commercial interest; suggest that there is no technological maturity at the industrial level yet; and show that biofuel development in Brazil has been driven by government policies.
***Keywords*—** Biofuels, Coffee grounds, Patents.

1 INTRODUCTION

Brazil stands out as a competitive producer in the agricultural *commodities* and extractive culture market, positioning itself as the second food exporting country in 2016 (FAO, 2018), while generating large amounts of agro-waste. Such wastes hold significant potential to be transformed into fuels, energy and chemicals (FORSTER-CARNEIRO et al., 2013). At the same time, signs of depletion of fossil fuel reserves, based on the world's energy matrix (LIMA et al., 2008) have motivated the use of other raw materials as a source of energy, among which we highlight coffee grounds in volume of waste generated and its calorific value. Almeida and Sparagino (2012) compared the calorific value of a series of agricultural residues, among which coffee grounds, which have the highest (5960kcal/kg) between residues studied, among them wood (5450kcal/kg), coconut fiber (4707 kcal/kg) and even sugarcane bagasse (4470.59-4600kcal/kg). This high calorific value indicates the great potential of using coffee grounds as an alternative energy source to the use of fossil fuels in a scenario of transition of the energy matrix on a global scale.

This study seek to map technologies for harnessing coffee grounds in biofuel production analyzing patent documents with *Derwent Innovations Index*, National Institute of Industrial Property (INPI) and LATIPAT-ESPACENET databases. To reach out this objective, the text was structured in sections: section 2 – It presents a brief literature review on the potential of applying coffee grounds as biofuel in a context of global incentive to use alternatives to fossil fuels; section 3 – It presents the methodology for collecting data in

patent databases. section 4 – It presents the results in terms of the historical evolution of worldwide patent filings, the main filing countries of origin, the main technology identification codes and the principal filers; section 5 – final considerations.

2 COFFEE GROUNDS AS BIOFUEL FEEDSTOCK

The growing worldwide demand for energy with concerns about the impact of climate change and rising oil prices have reinforced interest in the use of renewable fuels (SILVA and SAKATSUME, 2007; BRANCO, 2009; SALLET and ALVIM, 2011). Teixeira et al. (2007) argue that biomass is the strategic trend as a substitute for oil. Yet, Silva (2011) demonstrates that the use of biomass can promote a reduction until 86% of greenhouse gases, when compared to the gases generated by petroleum. The Paris Agreement [1], in turn intensified the commitment of 195 countries to reduce greenhouse gases. However, according to Caseiro (2011), alternative fuels production is still spatially concentrated, considering that only six countries account for 89% of this production on a global scale. Brazil acceded to Paris Agreement in 2016´s year and pledged to reduce its emissions about 37% by 2025 and 43% by 2030 from 2005 levels (when the Kyoto Protocol came into force). In this scenario, Brazilian Government have been created the National Biofuels Policy (RenovaBio), by #13.576/2017 Act, with purpose of expanding biofuels production in country and enabling the achievement of its international commitments.

Maricato, Noronha and Fujino (2008) argue biodiesel is an alternative promise in view of limited fossil fuel reserves. Fact is that Brazil has an extensive agricultural border is not enough. Moreover, technological domain in the area is fundamental. Dias, Vian and Grin (2008) highlight that technological innovations generation is related to agroenergy production chain and should be an ambitious goal for Brazil. Caseiro (2011) highlights needing to diversify raw materials used in biofuels generation, due to the environmental impacts derived from cultivation, such as deforestation, soil erosion, biodiversity loss, soil and water contamination, and exploitation of water resources and agricultural areas. For Mendes and Costa (2010), the major challenge for Brazilian biodiesel industry is to disassociate itself from the soybean production chain through the use of non-food high productivity raw materials, and one of the difficulties faced is to export national biodiesel to major international consumers, especially the European Union (EU).

