Sugar cane juice extraction innovation: technological prospecting study about diffuser and crush process

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Abstract
There are two processes for sugar cane juice extraction: milling process and diffuser, wich is a chemical leaching process. This paper deals with the competitive adoption of these two processes, the increasing use and evolution in the number of patent documents about diffusion and crush process.

Keywords: Sugar cane diffusion, crushing mill, sugar cane industry

INTRODUCTION

In the 2014-2015 harvest, the world sugar cane agroindustry was responsible for producing 155.7 million tons of sugar, Brazil, the largest producer in the world, yielded 35.8 million tons, followed by India with 27.3 million tons and then India with 10.2 million tons. In the 2014-2015 harvest, sugar cane occupied an approximate area of 26.5 million hectares, in Brazil 8.9 million hectares were planted, 5.1 million hectares in India, 1.9 million hectares in China and 1.3 million hectares in Thailand (FAOSTAT, 2015).

Currently, sugar cane juice extraction, which constitutes the preliminary operation for manufacturing sugar or ethanol, can be performed by two completely distinct processes: crushing mill and diffusion. The first, which is the most traditional and used method, consists of crushing the cane with grinding cylinders. Diffusion is a chemical process originating from beet sugar production has become increasingly used over the years by sugar cane agribusiness. It has to do with two distinct technological paradigms; crushing mill based purely on mechanical technology and diffusion on a chemical-technological principle.

Methods of technological prospecting have been used for decades in many countries as a tool to guide efforts for research, development and innovation (RD&I). The first systematic use of information records as a strategic tool is dated from the 50's with the main objective of reducing the time between the invention and arrangement of new products on the market and thus the

name of technological prospecting was given to this activity.

The aim was to identify the development of these two technologies from the technological prospecting tool. Search on the bases of industrial protection offices patents filed on the subject and analyze the evolution of orders made between the period of 1975-2015. This survey will identify the development of two technologies; depositors of the most significant patents; nationality and the nature of these depositors.

Theoretical Reference

The technological paradigm of crushing mill extraction is based on a mechanical principle of separation of the solid fraction (bagasse) from the liquid (stock) and is used to extract sugar cane. Over the years, this technology has evolved based on a typical research process of new technical options and selection of possibilities that momentarily had the best conditions for success.

According to Stupiello (1987), a classic crushing mill operates three grooved rollers, two installed on the same plane lower than the third. The purpose of this triangular arrangement is to enable the raw material to be squeezed twice. In the three cylinders, one may have two grinding rolls, one for power and other pressure (pressure-roller and top-roller). The extraction operation is to pass the rod through the grinding bed between the rollers resulting in an extraction of the broth which seep between the grooves of the rollers. During this passage the water is added to the bagasse in order to dilute the stock and facilitate the process.

This described set of three main cylinders and two optional supports as described is called a milling suit. Overall a standard plant has a sequence of five to six interconnected milling suits in its extracting line.

Diffusion is a technological process based on a chemical paradigm, it was initially designed to extract beet sugar. According to Ebeling (1978), the first tests and adaptations for the use of diffusers with sugar cane occurred between 1886 and 1889 in Louisiana. However, unsolved technical problems meant that the sugar cane industry abandoned this technology and invested in the crushing mill process.

During the 1960s, experiments in Germany enabled a new conception of continuous beet diffusion, more economical, efficient and easy to operate, and which has been adapted to the specificities of sugar cane agribusiness giving rise to the diffuser model currently used. In the current diffusion process, a layer of shredded sugar cane moves through a conveyor inside closed horizontal equipment. As this layer progresses, it is washed successively with water and flushed at a temperature around 80 to 85º C. The sucrose contained in sugar cane fibers is removed by osmosis, and the obtained stock is taken for sugar and ethanol manufacturing (Piacente, 2005).

According to Piacente (2005), institutional features (the relationship between sugar producers and machinery and equipment manufacturers for the sector) and technical (industrial output, cost of maintenance and adaptability to processing expansion) caused the different centers of sugar cane processors in the world to develop and adopt, in different measures, both technologies with predominance of the crushing mill process. Regardless of the sucrose extraction system adopted, it's a fact that different companies that make up the industry of machinery and equipment have been concerned over the years with developing or adapting their technology to the objectives of sugar cane processing sector. That's why they develop technical solutions within their R&D department which are tested and approved by the market with potential to become innovations. From this point on, these innovations are protected by a patent document.

