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MAPPING THE TECHNOLOGICAL CHAIN OF ETHANOL PRODUCTION FROM SUGARCANE FOCUSSING ON PATENT OF APPLICATIONS: BRAZILIAN SCENARIO

Eduardo Winter, Araken Alves Lima and *Cristina d´Urso de Souza Mendes*

INTRODUCTION

Currently, there is an increase in the interest for biofuels and alternative sources of energy such as ethanol, biodiesel and hydrogen. The demand for energy increased substantially because of the growing demand for consumer goods and transportation leading to an increased use of fossil fuels. The major countries are experiencing great difficulties to meet their energy needs which has led to a greater participation of fossil fuels in the global energy matrix and the consequences have been for climate change.

The environmental concerns are causing major transformations in the world. Businessmen and government officials are recognizing the importance of policies regarding environmental sustainability, which in part has been finding an echo in the concerns of society that has demanded political and environmentally clean products. In contrast to this concern, the sustainable development of nations requires increasingly complementary and/or alternative forms of energy.

These changes have created a new and growing market known as carbon credits market. This has been the solution that industrially developed countries have found to maintain their productive activities operating without major changes. In this market, the nations negotiate carbon quotas launched into the atmosphere by the industrial activity with other less developed nations. This activity is so developed that today is exchange-traded in the stock market (SCHLITTLER, 2006).

Trading of carbon credits already benefits a number of companies in Brazil. Those are companies from various sectors such as steel, pulp and paper, sanitation and renewable resources, among others. These companies are accessing a market that, according to experts, expected to hit $ 10 billion a year, and Brazil will account for 10% of this amount (MIGUEZ, 2004).

Some countries, like Brazil, are taking mitigation measures regarding the air pollution, such as the decree of the State of São Paulo which aims to end the fires in the plantations of cane sugar by 2012, (SCHLITTLER, 2006), this will require the development of technologies from the planting and harvesting sugarcane to suit these new policies of cultivation.

In the productive chain of ethanol fuel (hydrated ethanol) the key steps are identified, they are: planting, harvesting and transport of cane sugar, the preparation of cane sugar, to obtain the substrate for fermentation, distillation and fermentation. Within each, there are smaller steps such as plant breeding, development of specific pesticides for the cultivation, development of new microorganisms and enzymes for fermentation processes etc.

Given the importance that ethanol fuel from cane sugar has been manifesting in the current context of global energy discussion, this study took place in order to map, in Brazil, the technologies used in the production chain of this fuel using the information in patent documents, because they provide the best indicators regarding the "status quo" of technology development. According to

OECD (1994), patents are excellent indicators of the innovative effort and can be used to measure the results of research and development (R&D) productivity, structure and development of a specific technology/industry.

Because of the relationship between the activities of R&D and the number of patent applications, is possible to compare, monitor and analyze the research activities in a particular subject area or a new sector (ALENCAR *et al*. apud MENDES 2007, 2008).

In this context, this paper presents an analysis of the search for patent protection in the ethanol production chain during the last three decades aiming to identify the changes in the technology landscape and its relationship to public policies, identifying the actors and countries that develop and/or developed these technologies or have interest in national technology market through marketing and/or use of the technology developed.

METHODOLOGY

The present study aims to analyze the patenting activity in the production chain of ethanol in Brazil. The data regarding patent documents used were recovered in two different databases: i) database of INPI: System database of the INPI (SINPI) (database of patents filled and/or granted in Brazil), ii) ESPACENET database, described below:

SINPI – Brazilian patent database, available in the Internet. This is a free database containing the summaries of patent applications filed and published in Brazil.

Espacenet – The patent database Espacenet contains references to patent applications that make up the documentation search of the European Patent Office – EPO. The database contains bibliographic data from over 60 million patent applications in almost every country in the world.

The search was carried out using keywords (ethanol, alcohol and sugar) and the International Classification of Patents. The search was carried out taking into consideration the period between the years 1974 and 2006, a period that covers the begining of the national government Pro-Alcohol, its deceleration in the mid-80 and the resumption of investments in biofuels at the end of 90s.

Using the search strategy above, 2,932 documents were retrieved that, after gathering the data were read in order separate those who did not relate to patent applications for ethanol fuel, eliminating the irrelevant papers. Thus, 2,276 documents were removed; leaving then a total of 656 patent applications filed relating to the chain of ethanol for analysis.

The reading step was followed by steps of adequacy of data and harmonization of information, followed by the development of a database in Microsoft Excel. After the data harmonization and the development of the database, it was possible to extract basic information about the object of interest in this study, such as the total number of documents selected, the main lines of the study, countries and companies that dominate the technology and life cycle technology.

The search strategy selected 656 patent applications filed in Brazil related to the productive chain of the fuel ethanol derived from cane sugar in the period 1974 to 2006. The applications filed in 2007 were not considered in this work because of the secrecy period (18 months) present in the process of examination of patent documents. Yet it is worth mentioning that the search in the patent databases was performed on 11.06.2008, therefore some documents filed in 2006 had not yet been published yet, and that year will probably have diferent result regarding the evolution of the technologies involved.

Finally, this study is organized in two steps. The first step presents an evaluation of the patent applications in the supply chain as a whole, from the plantation of sugarcane to the obtaining of the the hydrated alcohol. Sequentially, we performed a treatment of the data taking into account the main international classifications, allowing a difente analysis for each step of the production chain.

PATENT APLICATIONS AND/ OR PATENTS IN THE ETHANOL PRODUCTION CHAIN

An assessment of the number of filings of patents in Brazil by year (Figure 1) allows observing some peaks of deposits. It is possible to conclude

that the number of patent applications in Brazil grows or shrinks according to the changing circumstances and the country's economic incentives from the government, as was the case with the Pro-Alcohol that has influenced significantly the investment in research and development (R&D) and technological development of ethanol production.

In the Figure 1 four distinct periods can be observed:

1st Period – 1974 to 1980: in this period, which coincides with the start of the Pro-Alcohol program, there is the highest growth rate in relation to the number of patent applications filed in Brazil, with an approximate five requests to year.

2nd Period – 1981 to 1989: The 80's, now known as the decade in which the technology, in general, was almost stagnant, there was the downturn in interest in ethanol. The dismantling of the government's ethanol program affected in the innovative effort and it is showed decreasing the number of patent applications filed in Brazil, with a rate of about -3 requests per year.

3rd Period – 1990 to 1996: in this period, the number of filings in Brazil remained stable, with an average of about 10 requests per year. However, during this period the debate on environmental issues intensified and Brazil played a great part of the discutions, as can be verified with the realization of ECO 92 in Rio de Janeiro. Another factor that interferes in this period is related to intellectual property with Brazil's signing of the TRIPS agreement, which culminated in the change of the existing Law of Industrial Property, culminating in the current Industrial Property Law (IPL – 9279/96), which dates from 1996. This new law, compared to the previous one, presents some important variations with respect to ethanol production chain, for example, matters related to biotechnology and chemicals.