Same time, coffee is one of the most consumed beverages in the world, with an estimated grain production around 165 million bags in 2018-2019 (ABIC, 2019); large amounts of waste are generated in the coffee sector, which are toxic and result in serious environmental problems (Mussato et al., 2011). Since the early 1990s, Vegro and Carvalho (1994) already indicated the need to dispose of these wastes, due to the growing concern about the environmental impact generated.

The sludge produced in the instant coffee industry is a waste whose use has been the object of research. It is estimated that 34 tons of coffee grounds are produced per day, which represents a potential for the production of 1.5 tons of oil for leveraging as biofuel (CUNHA et al., 2018). In fact, Brazil is the largest producer of coffee (FAOSTAT, 2018), around 3.7 million tonnes (CONAB, 2018), reveals the great economic potential associated with the generation and dissemination of technologies for leveraging coffee residues, including sludge, in the generation of biofuels.

The coffee production chain identifies the main stages of processing and consumption of the grain. Roasters are the main players in the chain, both for their ability to add value and to define product quality, as the organoleptic characteristics of coffee are largely determined in the roasting process, which usually includes a mixture of different varieties of grains (KHODAKARAMI et al., 2016). It is noteworthy that the roasting and grinding stage is part of the instant coffee industry. This has the greatest potential for use

[1] The Paris Agreement (2015) seeks to strengthen the global response to the threat of climate change and to strengthen countries' ability to deal with the impacts of climate change (Ministry of Environment, 2018).

of coffee grounds as it is the main byproduct of its processing activity. Consumption of healthy coffee represents an expanding market in which global sales were around US$ 28 billion in 2016´s year, with an estimated growth of 4.8% per year, reaching US$ 42.5 billion in 2025. (ABICS, 2017).

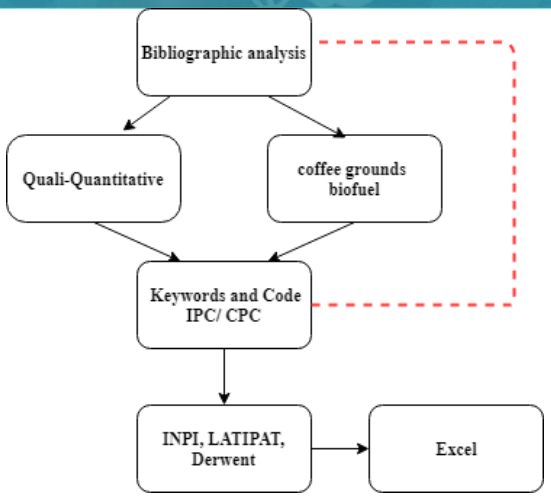
The bibliography review identified several researches carried out on ~~a~~ laboratory scale, which corroborated the technical feasibility of obtaining biofuels, both for the production of oils and esters and for the production of briquettes from coffee grounds. Santos and Haraguchi (2016) commented that coffee beans contain approximately 10 to 15% of lipids, whose 80-95% correspond to glycerides, and suffering oil exposition (triglycerides) to the presence of alcohol and catalyst in single transesterification process, ester and glycerol are formed, with characteristics very similar to conventional diesel. Page, Arruda and Freitas (2017) showed that the yield of crude ethanolic extract obtained from coffee grounds was higher than the yield of ether. Figini et al. (2017) observed that residual coffee sludge has a high oil content (12-20%), close to that obtained from conventional sources such as soybean (20%). Primaz (2018) demonstrated that coffee grounds and cottons seeds are waste with high lignocellulosic content, making them attractive for application in thermochemical technologies such as pyrolysis. Jang et al. (2015) points out that the use of coffee grounds through high temperature carbon fuel cell technology has a potential of 87.2 mWcm², which is almost twice as high as carbon black (46.3mW cm²) in the production of electric energy in fuel cells. Researchers at South Korea's Gwangju Institute of Science and Technology have shown that coffee grounds, after drying, have a higher combustion potential (by 88%) than better quality carbon sources, such as black coal, commonly used as fuel in addition, it produces a small amount of ash after generating electricity (FUEL CELLS BULLETIN, 2015).