The purpose of a legal patent system is to encourage technological progress and invention,

awarding the inventor with a grant for the temporary monopoly on its creation. The search for patent documents (technology prospecting) is done in the database by category and the documents are deposited with an international classification that allows their identification in different areas of knowledge. These searches can provide distinct purposes: to seek a particular technological solution to a problem; state of art, basis for the study of technological trajectories, forming indicators to support science and technology policies and others (Piacente and Silva, 2015).

A shift in paradigm with regard to technology foresight is needed and should be adopted as a routine in firms, especially in decision-making processes. It assists in the management of innovation, provides a broad view of studied technology and its bottlenecks, outlining possible paths for the future.

The prospecting methods are being used by various companies in the world as a tool for analyzing speed in the development of projects, particularly those related to technology and their acceptance by the market. This technological development, coupled with scientific research, is the instruments used by the National Institutes of Science and Technology to contribute to national development. Knowledge needs to be created and transferred to society in the form of innovation, improving people's lives and developing regions.

In the face of technological change, Godet (1997) and Mayerhoff (2009) list four possible attitudes of stakeholders. The first is passive, where the firm only monitors and receives the consequences of changes. The second is the reactive attitude, the firm acts only after anything happens, the third attitude is the pre-active, those firms that are prepared to change and finally demonstrate proactive attitude, where they lead technological change.

It can be noted that the value differential that the firms search for can be reached with the help of technological prospecting based on forecasting innovations. To this end, Coelho (2003) points out that firms must: i) systematically collect relevant information; ii) process it analytically; iii) and turn it into an element for decision making. The survey will indicate the areas that the organization should prioritize and thus can obtain advantage over other firms, and can advance or forecast and monitor technologies of interest.

Among the various strategies to achieve technological exploration, Canongia (2004) points out one that combines the techniques of Competitive Intelligence (CI), Knowledge Management (KM) and Foresight (F) in prospecting strategy applied in the R&D sector. The knowledge gained as a result of these processes must be shared, analyzed and used in conjunction with stakeholders, in order to direct products and partnerships that can contribute to the competitiveness and innovation.

To Kupfer and Tigre (2004), technological prospecting methods can be classified into three groups: i) assessment, which is the systematic and continuous monitoring of evolution of facts and identifying carriers of change; ii) forecasting, which consists of making projections based on historical information and modeling trends; and iii) foresight, which consists of forecasting possibilities, based on unstructured interaction among experts.

According to Castro and Lima (2005), due to the conceptual and methodological difficulties in organizing and understanding complexity of systems, use of the study of technology foresight is restricted to certain areas of knowledge, mainly those with technological solutions which can be identified in databases of industrial protection offices. In this case, systemic and analytical tools are necessary to simplify the system studied, and contribute to a cause-and-effect network of relationships which impacts on system performance.

Methodology

The methodology adopted for the construction of the article was based on the mapping of relevant information in order to identify patent documents related on crushing mill and diffusion processes used in sugar cane juice extraction, deposited in major industrial protection offices throughout the world between 1975 and 2015. Therefore, this purpose we used the technological prospecting tool, Questel Orbit, which is a system of search and analysis of information contained in patents and drawings industrial. This system allows them to be carried out searches through keywords, bibliographic fields, patent classification, quotes, patent families and legal status. Its coverage spans more than 96 countries for patents, 21 of them with searchable full-text and files available for download (Piacente, Silva and Biaggi, 2015).

In the specific case of the research carried out, the search in Questel Orbit was done with the following keywords: for the diffusion process: *"sugarcane* or sugar cane* or bagasse*" and "diffuser";* for the crushing mill process: *"sugarcane or sugar cane" and "crush* or mill*" and IPC Code=(C13* OR B30B* OR B02C*)*. The IPC (International Patent Classification) establishing a hierarchical system of symbols for classification Invention Patent and Utility Model according to different technological areas. It is adopted by over 100 countries and coordinated by the World Intellectual Property Organization. The C13 refers to sugar cane industry, B30B to mil and B02C to crusing (INPI, 2015).

The objective was to perform a sweep of all the patent documents found for these two technologies and analyze the evolution that occurred during the period of analysis. In this way, along with other information we could find: i) number of patents per technological subdomain; ii) number of patents by titleholder's country of origin; iii) number of patents by titleholder; iv) current stage of researched patent documents.

Results and Discussion

The research carried on Questel Orbit software with previously selected terms resulting in 222 patent documents on crushing mill and 22 on diffusers, showing greater interest in the development of a crushing mill process than the diffuser.

