

Second Generation Ethanol: Production Process and Environmental Aspects

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ABSTRACT : *The increased demand for conventional ethanol, also called first-generation ethanol, and the search for improvements in the sustainability of its production process, has become a challenge for the biofuels industry. In considering this scenario, second-generation ethanol presented as an excellent alternative for the energetic use of biomass, since its production occurs through the hydrolysis process of the lignocellulosic materials, that is, it uses as bagasse the bagasse or the residual straw of the production process of first generation ethanol. For the preparation of this work a literature review was carried out through a qualitative approach and descriptive research. This analysis of the production process of the second generation ethanol, and the main challenges and environmental aspects that are involved, made it possible to identify the advantages of the production and use of this biofuel and also the need for better production routes that overcome the existing difficulties.*

KEYWORDS Ethanol, Sustainability, Biofuels, Biomass, Lignocellulosics.

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I. INTRODUCTION

The growth in the use of petroleum products, mainly by the world transport sector, began in 1930, with the creation of the explosion engine (ANEEL, 2017). Oil is a non-renewable energy source and its use generates environmental problems, which encouraged the development of biofuels production, especially ethanol. (SCHUCHARDT; RIBEIRO, 2001).

The first oil crisis occurred in the 1970s, and for Brazil, as for other countries, it was necessary to find alternative energy sources to reduce this dependence on oil, which led to the emergence of the National Alcohol Program – Proálcool. During this period, a small part of ethanol was added to gasoline, but in 1979, due to the second oil crisis, or ethanol replaced gasoline, with Brazil as a precursor of this substitution (ALVES; MACRI, 2013).

Despite having an efficient energy generation process, conventional ethanol, also called first generation ethanol (ethanol (1G)), cannot meet the energy needs of Brazil, because the increase of the cultivated area for the production of this biofuel may mean a reduction in the area used for planting food. Thus, ethanol production (1G) has some limiting factors for its expansion (PACHECO, 2011).

Given the environmental problems caused by the use of petroleum products, and the possibility of increased demand for the biofuel used to compromise the food supply, the search for a renewable energy that had lower impacts has grown (ARAUJO; NAVARRO; SANTOS, 2013).

In this context, the production of second generation ethanol (ethanol (2G)), also called bioethanol, has become an excellent alternative because it occurs during the processing of lignocellulosic materials, which are the fibrous materials present in vegetables, especially with the use of sugarcane bagasse and straw, which account for more than half of the energy stored in the plant (ARAUJO; NAVARRO; SANTOS, 2013).

By reusing the residues from the production of ethanol (1G) and sugar, or bioethanol does not negatively impact the food production chain, or allows the expansion of biofuel supply, without causing the possibility of increased planted area.

Besides sugarcane bagasse and straw, other residues are used in the production of ethanol (2G), such as straw and corn cob (RAMOS, 2010). Corn is mainly used in the food industry, but a part of this plant has no direct use, so these residues can be used to produce ethanol (2G), because they have the available sugars in its composition (SANTOS, 2014). Another product is a carrot, where waste generated after carotenoid extraction is used to produce this biofuel (PASSOS et al., 2017).

However, there are some challenges for the production of second generation ethanol that should be considered, for example, the difficulty of extracting fermentable sugars due to the complex structure of lignocellulosic materials, and the fact that the use of sugarcane bagasse for production Biofuel reduces the availability of this material for the generation of electric power (gas firing in boilers), or what records discussions among the proponents of each of these applications.

However, you should not miss the reduction of environmental impacts that the use of ethanol (2G) provides to society. In order to increase the knowledge on the proposed theme, it is essential to verify these contributions, given the need for more efficient production methods, mainly due to the growing demand for conventional ethanol.

II. THEORETICAL REFERENTIAL

Ethanol is an organic compound from the group of alcohols (hydroxyl-linked saturated carbon, a bond between an oxygen atom and a hydrogen atom), and is commonly known as alcohol, cereal alcohol, or ethyl alcohol (MENDONÇA, 2008; TOZZETTI et al., 2009).