Considering the importance of patent documents in identifying solutions and technological trends as well as the construction of thematic indicators, several studies were performed in order to identify the technological development related to biofuels. In general, such research addresses (i) the analysis of biofuel production and consumption worldwide, (ii) the efforts made to use different materials in biofuel generation, (iii) the potential and evolution of these technologies, and (iv) the lifting of patents in the biofuels area. Moreover, they point out the importance of countries and companies to continue investigating and improving technologies in this area of interest. However, the literature lacks a search for patent documents specifically focused on the use of coffee grounds in biofuels generation.

3 METHODOLOGY

At first, a biographical analysis was performed to classify and parameterize the characteristics and definitions of the research. Thus, the technological prospection carried out in patent documents the insertion of qualitative and quantitative aspects, since there was a need for analysis and interpretation of contexts, information and facts, as well as the organization, characterization and interpretation of numerical data. In parallel to the research parameterization, bibliographical analyzes were carried out in scientific documents related to biofuel technology derived from coffee grounds. Figure 1 illustrates the block diagram of the methodology used. The keywords and codes of the International Patent Classification (IPC) and the Cooperative Patent Classification (CPC) were searched. The dashed line in Figure 1 indicates the resumption movement of the bibliographic analysis to enable and adjust keyword extraction, IPC and CPC.

Figure 1. Block diagram with applied methodology



Source: The Authors (2019)

Searches were carried out in Derwent Innovations Index, the INPI and LATIPAT. The choice of these databases was due to the accessibility, the reliability of the data and the breadth of temporal and territorial coverage of the publications. In addition, considering that Spanish- speaking countries are among the main coffee producers, the selection of these patented bases, complementary in their scope, sought to ensure the recovery of technologies developed in these countries, as well as for commercial exploitation in these markets.

Data collection in these databases was performed on November 22, 2018. The search strategy used the combination of prefixes "coffee", "diese", "combust" and the word "coffee", as indicated in Table 1 (in English, Portuguese and Spanish) in the advanced search fields of their respective databases. This preliminary search in patent documents has allowed us to identify seven IPC and CPC codes that are directly related to coffee grounds biofuel production technology: C07C51 *, C10B53 *, C10G *, C10L *, C11B1 *, C11C3 * and Y02E50 *. The Excel tool was used to create a database from the Derwent Innovations Index database, which generated a file with the patent fields (patent number, abstract, authors, etc.). Summaries of all patent documents exported to the Excel platform were read to certify technologies and to exclude duplicate or non-pertinent data to the research object.

TABLE 1 KEYWORDS AND TERMS USED IN PATENT SEARCHES RELATING TO THE USE OF COFFEE GROUNDS IN THE PRODUCTION OF BIOFUELS

Keywords					*Terms*
caf*	OR	coffe*	AND	diese*	(caf* OR coffe*) AND diese*
caf*	OR	coffe*	AND	bio?diese*	(caf* OR coffe*) AND bio?diese*
caf*	OR	coffe*	AND	combust*	(caf* OR coffe*) AND combust*
caf*	OR	coffe*	AND	bio?combust*	(caf* OR coffe*) AND bio?combust*
caf*	OR	coffe*	AND	fuel	(caf*OR coffe)* AND fuel
caf*	OR	coffe*	AND	ester	(caf*OR coffe)* AND ester
caf*	OR	coffe*	AND	bio?oil	(caf*OR coffe)* AND bio?oil

Source: The Authors (2019)

Regarding the limitations of this research, it can be verified that the search did not retrieve patent applications in a period of secrecy, which represents a technological gap of eighteen months. In addition, the INPI and Derwent Innovations Index databases do not allow searches using CPC, but only IPC. It has also been found that the INPI database does not have keyword queries in the body of the document, but only in the title or abstract, which restricts the gathering of patent information.