Figure 1 shows the results of the search terms per year according to the patent's deposit date. For the survey of the term crushing mill, stronger growth was observed in the number of deposited documents from the year 2006. In the period between 2006 and 2015, 98 documents related to the crushing mill process which represents approximately 45% of total researched documents (40 years).

This period is related to the recent expansion of sugar cane production in Brazil which is the main production center in the world. This expansion was characterized by the resumption of Proálcool, a large-scale national development program for a gasoline fuel substitute. In the early 2000s, the Brazilian automotive industry developed a flex engine that runs on gasoline and sugar cane ethanol in any proportion.

This innovation reheated the sugar cane industry in Brazil, specifically ethanol producers, steering part of the production of sugar cane to the manufacturing of ethanol to the detriment of sugar which stimulated the sugar expansion in other producing countries such as India and Thailand. The growth in demand for sugar cane ethanol fuel in Brazil directed new investments

to this country, which stimulated the machinery and equipment sector for sucrose extraction to develop new technological solutions.

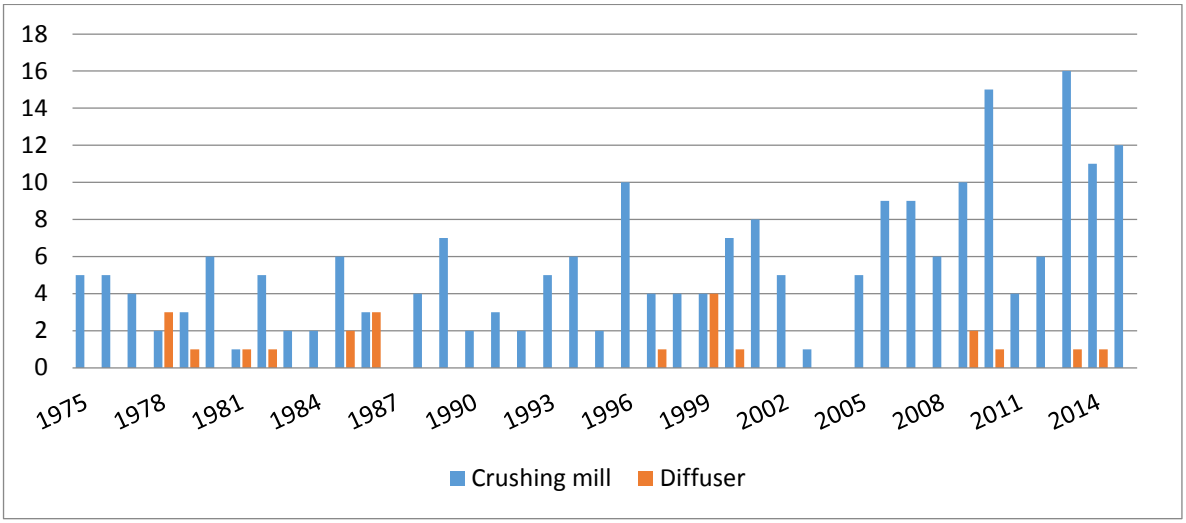

Figure 1 - Distribution of obtained results with search terms (crushing mill and diffuser) carried on Questel Orbit, by year according to the date of deposit

Regarding the diffuser, it is noted that 22 documents were deposited in the period 1975-2015, focusing on the end of the 1970s and late 1990s and from the decade of 2010. Specifically at the end of the 1970s, Brazil, that it was the main production center and processor of sugar cane in the world, began Proálcool. The program supported the installation of hundreds of distilleries across the country for the production of ethanol fuel, stimulated the capital goods industry to serve the sugar cane processing industry and has created research centers to contribute technologically to the established objectives.

Part of the technology developed during this period was directed to more efficient alternative extraction of sucrose from sugar cane, technical solutions aimed at crushing mill and dissemination systems. At the end of the 1970s the main European manufacturers of machines and equipment for sugar beet production had adapted their equipment and developed continuous bagasse diffusers for sugar cane processing. Technologies were developed to meet, in part, the growing Brazilian market at the time and which was protected by patents that may be evidenced in the data presented in Figure 1.

According Piacente (2005), during the Proálcool program (1975-1985) have been installed in Brazil at least 4 distilleries to produce ethanol from sugar cane that used the diffuser as the dominant technology in the extraction of sucrose. The diffusers were manufactured in Brazil under license of European developers, 3 sets of the BMA (Austrian) and 1 DDS (Danish), both producers of equipment for sugar beet processing.