4th Period – 1997 – present: in the late 1990s, in addition to the IPL comes into force, other factors took place that made Brazil and the rest of the World start a "race" for alternative energy sources, the main one being the high price of oil. Thus, the number of patent applications related to ethanol production strated to grow, with a growth rate of about three applications a year.

Regarding the origin of these documents (Figure 2), is possible to observe that the fillings are maily from residents (Brazilians), totaling ap-

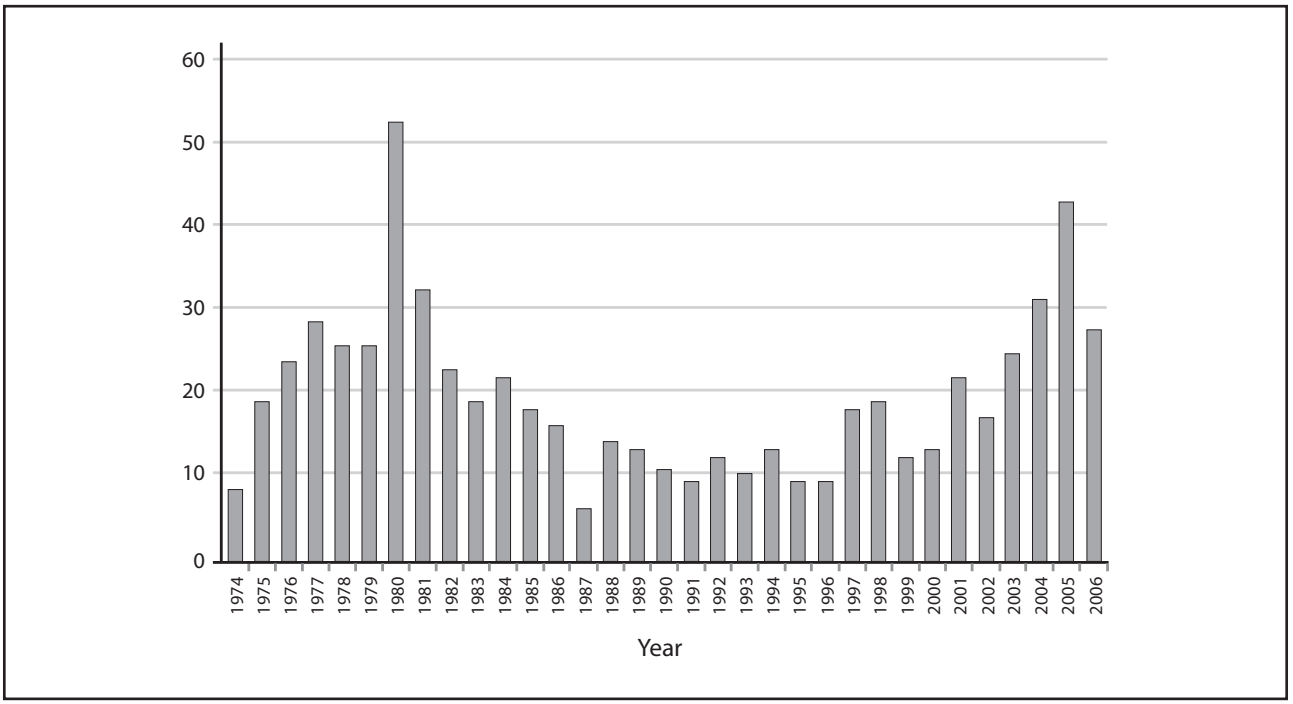

FIGURE 1 Evolution of the number of patent aplications from 1974 to 2006.

proximately 68% of the documents. The remaining 32% are non-resident applicants, maily patent applications made by the U.S. intutuitions, followed by Japan, Germany, Netherlands and Australia.

Subsequently, the participation of applicants involved in ethanol production chain (Figure 3) was evaluated. It is verified that the distribution of documents is well balanced and the main applicant (COPERSUCAR) has only 6.3% of the total, followed by Santal and Massey Ferguson. It should be noted that, of 656 documents, 459 are of different applicants, which shows an existence of a large number of actors involved in the processes of producing ethanol from cane sugar. Among the ten largest applicants, four are individuals and only two are non-resident applicants. Still, it is interesting to note that among the applicants with three or more documents filled, there can be found various educational institutions.

The COOPERSUCAR (Cooperative of Producers of Sugarcane, Sugar and Alcohol of the State of São Paulo) is a major producer of sugarcane, sugar and ethanol in Brazil. In relation to alcohol the company has sales office and tanks in Rotterdam, the Netherlands, from where the company exports to 10 countries in Europe, and should sell in the 2008/2009 crop, about 300 million gallons (c.2.27 billion litre) of ethanol fuel in the European standard. With tanks in Houston and New York, will put about 600 million liters in North America. The company also exports to Japan, India, Korea, Nigeria and the Gulf countries, among others.

Since the production chain of fuel ethanol from cane sugar is very extensive, involving equipment technology for planting and harvesting, through microorganisms and genetically modified plants, until the processes of fermentation, there was a need for a study detailing the distribution of patent documents regarding each specific technology. In this case, because of the use of patent documents, the best way to accomplish this separation is to use the International Patent Classification (IPC – the English International Patents Classification) (INPI) as shown in Figure 4 and Table 1, that show, respectively, the main classifications and descriptions of the classifications of patents.

Thus, seven classifications were selected for appearing over 100 times. They are: A01D, C12P, A01C, C12N, A01N, C13D, C07C. These classifications are described in Table 1.

Evaluating the classifications that predominate in the production chain of ethanol fuel and comparing with the information presented in