4 RESULTS AND DISCUSSION

The results of this research were structured according to: i) the evolution of the amount of patent filings; (ii) markets of commercial interest by identifying the countries in which applications have been filed; iii) the profile of applications, in terms of their legal nature; and iv) the technological areas with the highest incidence of patent filings. Initially, 534 patent documents were recovered from Derwent, INPI and LATIPAT. After deletion of duplicate and non-pertinent documents, 99 patent processes remained (Table 2). It was noted that the first patent document contained in these databases dates back to 1979 from Japan, representing a 39-year timeline in search of the use of coffee grounds in the generation of biofuels. In the present study, the filing date of patent documents exported to Excel has been considered.

TABLE 2 PATENTARY DATA RECOVERED FROM ERWENT, INPI AND LATIPAT BASES CONCERNING THE USE OF COFFEE GROUNDS IN THE PRODUCTION OF BIOFUELS

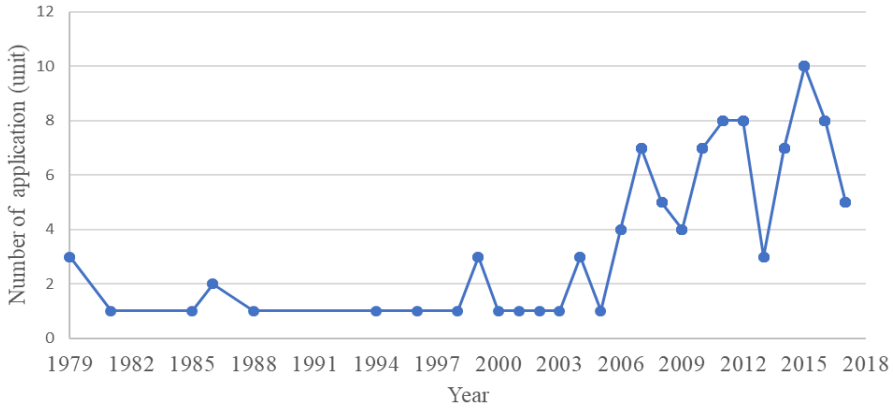
	Derwent	**INPI**	**LATIPAT**	**Total**
Number of documents retrieved	315	1	218	534
Number of documents after refinement	94	0	5	99

Source: DERWENT, INPI and LATIPAT (2019)

4.1 EVOLUTION OF PATENT APPLICATIONS

The patent survey identified, from 1979 to 2005, an annual average of two patent applications. Since 2005, with the entry into force of the Kyoto Protocol, patent applications for this type of technology have expanded, followed by a decline from 2008 to 2009, as shown in Chart 1. It should be noted that in 2013 there was a crisis in Brazil coffee industry, due to higher production costs, falling coffee bag prices and reduced coffee consumption in the country (LOPES and ALVES, 2015). As Brazil was the largest world producer at the time, this may have negatively influenced the pace of patent applications, as observed in 2014.

Chart 1. Developments in the number of worldwide patent Applications concerning the use of coffee grounds in biofuel production from 1979 to 2018



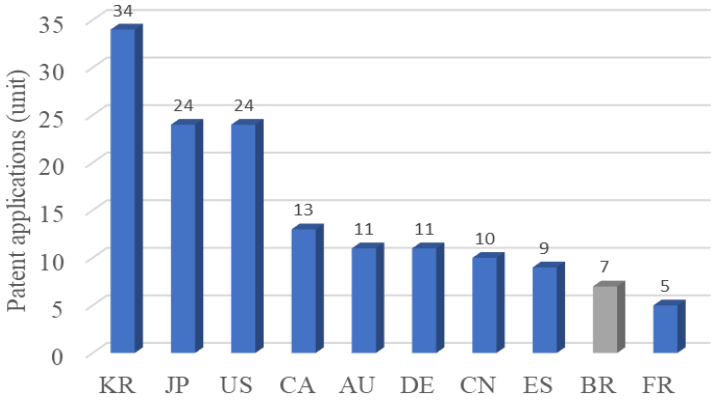
Source: DERWENT, INPI and LATIPAT (2019)