Beginning in the late 1990s and early 2000s, with the recovery of Brazilian ethanol production and perspectives of this fuel turning into an international commodity, sugar cane agroindustry of this country underwent a new period of investment and growth. This fact stimulated installation of new sugar cane processing plants in order to meet increasing demand for ethanol fuel. Part of these new plants was constructed with more modern and efficient cane diffusers than the 1970s generation.

Figures 2 and 3 show the distribution of patent documents observed during the research

according to their country of origin. For crushing mill, 21.3% of documents were deposited in China (CN), 16.3% in India (IN), 14.9% in Brazil (BR), 14.0% in the United States (US), 10.4% with WO acronym (Wipo), 3.6% in France (FR), 3.2% in Australia (AU) and European Patent (EP), 2.7% in Germany (DE) and Great Britain (GB), 1.8% in Japan (JP) and Thailand (TH), 1.4% in Cuba (CU), two documents in Canada (CA) and South Korea (KR) and only one document filed in Spain (ES) Mexico (MX), Sweden (SU) and South Africa (ZA). The WO acronym refers to PCT (Patent Cooperation Treaty) requests, those that make deposit in more than one country at the same time.

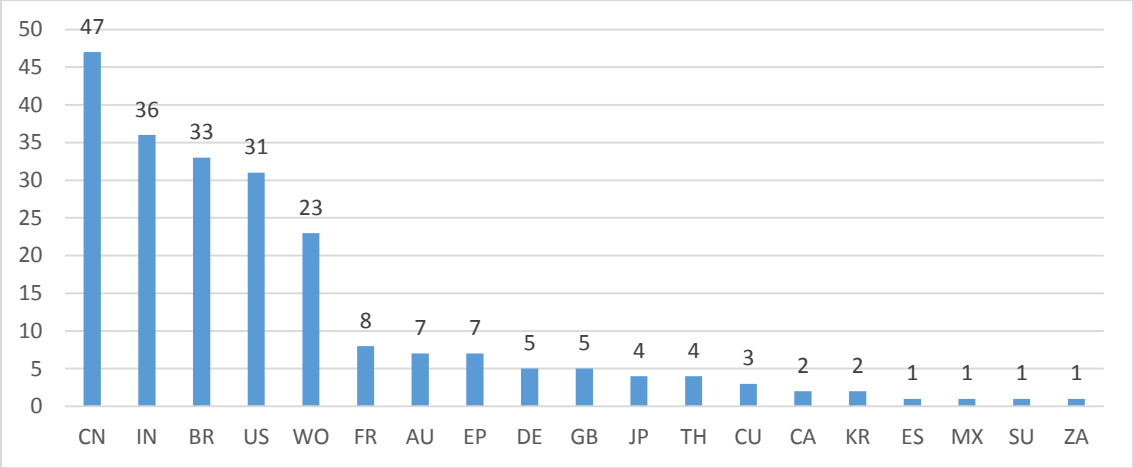

Figure 2 - Distribution of results obtained with the search term crushing mill by country where the invention was initially(priority country) deposited in the period from 1975 to 2015

For diffuser, it was verified that 22.7% of documents were deposited in Germany (DE) and in the United States (US), 13.6% in Great Britain (GB) and with the WO acronym, 9.1% in European Patent (EP) and only one document (4.5%) in China (CN), Cuba (CU), France (FR) and India (IN).