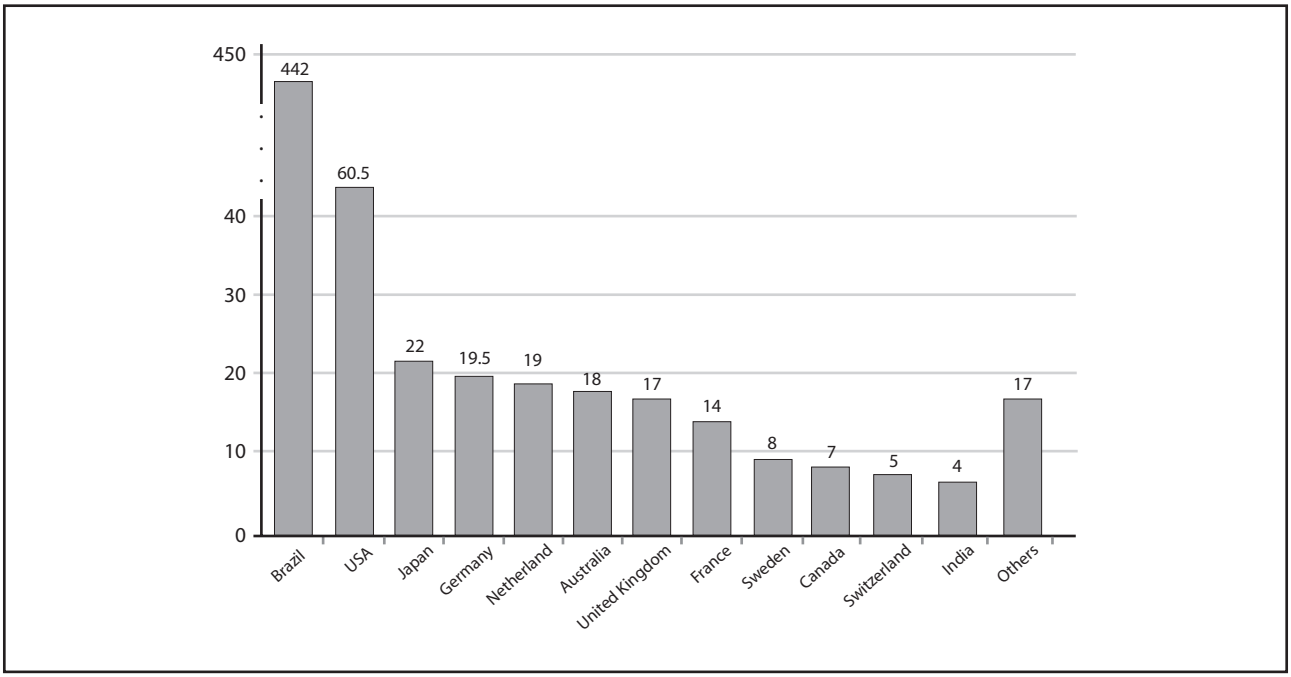

FIGURE 2 Distribution of patent documents filed in Brazil versus the country of the applicant.

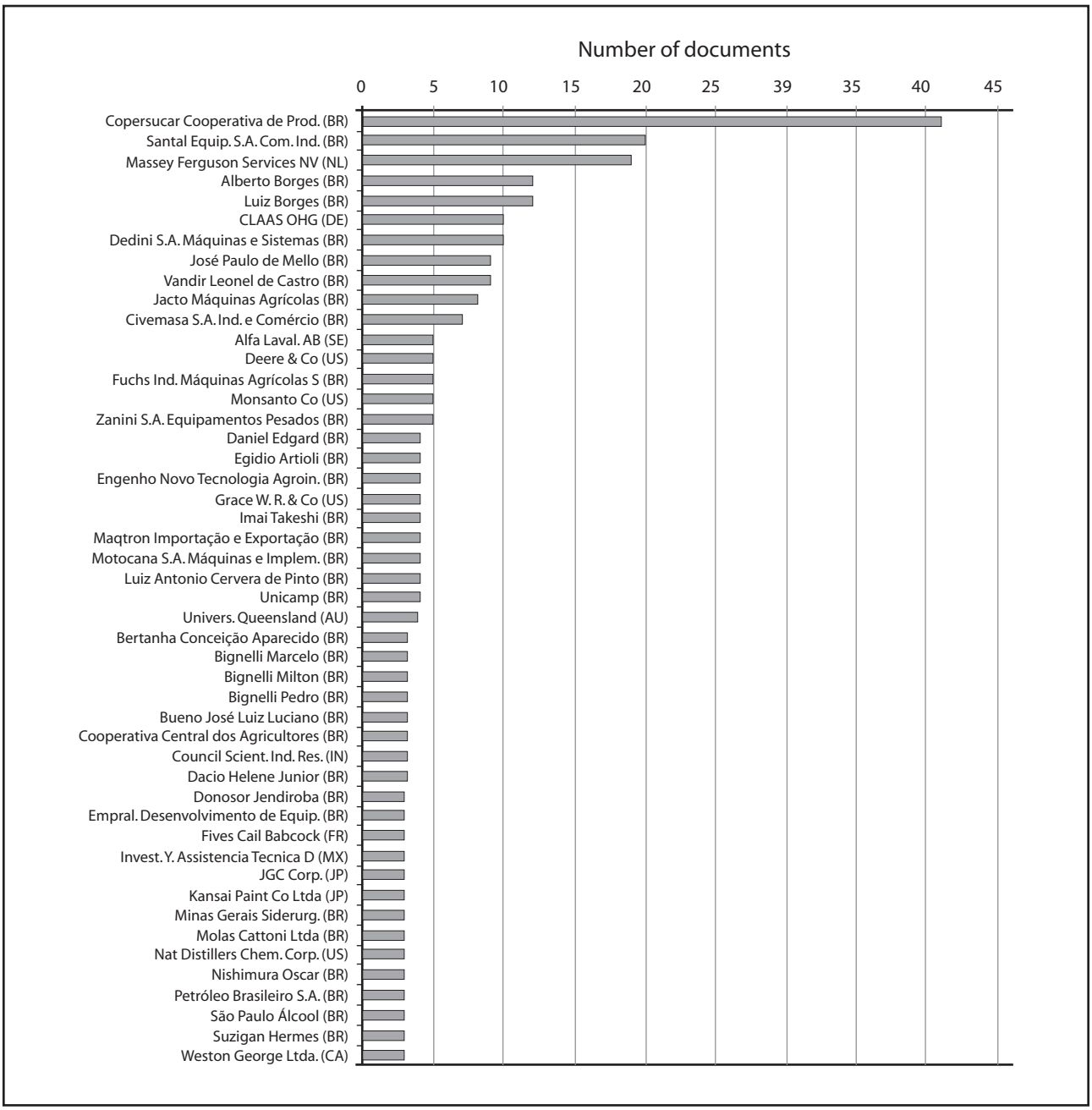

FIGURE 3 Distribuition of the main applicants of patent documents in Brazil.

Table 1, are found equipment designed for planting and harvesting (A01C and A01D), followed by biotechnological products/processes (C12P and C12N), such as fermentation. Still, there are classifications for the extraction of sugarcane juice (C13D), pesticides (A01N) and production of acyclic compounds (C07C). Because of the diversity of technologies involved the main classifications of patents involved in this chain were detailed, which enabled the identification of the main actors involved and the historical evolution of each step. The detailing took into account four main classifications (A01D, C12P, C12N and A01C), since these represent the two major technology groups, namely, processes and equipment for planting and harvesting (A01C and A01D) and fermentation processes, especially those involving biotechnology (C12P and C12N).