4.2 MARKETS OF COMMERCIAL INTEREST

South Korea, Japan and the US stand out as countries with the highest interest for commercial exploitation of the technology, with 34, 24, and 24 patent filings respectively in the period 1979-2018 (Chart

2). In case of South Korea, there have been governmental incentives to reduce dependence on fossil fuels by expanding the use of second and third generation biofuels (MASIERO, 2008). In such scenario, the increase of coffee consumption in the Asian countries in the last decades, and the consequent generation of sludge aroused the interest in the utilization of this residue. It is noteworthy that, as South Korea does not have adequate climatic conditions for coffee cultivation, Brazil has been its main supplier.

Chart 2. Countries with the largest number of patent applications related to the use of coffee grounds in biofuel production from 1979 to 2018



Source: DERWENT, INPI and LATIPAT (2019)

In turn, the government of Japan has promoted the use of renewable energy in biofuel production and use, and has encouraged R&D for second-generation biofuels and the establishment of sustainable production standards (KOIZUMI, 2013). To promote the development of biofuels, the country has adopted national strategies and plans, such as: Nippon Biomass Strategy, Kyoto Protocol implementation plan and National Energy Strategy. As strategies have led to import tax reduction initiatives, financial and fiscal support for producers of raw materials, and support to biofuel pilot projects (MATSUMOTO et al., 2009). The US is among the largest producers of industrial commodities, agricultural product supplier and world leader in biofuel development, especially biomass (SU et al., 2015). The authors also mention that the US driving force for biomass development is guided by the goals of: i) reducing dependence on oil imports; ii) create job opportunities and develop agriculture; iii) promote low carbon development and sustainable economy; and iv) explore new technologies to provide alternative energy sources. Encouraging government policy through the enactment of energy-related laws and regulations, including fiscal and financial policies, grants and loan guarantees for research and development (R&D) of biomass-derived biofuels, have enabled growth in biofuel production in the country.

China has been a major player in energy investment and promotion for Its interest in developing hydropower, solar and wind, bioenergy and biofuels (DYK et al., 2016). Even though It is a promising market for coffee consumption, with an increase of 300 thousand bags in 2008/2009 to 3.8 million bags in 2017/2018 (CONSORTIUM, 2018), China is still not among the main markets for commercialization of this technology. Biofuel, indicating ten patent filings in the period 1989-2018. As a result of the rapid increase in oil consumption, the International Energy Agency (IEA) projection reports that about 75% of China's oil consumption will be imported up to 2030 (QIU et al., 2012). The authors also mention that China has made considerable progress in using renewable energy, including liquid biofuels (maize, cassava and soy), making it the world's fourth largest producer of liquid biofuel after US, Brazil and EU. This may indicate the country's lack of interest in coffee grounds biofuel technology.

Brazil, in turn, is ranked ninth among the countries in which there is commercial interest, with seven patent filings, from 1979 to 2015 (Table 3). The patent document obtained in 1979 possibly results from the oil crises in 1973/74 and 1979/80 (FERREIRA et al., 1999). In response to the shortage of oil, interest in the search for alternative sources was renewed in the country. During this period, the federal government created the Plan for Production of Vegetable Oils for Energy Purposes (PRO-OLEO), prepared by National Energy Commission, through Resolution No. 007/1980, which provided for a mixture of 30% vegetable oil (SUAREZ et al., 2007). With the signing of the Kyoto Protocol in 1997, the Brazilian government resumed discussions and studies on the use of biodiesel, launching in 2004 the National Program for the Production and Use of Biodiesel (PNPB), with the objective of ensuring economically viable production, biofuel (SUAREZ et al., 2007). The main legal action of the PNPB was the introduction of biofuels derived from oils and fats in the Brazilian energy matrix, through Law No. 11.097/2005. This context, coupled with the fact that the government assumed the coordination of public policies to support coffee activity in the 1990s, following the extinction of the Brazilian Coffee Institute (IBC) in 1989, may have motivated patent applications filed with Brazil from 1989 to 2002.