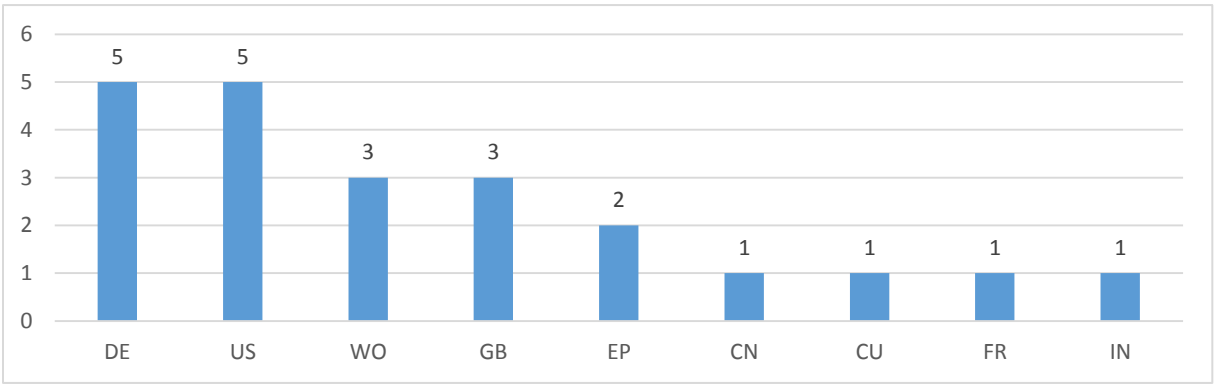

Figure 3 - Distribution of results obtained with the search term diffuser by country where the invention was initially (priority country) deposited in the period from 1975 to 2015

We cannot say in which country there is greater development on the subject of crushing mill and diffuser, as there is a possibility a company has research centers in several countries,

especially in countries where the production of sugar cane for the manufacturing of sugar and ethanol is important such as Brazil, India, Thailand and others. This technological information in a patent document allows us to more accurately observe that the countries with the most significant technological development in a particular sector is the "country of priority" of the document, which is where the first patent deposit was made for the referred technology in the world and that is the focus country for the protection of technology.

In patent applications on the term crushing mill, the following depositors stand out: Nikam Bahusaheb Bapurao (10 documents), Fives Cail Babcok (7 documents), Nishimura Oscar (6 documents), Guiangxi University and Waschandnagar Industry (5 documents), Bhausaheb Bapurao Nikam, Braunschweigische Masch Bau and Bundaberg Foundry (4 documents), Liuzhou Tianmimi Renewable Energy and Maqtron Imp Ação & Exportação (3 documents) (Figure 4).

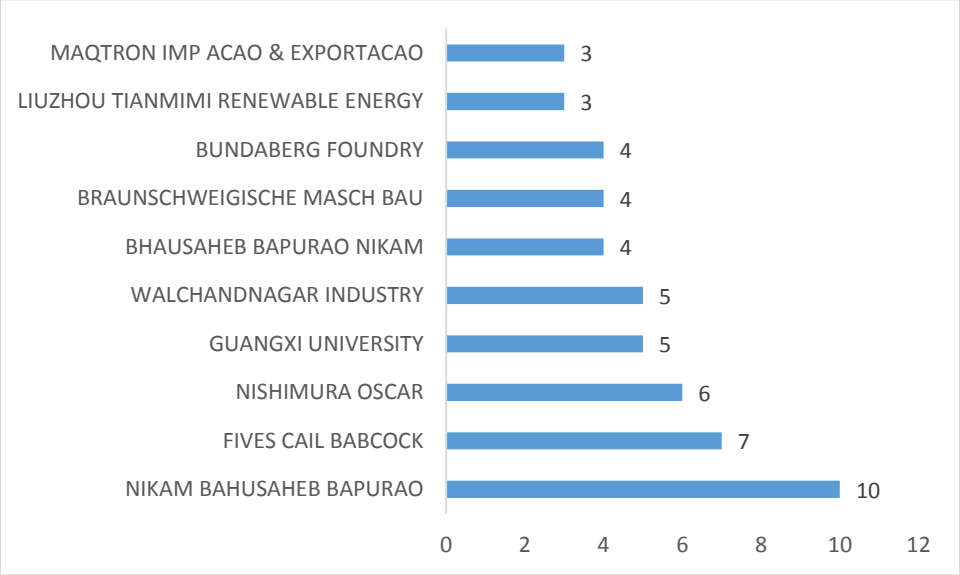

Figure 4 - Relation of main depositors of patent applications with the search term crushing mill in the period 1975-2015

Specifically in Brazil, the largest producer and exporter of sugar cane ethanol and sugar, the patent documents that have been deposited as "priority country" (BR acronym) and call attention are: Nishimura Oscar (6 documents), Maqtron Imp Ação & Exportação (3 documents), Center Royal Quimica Industry and Empral Desenvolvimento de Equipamentos (2 documents), Cooperativas de Produtores de Cana, Centro de Tecnologia Canavieira (CTC), Renk Zanini, Salim Nogueira Rodrigo, Silveira Gravata Carlos Edu and Veloso Silva Helio Jose (1 document).

With respect to the diffuser, the Austrian company, BMA (Braunschweigische Masch Bau) appears among the main ones with 24 documents (Figure 5).