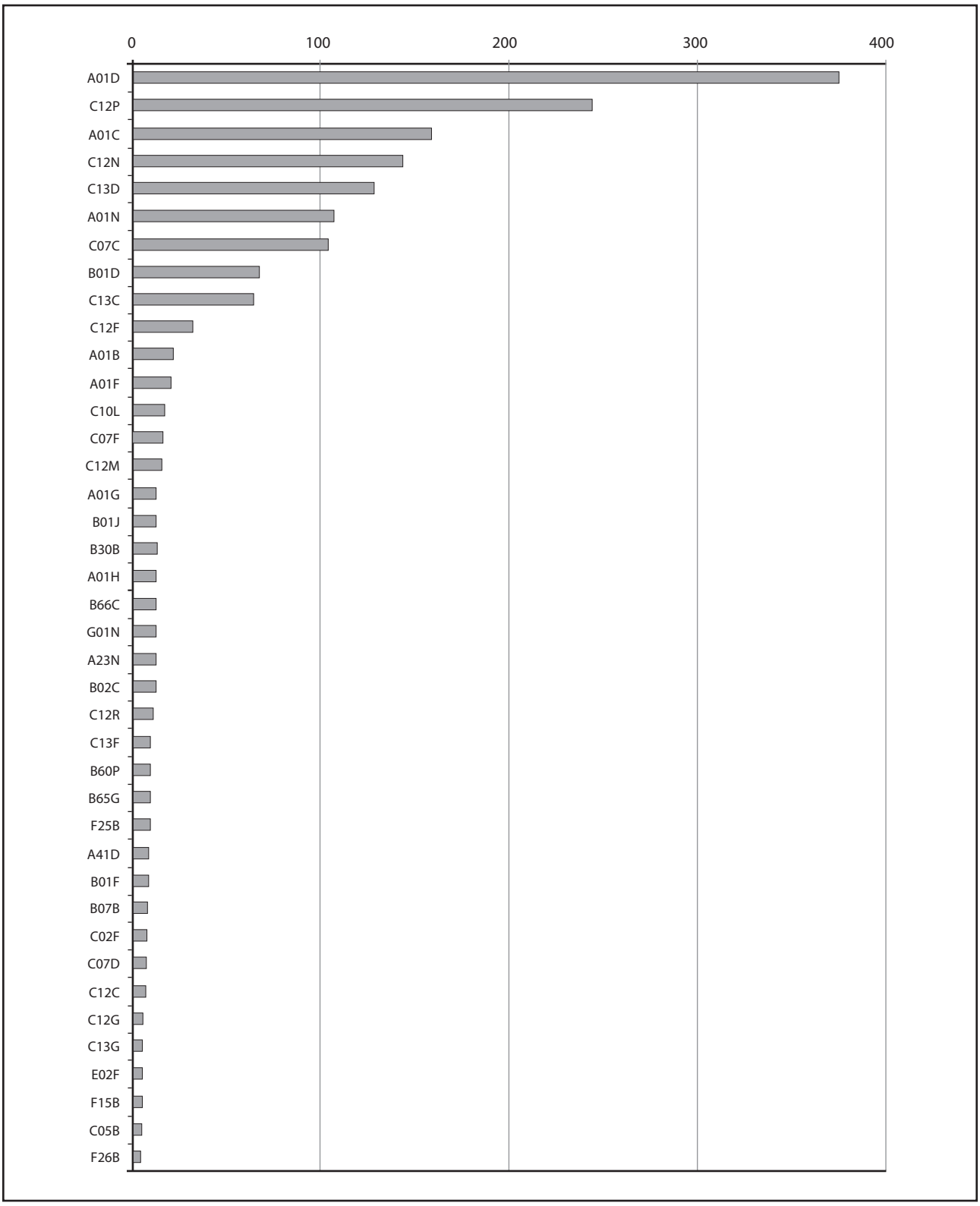

FIGURE 4 Distribuition of the main classifications (IPC).

TABLE 1 Description of the main classifications (IPC).

IPC	Description
A01C	Planting; Sowing; Fertilising.
A01D	Harvesting; Mowing.
A01N	Preservation of bodies of humans or animals or plants or parts thereof; biocides, e.g. as disinfectants, as pesticides or as herbicides; pest repellants or attractants; plant growth regulators.
C07C	Acyclic or carbocyclic compounds.
C12N	Microorganisms or enzymes; compositions thereof propagating, preserving, or maintaining microorganisms; mutation or genetic engineering; culture media.
C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture.
C13D	Production or purification of sugar juices.

A01D – HARVESTING; MOWING

This classification is intended to steps of harvesting and mowing, which involve mainly equipments for the harvesting of agricultural products, in our case more specifically, sugarcane.

First, it is interesting to evaluate the historical behavior of patent applications in this classification (Figure 5) and compare with the behavior shown in Figure 1.

Evaluating and comparing Figure 6 with Figure 1, it is possible to verify that there is much similarity in the behavior of both figures, but the highest peaks of applications occur on average two years before the behavior displayed in the Figure 1. This feature can be justified by the fact of referring to the initial stage of the production chain, which begins the process of innovation.

Regarding the country owning the technology filed in Brazil, it was examined the countries of origin of the applicants of the documents (Figure 6). In this case, it is verified that 68% of patent documents with CIP A01D filed in Brazil are from resident applicants, followed by the Netherlands, Germany and the United States. It is noteworthy that Brazil stands out as the largest producer of cane sugar in the world, therefore, it needs a lot of equipment adapted to working conditions in Brazil to harvest the cane, explaining their predominance in the documents filed.

C12P – FERMENTATION OR ENZYME-USING PROCESSES TO SYNTHESISE A DESIRED CHEMICAL COMPOUND OR COMPOSITION OR TO SEPARATE OPTICAL ISOMERS FROM A RACEMIC MIXTURE

The second IPC that stands out among the documents is the C12P, classification for the fermentation processes, the main process of production of ethanol using sugarcane as feedstock. First, it was evaluated the behavior of the patent applications in time (Figure 7). It is observed that the historical profile of existing patents in this technological niche has some differences when compared with the general behavior shown in Figure 1. It is noted that the first patent application regarding fermentation processes filed in Brazil occurred only in 1979, with peaks in 1980 and 1981, later going into decline.

This behavior may refer to different assumptions: i) the conditions of the fermentation process have little chance of variations, and the research in this area has saturated quickly, ii) the researchs are directed to the microorganisms used in fermentation processes, thus ltering the technological focus and therefore changing to the classification C12N iii) ther may be a change of the raw material used for production of ethanol, changing to other non-fermentative processes. It is possible that