With regard to the 2010 patent process, it was found mandatory to mix 2% (B2) of vegetable oil biodiesel with diesel from 2008; In July 2009, the mandatory biodiesel blend at 4% (B4) enters the market and, in January 2010, at 5% (B5) (TÁVORA, 2011). This stimulus of renewable fuel derived from vegetable oils possibly influenced the entry of the 2010 document in Brazil. The 2015 documents, in turn, may be associated with Brazil's participation in the United Nations Conference on Climate Change in 2015, of which the goal for Brazil was to increase the 18% share of bioenergy in the energy matrix (DENNY, 2016). It should be noted that the seven patent applications made in Brazil consulted period, six were performed via the Patent Cooperation Treaty (PCT[2]), three applications from the United States, one from Switzerland, one from Canada and one from Korea (Table 3).

Although Brazil has accumulated experience in the production and use of biofuels (SILVA and SAKATSUME, 2007) and has developed the largest coffee research program in the world through the Research Coffee Consortium, an integrated network of 45 Brazilian research institutions (DURÁN et al., 2017), articulated implementation of public policies that enable the production of fuels from renewable sources as necessary. For Melo (2018), the National Biofuels Policy (RenovaBio), implemented in 2017 with the goal of developing all types of biofuels in Brazil, in line with the Paris Agreement's sustainability assumptions, differs from other policies by not focusing on tax creation; On the contrary, It seeks to stimulate competition with fossil fuels to ensure quality and price for consumers. Roitman (2019) explains that the measures adopted in Brazil so far were based only on the tax differentiation between fossil and renewable fuels, and comments that RenovaBio, an innovator in Brazil, was inspired by several international initiatives in force for over eight years, including the United States *Renewable Fuel Standard* (RFS), the California *Low Carbon Fuel Standard* (LCFS) , and the European Union *Renewable Energy Directive* (RED).

TABLE 3 INFORMATION REGARDING PATENT DOCUMENTS APPLICATIONS IN BRAZIL

Applications in BR	Priority Date PCT	Source	Applications Profile
1979	--	Brazil	Physical person
1989	1988	Switzerland	Physical person
2000	1999	Canada	Physical person
2002	2002	U.S	Physical person
2010	2009	U.S	Legal person
2015	2014	U.S	Legal person
2015	2015	Korea	Legal person

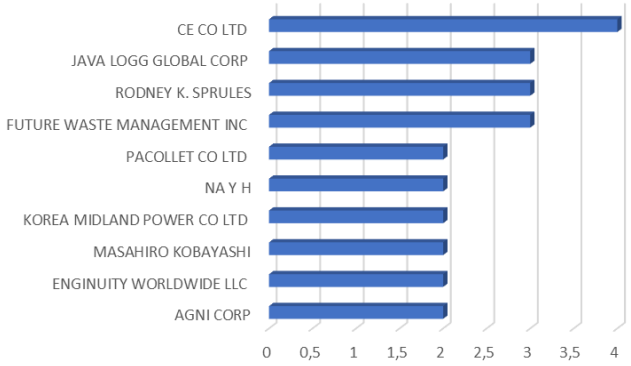
[2] The PCT is a multilateral treaty that allows the patent protection of an invention to be filed, using a single international patent application, simultaneously in several signatory countries.

Source: DERWENT, INPI and LATIPAT (2019)

4.3 PROFILE OF MAJOR APPLICATIONS

From 99 patent documents identified, 135 applications (including co-holders), including individuals and legal entities, from different countries were accounted for. Chart 3 indicates the main applications, with the South Korean environmental business company CE CO LTD having four patent documents, the Canadian company, Future Weste Management. The waste management segment, the application independent Canadian Rodney K. Sprules and the Barbados-based Java Logg Global Corp. with three orders each. A noteworthy fact is that Rodney K. Sprules patent documents, containing technologies related to coffee-based fuel composition, were transferred to other companies, including Java Logg Global. It is also worth mentioning that the South Korean company CE CO LTD is the applications of one of the seven required patent processes in Brazil.