Its molecular formula is composed of 2 (two) carbon atoms, 6 (six) hydrogen atoms and one oxygen atom (C_2H_6O or CH_3CH_2OH), where the two carbon atoms are bonded to the five hydrogen atoms and the only oxygen atom is attached to the sixth hydrogen atom. It is a light and easily obtainable compound, and the structural formula of ethanol can be seen in Fig. 1. (PARAIZO, 2013; SILVA; CAMPOS, 2013):

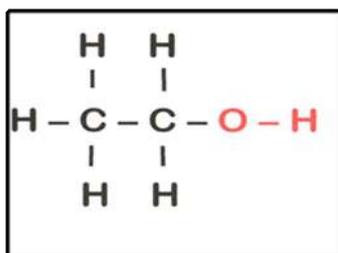


Fig. 1. Structural Formula of Ethanol

Fonte: Fonseca, 2010.

Due to the presence of hydroxyl in its structure, ethanol is considered a polar substance, thus having different poles because of the significant electronegativity difference between oxygen and hydrogen. Considering that the polarity of organic molecules is an important factor in the conception of their chemical and physical properties, it can be concluded that this substance is miscible in water (which is also a polar substance) and with any other substance that has this same characteristic, because every polar substance dissolves only polar substances (MARTINS; LOPES; ANDRADE, 2013).

Ethanol is a colorless liquid, with a characteristic smell, volatile, highly flammable, boiling point approximately $78^{\circ}C$ and melting point around $-114.1^{\circ}C$, where PE and PF may change when altitude changes, as these values are referring to the pressure of 1 (one) atm, at sea level. This alcohol has a relative density of 0.789 g/cm^3 at $25^{\circ}C$ and an ignition temperature of $363^{\circ}C$ (ARAÚJO, 2008; PARAIZO, 2013; SILVA; CAMPOS, 2013).

As the uses of ethanol are diverse, it can be used as a solvent in laboratories and industries, in perfumery, pharmaceuticals, organic substances, among other applications (ARAÚJO, 2008).

The flash point indicates the minimum temperature at which the fuel vaporizes and forms a flammable mixture with air. The flash point of anhydrous (water-free) ethanol is $13^{\circ}C$ and hydrous ethanol is $17^{\circ}C$. This point of ethanol is considered low in relation to other liquid fuels, such as diesel and biodiesel, which have values of $62^{\circ}C$ and $130^{\circ}C$, respectively. This makes fuel ethanol easier to ignite and can be considered a flammable substance, which has a flash point below $70^{\circ}C$ (BOCHI, 2016; COSTA NETO et al., 1999; PARAIZO, 2013).

Faced with concerns about future oil scarcity and the advance in the search for fuels that do not derive from fossil sources, but which are competitive, ethanol has become a promising alternative, whether pure or blended, as it is derived from renewable sources such as sugar cane, which pollutes the environment less, mainly because it absorbs in photosynthesis, high amount of carbon dioxide released into the atmosphere (PARAIZO, 2012).

Studies show that ethanol decreases by almost 90% of greenhouse gas emissions compared to gasoline. As fuel, the common ethanol sold at the stations has in its composition 95% hydrated ethyl alcohol and 5% water. Ethanol sold mixed with gasoline is anhydrous alcohol, with 99.5% pure alcohol (OLIVEIRA, 2010; UNICA, 2017).

Conventional ethanol, also called first generation (1G) ethanol, is a biofuel from the fermentation of sugars present in various plant products, such as sugar cane, beet, corn, cassava, among others (JARDINE; BARROS, 2017).

Each country uses the most favorable raw material when considering climate issues and their supply. And due to its great territorial variety, Brazil can use several crops, and many of these have characteristics favorable for the production of ethanol (MARCOCCIA, 2007).

Ordinary ethanol is normally produced by fermentation of sugar cane, and the steps of this production process are presented in Fig. 2.