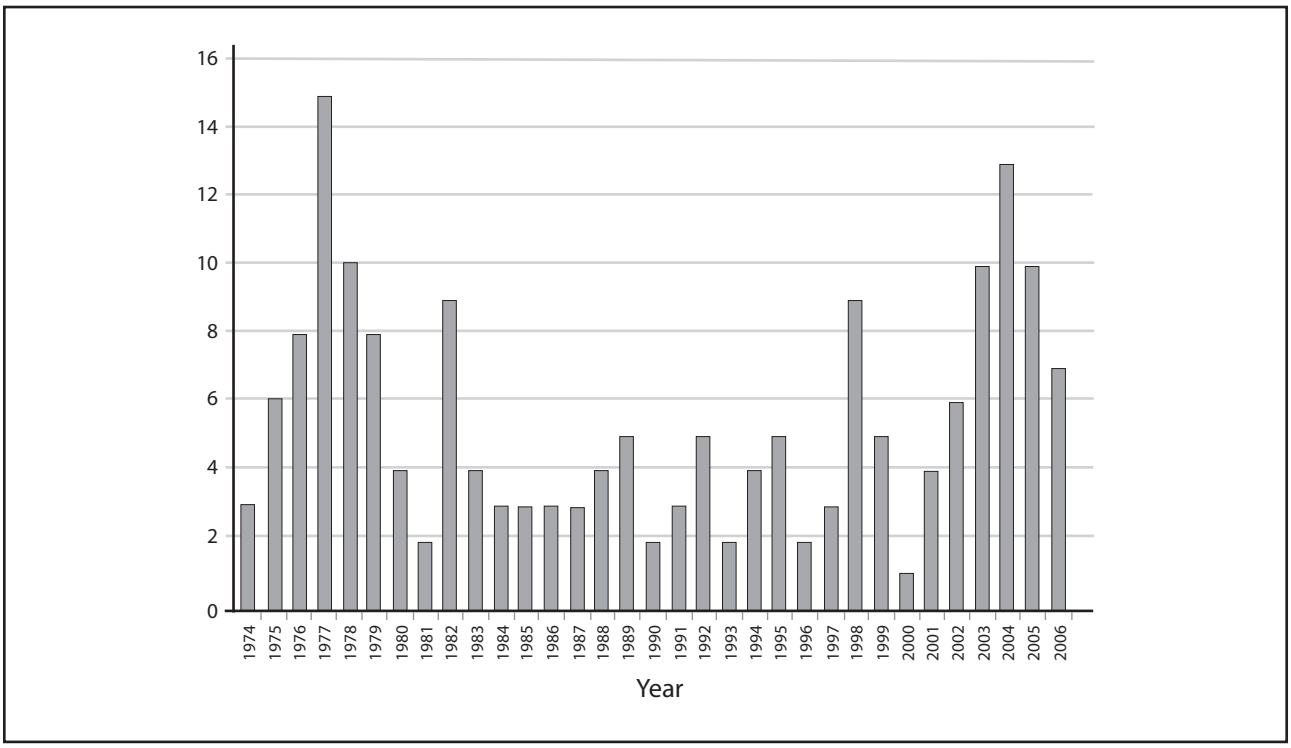

FIGURE 5 Evolution of the number of patent applications in the period between 1974 and 2006 refering to the international patent classification A01D.

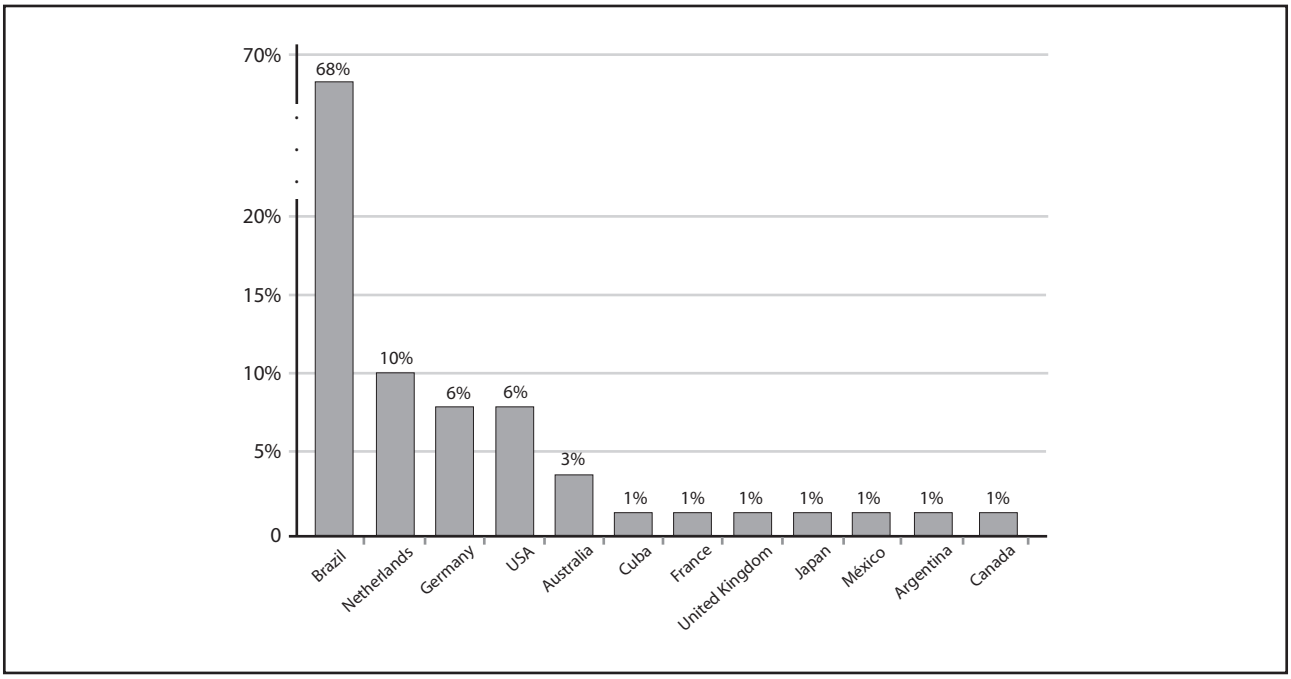

FIGURE 6 Distribution of patent documents filed in Brazil versus the country of the applicants in the internationa patent classification A01D.