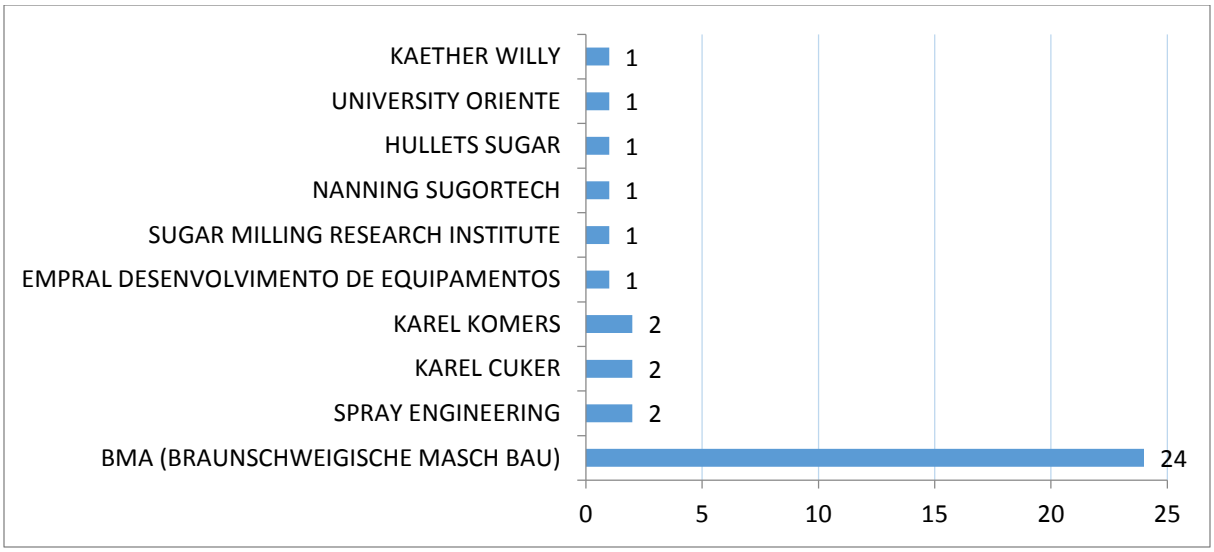

Figure 5 - Relation of main depositors of patent applications with the search term diffuser in the period 1975-2015

Regarding the current situation of the documents obtained in the research, the classification "pending" shows some kind of documentary nonconformity or payment that prevents the continuation of registration or ownership. "Expired" classifies patent documents that expired due to exhaustion of the maximum concession period. "Lapsed", in which a patent application was deferred at some point and had not been revalidated every five years by the holder. “Revoked”, when there is no realization of the payment of patent Those considered protected or "granted patents" are those which have had their request deferred or granted and whose holders have collected the payment of the charter.

For the search term associated with the crushing mill, 41% of the documents found are lapsed, 26% pending, 18% expired, 10% granted and 5% revoked. As for diffuser, 47% of fetched documents are expired, 20% granted, 15% lapsed, 9% pending and 9% revoked.

Final Considerations

The research developed in this studies enables verification beginning from a search of selected with Questel-Orbit software, the relevance of the research involving crushing mill and diffusion processes in the world’s main industrial protection bases. This type of study makes up an important tool for the diagnostic of the state of art of certain technologies, visualization of main owners of techniques and cutting-edge innovations and make up an import way to help determine science and technology policies in several government branches.

The collection of patent documents studied enables the pointing out of important aspects about research and development initiatives on the area in question and it was clear that the crushing mill process is more used than the diffuser, notably in Brazil, the main production center in the world.

In general, the innovations in the field of sugar cane physiology, starting at the second half of the 20th century, they enabled important advances in the conception of new equipment for sucrose extraction. The introduction of wood chippers and sheredders was spawned by these advances. They are equipment that precede the juice extraction stage and responsible for the

opening of the cane cells, facilitating and increasing extraction efficiency, mainly from the diffusers.

It can be noted that for the crushing mill process, between countries in which innovations were initially deposited (priority country), China, India, Brazil and the United States stick out and are among the largest producers of sugar and ethanol from sugar cane.

For the process of diffusion, Germany and the United States stick out. Historically, Germany is the main European center of technology development for beet sugar production which only uses diffusion as a sucrose extraction system. Thus, adaption studies of technologies developed so beet diffusers process sugar have been carried out since the end of the 19th century, and been successful ever since the 1990s, which justifies development of the technological trajectory of this process being concentrated in the Austrian-German manufacturer, BMA.

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