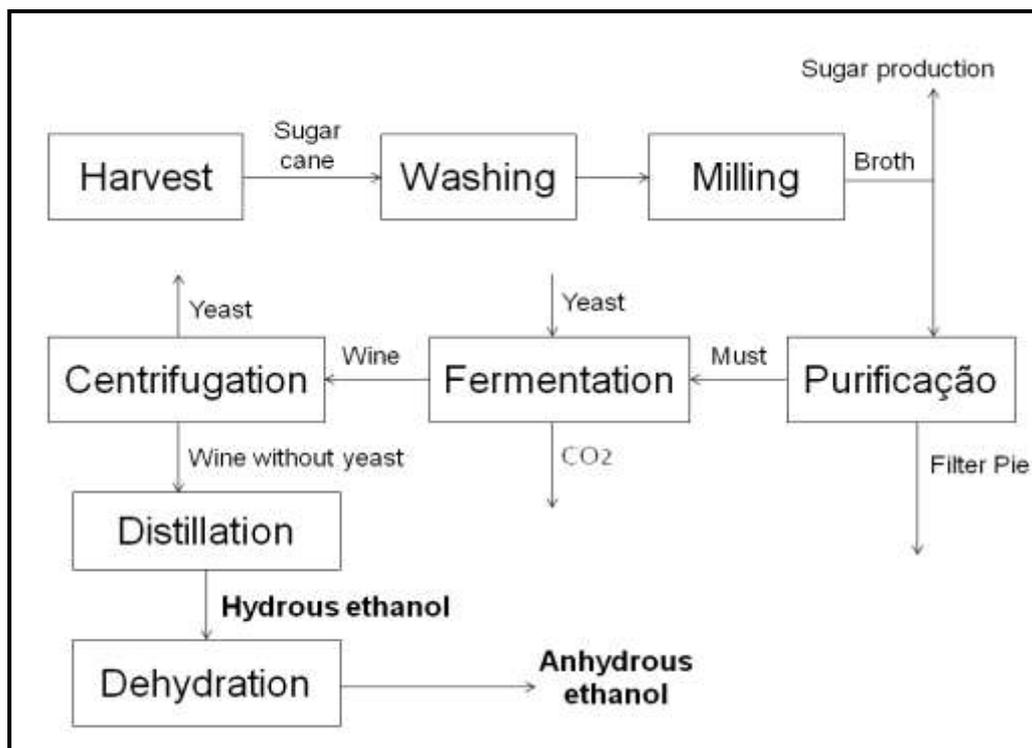


Fig. 2. Flowchart of the ethanol production process

Fonte: Carvalho, 2018.

The residues of the milling step, in both sugar or ethanol production processes, such as bagasse or straw from plant materials, can be used as raw material of another type of ethanol, known as second generation ethanol or ethanol (2G). With this, it is clear that if all sugarcane juice is used for sugar production, and does not occur for ethanol production, this will not affect the production of ethanol (2G).

Second generation ethanol (ethanol (2G))

One of the main differences between conventional ethanol, also called first generation ethanol (ethanol (1G)), and ethanol (2G) is the raw material. Second generation ethanol (2G ethanol), also called bioethanol, is produced through the processing of lignocellulosic materials, and uses mainly sugarcane bagasse and straw as raw materials (TOMÉ, 2014).

The first record of the possibility of producing ethanol from cellulose occurred around 1819, when French chemist Henri Braconnot identified that sulfuric acid hydrolyzed cellulose and thus formed fermentable sugars by the acid hydrolysis technique. In 1838, another French chemist, Anselme Payen, was able to isolate cellulose from lignocellulosic material and characterize it (BERNI, 2017).

The Germans in 1898 used the acid hydrolysis technique to produce ethanol through wood on a commercial scale. In response to the lack of fuel caused by First World War, the American Standard Alcohol Company, in 1910, to produce cellulosic ethanol undertook the construction of two (2) industrial plants. But this technology in later years became economically unfeasible (SOLOMON; BARNES; HALVORSEN, 2007).

During Second World War, North American military troops on the Solomon Islands in the South Pacific noticed the rapid deterioration of their uniforms, tents, purses, and other cotton goods. Some researchers, along with the military, set up laboratories for explanations, and found a fungus that released enzymes that could turn cellulose into glucose. And with that, the studies of enzymatic hydrolysis began, an alternative to acid hydrolysis (BERNI, 2017; CASTRO; PEREIRA JR., 2010).

During some years after Second World War, little discussion took place about second-generation ethanol, mainly because of low oil prices. However, in the 1970s, this situation changed, especially due to the oil crises and the development of biotechnology, and several companies began their activities in the production of enzymes and / or yeast, which are necessary inputs for the production of ethanol (2G) by enzymatic hydrolysis (BERNI, 2017).