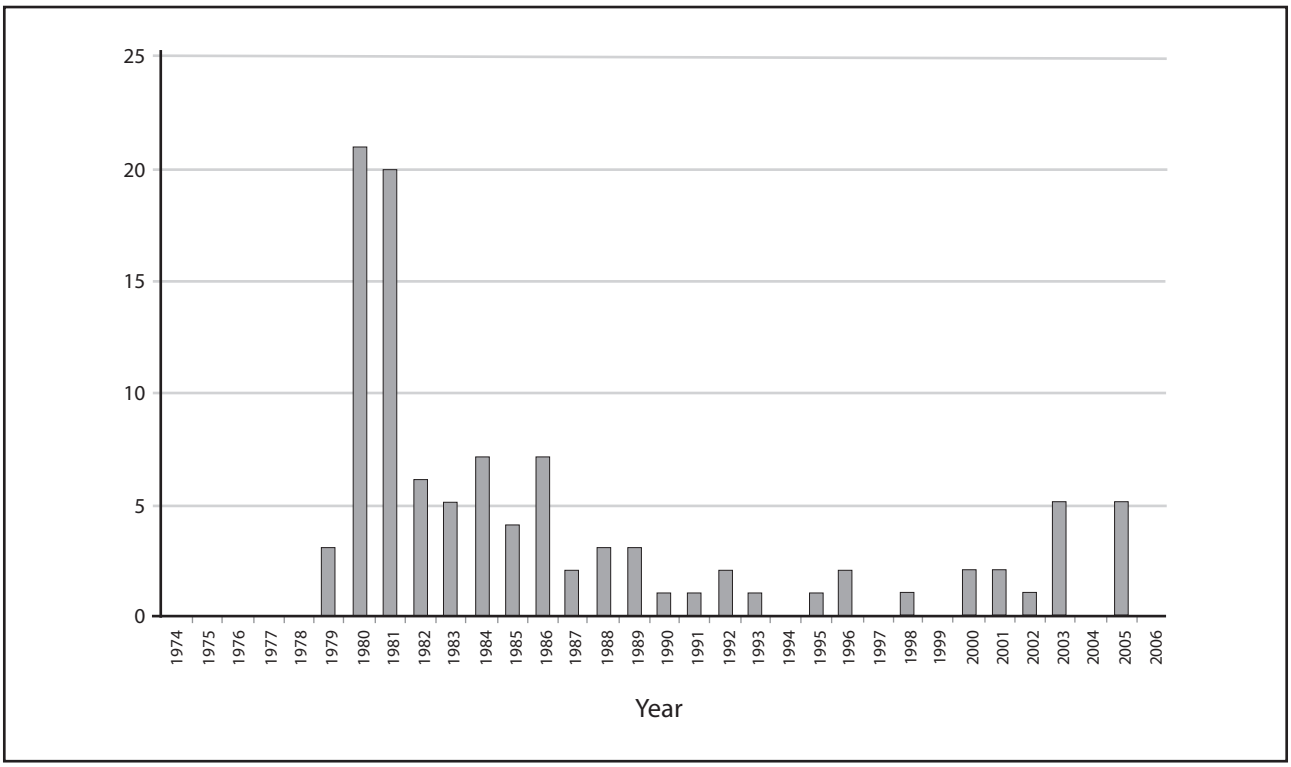

FIGURE 7 Evolution of the number of patent applications in the period between 1974 and 2006 refering to the international patent classification C12P.

these three cases are occurring simultaneously or separately.

Analizing the countries owning this technology filed in Brazil (Figure 8), it is observed that the percentage of documents filed by residents decreased when compared to all the documents, from 68% to 42%. However, Brazil still shows as the main holder of technologies involving the fermentation of sugarcane juice, but the U.S. and Japan have a significant share.

A01C – PLANTING; SOWING; FERTILISING

This IPC is also present in the early stages of the production of ethanol obtained from sugarcane and has great importance, since the process of planting of cane sugar has important features, either at planting or tillage.

Assessing the historical behavior of patent filling in Brazil in this classification (Figure 9), there is a behavior similar to that presented by IPC A01D and the behavior of the total number of documents in this study (Figure 1).

Later, as done in previous classifications, was studied of the countries within this niche of technology filed in Brazil (Figure 10).

It can be seen in Figure 10 that 95% of patent documents filed in Brazil are resident applicants, this can be justified due to the Brazilian peculiarities, especially the topography, climate and soil characteristics that need to be taken into account when developing technology cultivation for planting various types of plants.

C12N – MICROORGANISMS OR ENZYMES; COMPOSITIONS THEREOF PROPAGATING, PRESERVING, OR MAINTAINING MICROORGANISMS; MUTATION OR GENETIC ENGINEERING; CULTURE MEDIA

This IPC accounts for the the major advances in biotechnology for the production of ethanol obtained from sugarcane. Since the process occurs mostly in fermentative pathways, the existence of microorganisms for the conversion of carbo-

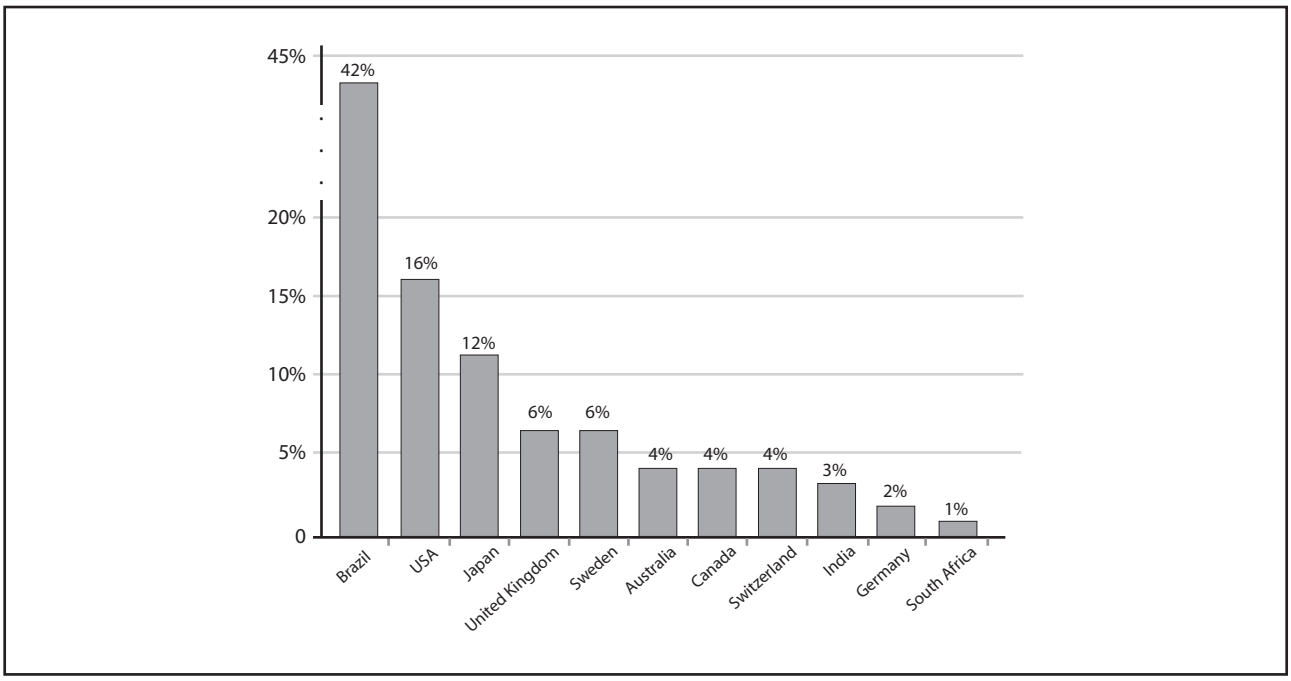

FIGURE 8 Distribution of patent documents filed in Brazil versus the country of the applicants in the internationa patent classification C12P.