Chart 3 - Main application identified in patent searches, concerning the use of coffee grounds in biofuels production, from 1979 to 2018

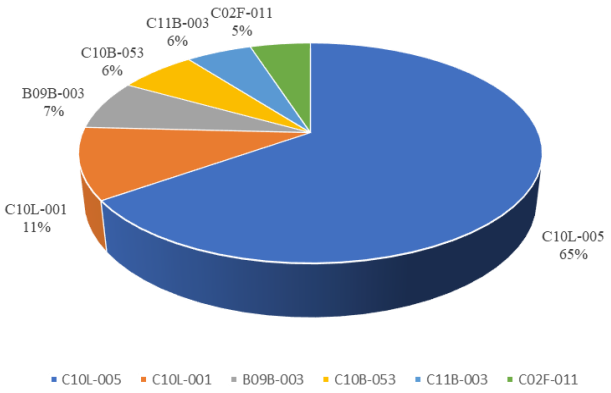


Source: DERWENT, INPI and LATIPAT (2019)

4.4 AREA OF INTEREST IN TECHNOLOGY DEVELOPMENT

Chart 4 shows the most commonly used International Patent Classification codes, which focus on the technological development of retrieved documents, with significant emphasis on class C10L-005, present in 65% of documents. Then the codes C10L-001 at 9% and B09B-003, which was not defined in the search parameters, but which appeared in 7% of the documents. The C10L class is the group that refers to the area of solid fuels produced by solidifying fluid fuels for briquettes. Class B09B includes waste disposal technologies, where subgroup B09B-003/ 00 is characterized by destruction of solid waste or transformation of solid waste into something useful or harmless. As biomass from waste, plants, crop and other waste can be used for heat or power generation, or transformed into solid, liquid or gaseous biofuels (CAVALCANTI et al. 2015), the physical and chemical properties of sludge of coffee associated with the large volume of sludge produced in the world encourages the use of sludge-shaped sludge biomass.

Chart 4. Number of patent publications by international patent classification codes concerning the use of coffee grounds in the production of biofuels from 1979 to 2018



Source: DERWENT, INPI and LATIPAT (2019)

5 CONCLUSION

Given the high calorific value of coffee grounds identified in the literature review and considering the large volume of coffee production and consumption worldwide, It can be inferred that technology for energy supply based on this type of waste has a high potential for implementation and economic return, especially when there is a context of recurring concern about environmental issues and commitments made by countries in multilateral agreements.

However, It is clear that there is still no technological maturity for the exploitation of coffee grounds on an industrial scale, given that results of the search on a patent basis were not quantitatively relevant, with only 99 documents identified worldwide, although there was an amount scientific publications and news about the use of coffee grounds in the production of biofuels. Possible barriers to the adoption of these technologies include the logistical issue of large scale sludge collection and the production costs associated with biofuel generation from coffee sludge.

It was found that in the patent documents retrieved from this survey, there was a prevalence of order entry in Korean country, with coffee grounds predominantly designated for solid fuel, especially briquettes. It was also noted that although the literature review indicates that the development of technologies using coffee grounds in biofuel production dates back to the 1960 in Brazil and that it is the largest producer of coffee, the number of patent applications (7) in or originating from Brazil (1) is incipient. It remains to be seen why this potential for exploitation does not develop in Brazil, as occurred with the National Alcohol Program (Proálcool), created by the government in 1975 to promote the production of bioenergy in the country. In addition, if there is a need to develop solutions for waste management in the coffee sector, coffee sludge biofuel generation technologies could be submitted to the Priority Program for Green Patents in Brazil in order to accelerate the examination of the process at the INPI. This could foster the interest of companies, institutes and others in investing in new technical solutions in the area.

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