In the United States, ethanol (2G) incentives began in 2000, when the federal government approved the Biomass R&D Act, a law that was instituted with the goal of rapidly enabling the necessary technologies and procedures so that through biomass, abundant production of biofuels and other products would occur. And in Brazil, the first plant for the production of ethanol (2G) was inaugurated by the company GranBio in 2014, in the city of São Miguel dos Campos - AL (BERNI, 2017; NYKO et al., 2010; UNICA, 2016).

One of the main raw materials for ethanol (2G) is sugarcane bagasse, which is one of the byproducts of the sugarcane industry, and accounts for more than half of the energy stored in the plant. This has advantages over other celluloses sources, because in mills it is already pretreated, and is abundant and has the possibility to be used in the mill itself, which avoids the logistics costs (ARAUJO, NAVARRO, SANTOS, 2013)

In addition to sugarcane, there is the possibility of using other materials such as wood, carrots, agricultural residues, corn cob and straw, and rice straw, which are already most used for ethanol production (2G) in other countries (TOMÉ, 2014).

Corn is considered one of the most produced crops in Brazil, and its processing has tailings such as cob, stem, leaves and straw, and it is estimated that for each ton of corn produced, 2.3 tons of tailings are generated. These wastes can be used as biomass for second generation bioethanol production (SILVA, 2018). Waste generated after carrot carotenoid extraction can be used for bioethanol production, and these by-products are considered an accessible raw material (PASSOS et al., 2017).

Ethanol Production Process (2G)

The production process of second generation ethanol (ethanol (2G)) from lignocellulosic materials, in a simplified manner, can be defined in four steps: pretreatment, hydrolysis, fermentation and distillation, which can be seen in Fig. 3 (MIRANDA, 2011):

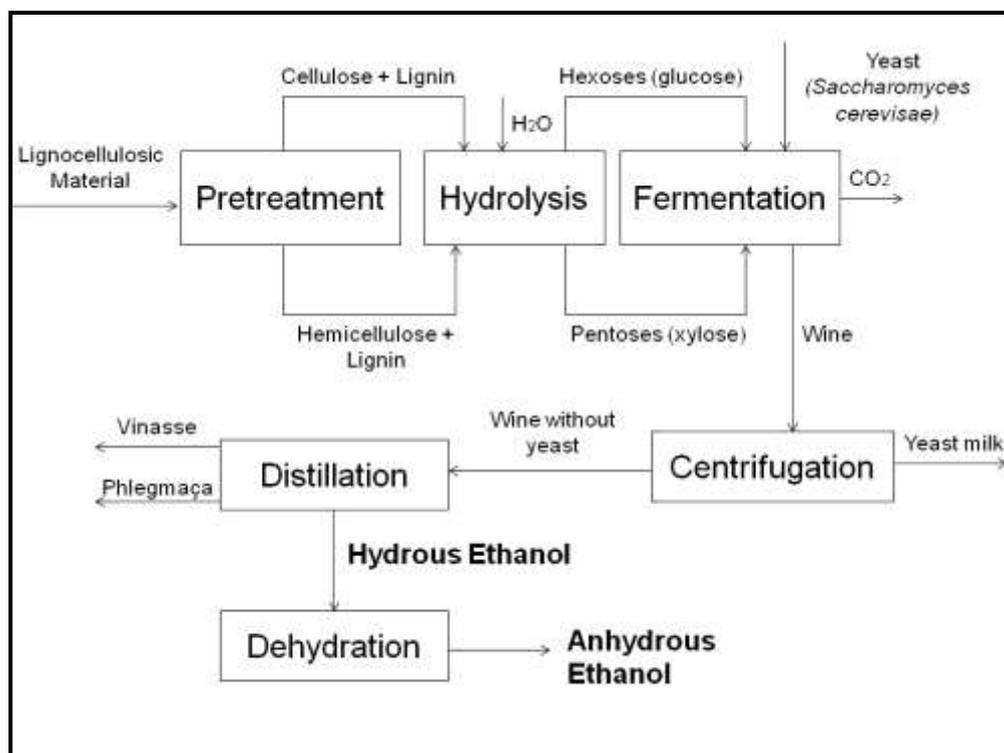


Fig. 3. Flowchart of ethanol production (2G)

Fonte: Carvalho, 2018.