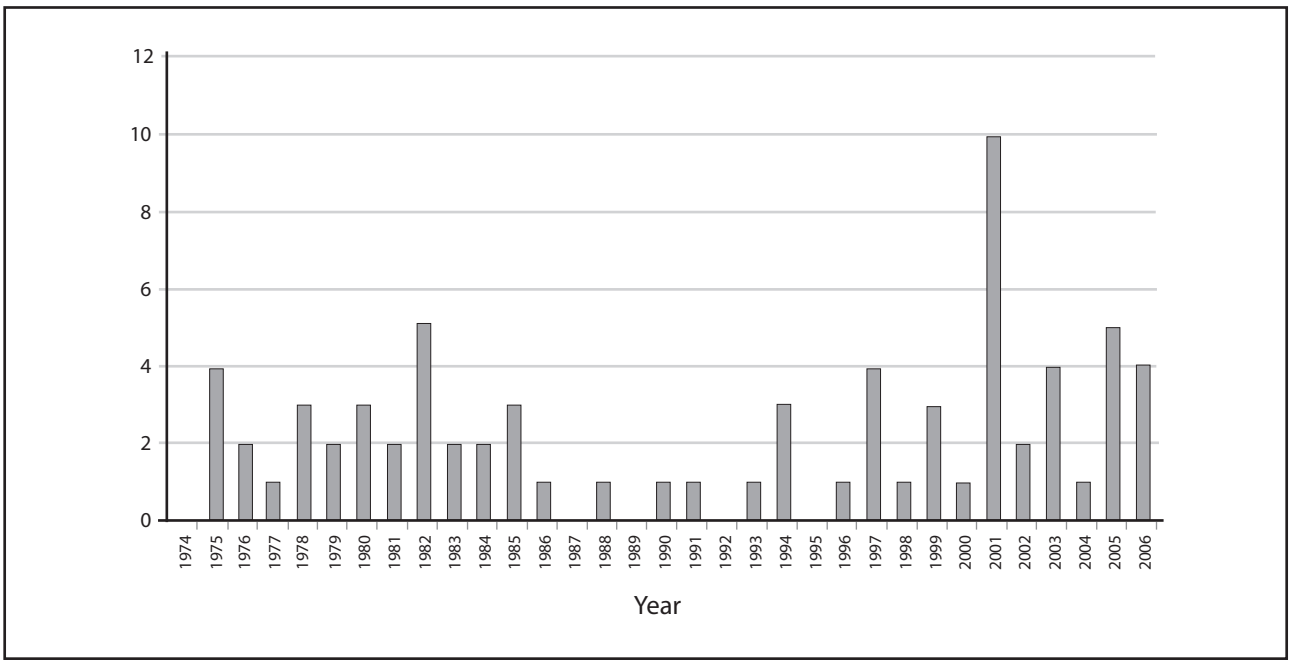

FIGURE 9 Evolution of the number of patent applications in the period between 1974 and 2006 refering to the international patent classification A01C.

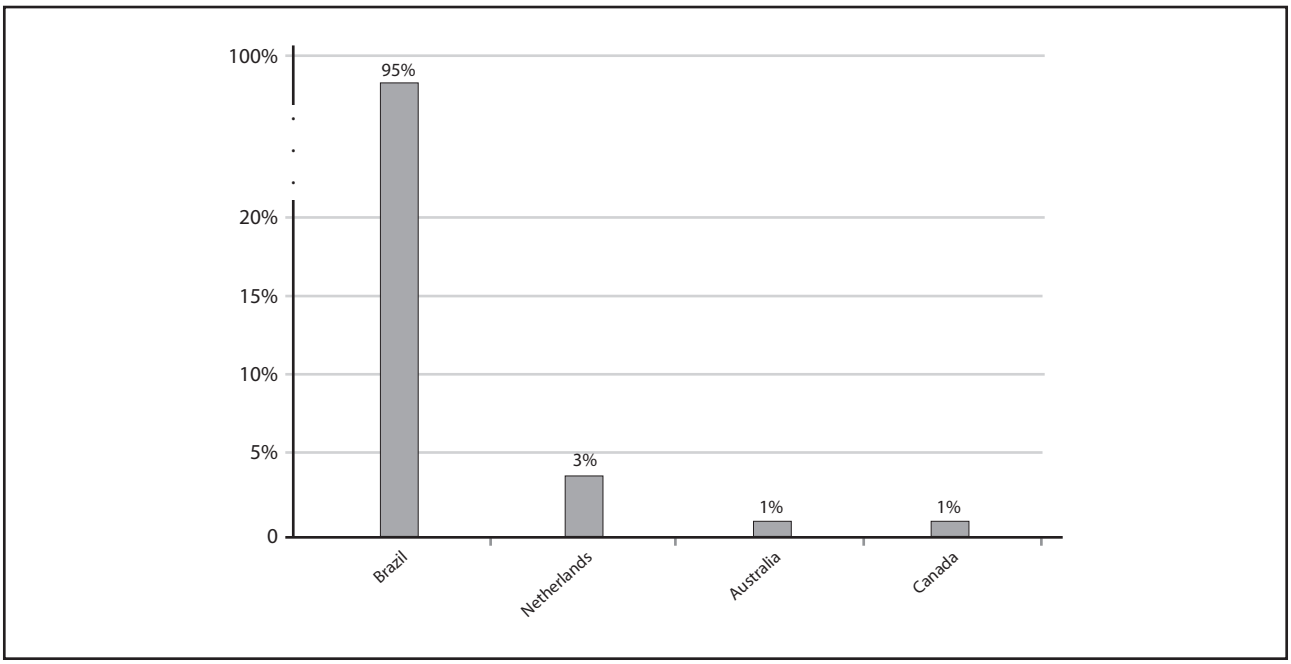

FIGURE 10 Distribution of patent documents filed in Brazil versus the country of the applicants in the internationa patent classification A01C.

hydrate to ethanol is necessary. Development of new microorganisms, mainly making use of genetic engineering has become a focus of research in several countries.

The historical evolution of patent applications in this IPC are shown in Figure 11. It can be observed, in this case, that the patent documents filed in Brazil had a higher concentration from the 90's, the largest peak of deposits in 2003 and approximately 45% of the documents filed in Brazil, occurred from 2000 to 2006. This profile is entirely different from the profile presented in the chain as a whole (Figure 1). This is probably due to the fact that biotechnology is a relatively new area, especially regarding genetic advances, what explains the predominance of documents in more recent times.

This result confirms the second hypothesis presented in the discussion of the classification C12P, because studies on fermentation processes had a drop in patent filling begining in the 90's and the applications regarding to microorganisms increased around that time.

Still, due to the complexity of the area, it is important to assess who owns this technology, mainly because it is one of the most important steps in the process of producing ethanol from sugarcane (Figure 12).

When evaluating the results shown in the Figure 12, it appears that the U.S. is alomost tied with Brazil, followed by Japan, United Kingdom and Australia. One hypothesis that could explain this result is that this technology niche has little regional dependency, and microorganisms developed for the fermentation of sucrose and other carbohydrates do not apply only to sugarcane and can be applied for the fermentation of sugars from corn, beets and other crops. Therefore, it is a technology that presents higher competitiveness and the countries with a more developed biotechnology research area of developed have more advantages.

FINAL CONSIDERATIONS

After evaluating the technology landscape of the production of ethanol fuel in Brazil in the last 3 decades, it is found the participation of various actors involved in the ethanol production chain, which reported over 400 different applicants in 656 documents filed in Brazil between 1974 and 2006.