Pretreatment

In the production of ethanol (2G), the initial stage is the pretreatment, and one of the most important, as it seeks to disrupt the lignocellulosic material, so that the cellulose, which was protected, become more exposed to the action of chemical reagents and enzymes, ie make it more accessible to subsequent chemical or biological treatments (AGBOR et al., 2011; BNDES; CGEE, 2008; MOSIER et al., 2005).

In order to be considered efficient, a pretreatment must cause in the biomass, the separation (fractionation) of its constituents, avoid the degradation or loss of cellulose, preserve the hemicellulose fraction, not give rise to inhibiting compounds to the growth of fermentation microorganisms, have low power consumption, minimize costs, among other features (AGBOR, 2011, MOSIER et al., 2005).

Due to the variety of raw materials, there are also a variety of methods, in which the most technically mature pretreatment process is called the "Steam Explosion" (TOMÉ, 2014).

The steam explosion process is considered technically and economically viable, allowing the recovery of most components of lignocellulosic materials, as it minimizes their degradation. In addition to being an effective technique for a wide variety of lignocellulosic materials (AVELAR; GLASSER, 1998; BALLESTEROS et al., 2006; SAAD, 2010).

In this process, the crushed lignocellulosic material receives a saturated steam treatment (160-260 ° C). This vapor penetrates the material and condenses, causing high temperature liquid water inside the fiber, and after reaching pressures between 10 to 19 kgf / cm², this water vapor continues in direct contact with the material between 5 (five) to 10 minutes, in which the exact pressure and time conditions will be influenced by variables such as humidity, enzyme type, fiber size, among others (BABCOCK, 1932; HAMELINCK, 2005; MASON, 1926; TOMÉ, 2014).

Subsequently, a rapid decompression of the reactor is performed, and the water that is in equilibrium with the steam at high pressure is evaporated, which literally causes an explosion within the fibers, resulting in their disruption and breakdown, apart from its disruption in the high density regions of amorphous cellulose, which causes some of the hemicellulose sugars to become soluble and make the cellulose more exposed. During this type of pretreatment, lignin softens, is partially depolymerized and becomes more soluble (AGBOR, 2011; MICHALOWICZ; TOUSSAINT; VIGNON, 1991; MIRANDA, 2011; TOMÉ, 2014).

Then, after steam blast pretreatment, two fractions are formed, a solid composed of cellulose and lignin of altered structure, where most of this lignin can be extracted with alkali, ethanol or dioxane, and a hemicellulose-rich liquid fraction with a small amount of solubilized lignin (KOMURA, 2015; SAAD, 2010).

The removed lignin can be burned in boilers to generate steam and produce electricity along with some other wastes such as straw and unhydrolyzed bagasse (BACOVSKY et al., 2013).

Major changes in the structure of lignocellulosic materials can be caused by steam explosion, mainly due to the rapid evaporation of intracellular water, which causes the degradation of sugars formed and generates toxic compounds to microbial metabolism, such as furfural, hydroxymethylfurfural and phenolic compounds (CANETTIERE, 2004).

The selection of the pretreatment method should be compatible with the cellulose hydrolysis method to be used later. In steam explosion, if the next step is acid hydrolysis, it will be most efficient because the application of acid in the biomass in this process increases the degradation power of hemicellulose (KNAPPERT; GRETHLEIN; CONVERSE, 1980; TAHERZADEH; KARIMI, 2007).

Hydrolysis

It is the process in which complex carbohydrates (cellulose) break down into their monosaccharide components (glucose). This step can be performed in three (3) different ways: dilute acid hydrolysis, concentrated acid hydrolysis and enzymatic hydrolysis (MIRANDA, 2011).

In the hydrolysis step, the cellulose is converted to glucose according to the following reaction, which may be catalyzed by dilute acid, concentrated acid or by enzymes (cellulase) (CGEE; BNDES, 2008):



Acid hydrolysis

Two types of acid hydrolysis can be used: dilute acid with acid concentrations less than 5% (m/v) and concentrated acid with acid concentrations greater than 5% (m/v) (GURGEL, 2010).

Some concentrated acids such as H₂SO₄ and HCl are used for the treatment of lignocellulosic materials. Although powerful agents for cellulose hydrolysis, these acids have toxicity, are corrosive, hazardous and require corrosion-resistant reactors. And to make the process economically viable, concentrated acid should be recovered after hydrolysis (MIRANDA, 2011; SILVERS; ZACHI, 1995).