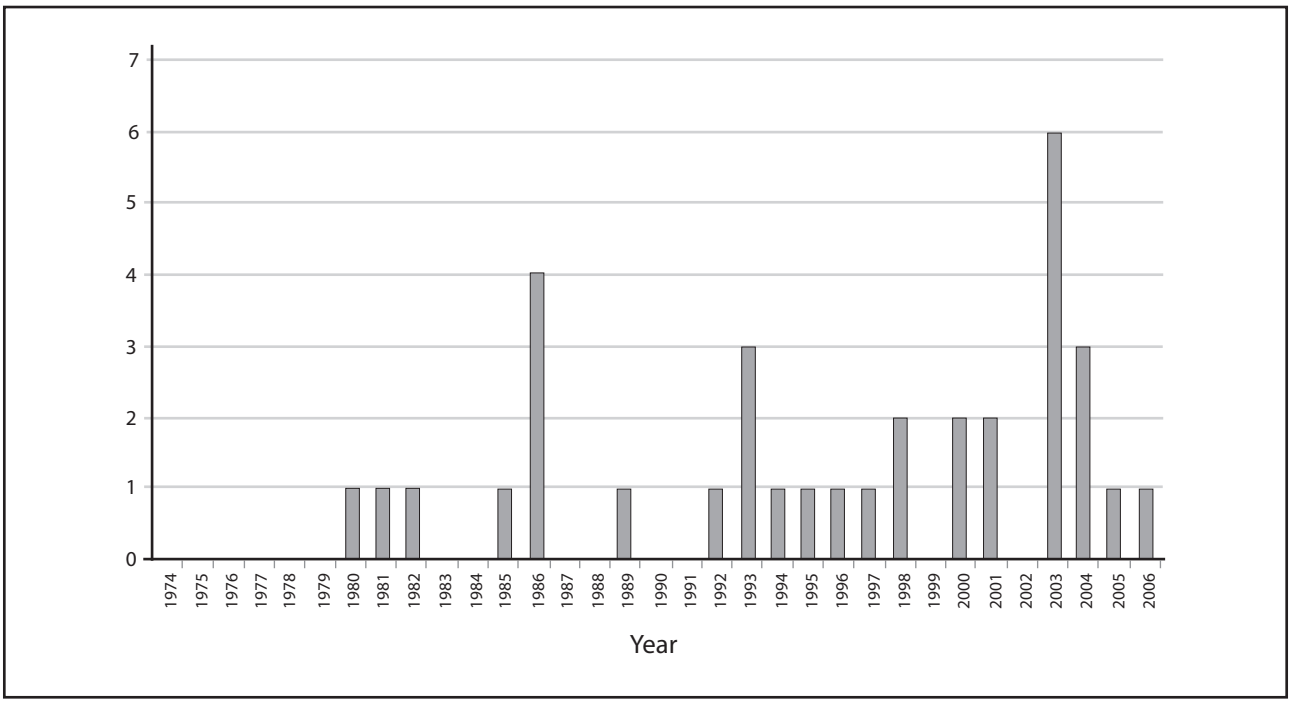

FIGURE 11 Evolution of the number of patent applications in the period between 1974 and 2006 refering to the international patent classification C12N.

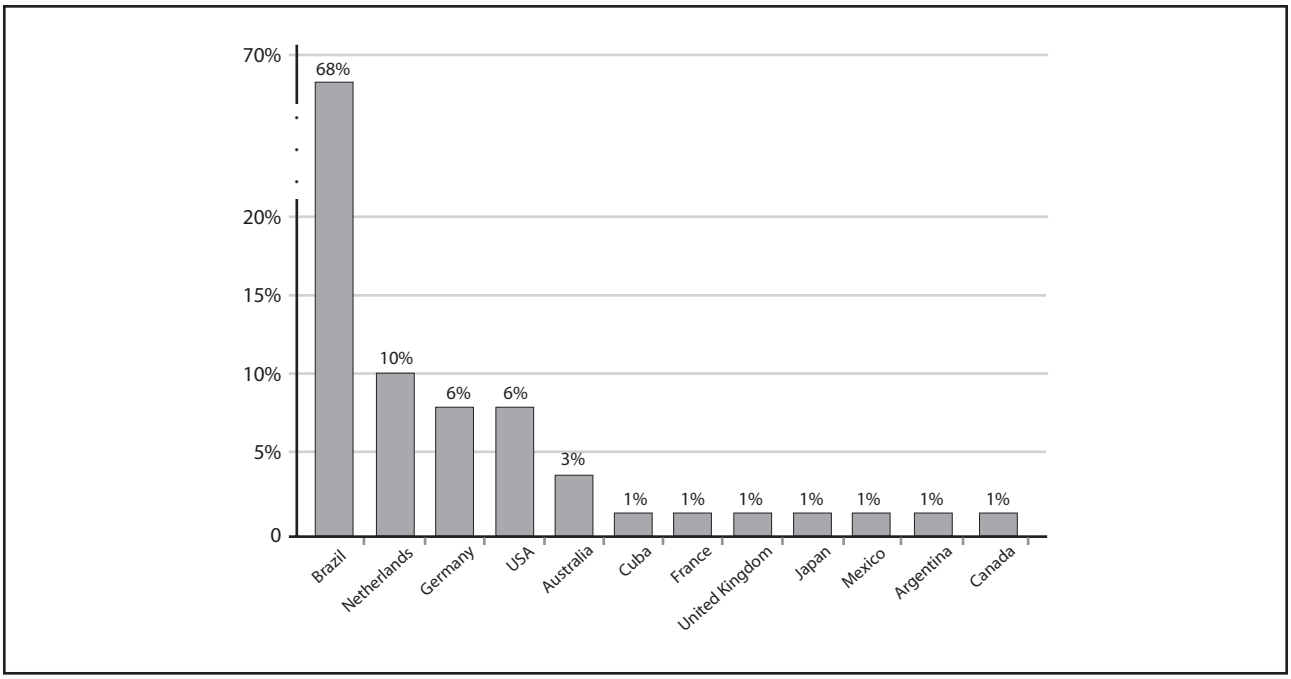

FIGURE 12 Distribution of patent documents filed in Brazil versus the country of the applicants in the internationa patent classification C12N.

Second, as in the case of Proalcohol, it is perfectly possible to see the impact of public policies on the behavior in the development and patenting of new technologies in production chain of ethanol from cane sugar.

Finally, that Brazil has a large percentage of the technology developed and filled in the country. However, it is worth noting that mosto of the documents relates mainly to equipments and processes of planting, harvesting and soil preparation. On the other hand, when it comes to the biotech industry, it appears that countries like USA and Japan gain market and become more competitive even in Brazil. This should serve as a warning to businessmen and authorities of the country, as these technologies are key to the so-called "second-generation ethanol," whose success is not only linked to the quantity of raw material that the country can produce, but also to process for the production of ethanol, especially the ethanol produced by biotechnology.

One conclusion to be drawn from this result is Brazillian reserch and development must not only seek the technologies already known, but rather, needs to intensify scientific and technological development and the protection of more complex technologies such as chemical and/or biotechnology in order to act competitively in this productive activity.

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