In the concentrated sulfuric acid process there is a high sugar production in which various raw materials can be treated, is relatively fast, and a slight degradation of the material occurs. And cellulose

hydrolysis is more favorable in high temperature sulfuric acid treatment (MCMILLAN, 1994; MIRANDA, 2011).

In order to take advantage of the differences between hemicellulose and cellulose, acid hydrolysis (concentrated or diluted) takes place in two (2) stages, in which in the first there is the hydrolysis of hemicellulose performed at low temperature, which occurs according to the pre-treatment conditions. In the second stage, higher temperatures are applied to optimize the hydrolysis of the cellulosic fraction (DIPARDO, 2000).

Two types of sugars are generated in hydrolysis processes of lignocellulosic materials: the pentoses obtained in the hydrolysis of the hemicellulose fraction, and the hexoses that originate in the degradation of part of hemicellulose and cellulose. These sugars (must) after hydrolysis must pass through the fermentation step. (MIRANDA, 2011).

The dilute acid process occurs at high temperatures and pressures, with reaction times from seconds to a few minutes, which makes continuous processes easier to use. And concentrated acid processes are carried out under milder conditions, however reaction times are typically longer. (GRAF; KOEHLER, 2000).

According to Miranda (2011), the type of reactor used will also influence the final concentration of sugars obtained in the hydrolysis of lignocellulosic materials. The most commonly used are CSTR (Continuous Stirred Tank Reactor), piston flow reactor, countercurrent reactor, percolation, and bed shrinkage flow reactors.

Enzymatic Hydrolysis

Enzymes are proteins that contain in their structure the so-called "active sites", in which very specific chemical reactions occur in an accelerated manner. Because of this, they are considered biological catalysts (TOMÉ, 2014).

An enzymatic cocktail is used in the production of ethanol (2G), ie a mixture containing different enzymes that must act on the biomass, in a region and in a specific component. Cellulase is considered to be the main enzyme because it speeds up the cellulose hydrolysis reaction for glucose generation, which then goes through fermentation to produce ethanol. Cellulases used for the hydrolysis of lignocellulosic materials may be produced by bacteria or fungi (BONFÁ, 2016; TOMÉ, 2014).

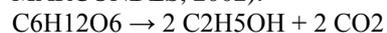
In enzymatic hydrolysis, some factors may cause interference in the process, such as material porosity, which influences surface area access, the presence of crystalline fibers in cellulose, and the presence of lignin and hemicellulose, as these make it difficult for the enzyme to access the cellulose, which causes hydrolysis to decrease its efficiency (SUN; CHENG, 2002).

This process has more advantages than the old acid hydrolysis because it is conducted at a low temperature, which prevents the formation of harmful byproducts that inhibit fermentation. In addition to the relatively low energy requirements, this type of process has other advantages, such as: high efficiency, control in the production of derivatives, lightweight process in which construction does not require expensive materials, low maintenance costs (because enzymes do not cause corrosion), and high sugar yield (75-85%), and expected to achieve improvements (85-95%) (HAMENLINK; VAN HOOIJDONK; FAAIJ, 2005; TOMÉ, 2014).

According to Tomé (2014), enzymatic hydrolysis also had disadvantages, such as the long reaction time and the cost of enzymes. But investments in research in recent years have, in addition to reducing this cost, significantly improved the speed of the process.

Alcoholic fermentation

Fermentable sugars contained in a solution / suspension may undergo the action of yeast, and this action is called alcoholic fermentation, which occurs according to the following reaction (LIMA; MARCONDES, 2002):



Yeasts provide enzymes that act to ferment the sugars obtained in the hydrolysis step, which are pentoses and hexoses. And through the fermentation of these sugars occurs the production of wine and carbon dioxide (CO₂) (LIMA; MARCONDES, 2002; MIRANDA, 2011).

Some characteristics must be present in the yeasts used, such as: fermentation speed, alcohol tolerance, yield, resistance and stability. The amount of sugar that is fermented by a quantity of yeast over a given time period specifies what is the speed of fermentation (ALACARDE, 2017).

Through rapid fermentations there is a gain in productivity due to increased daily production and consequently reduces the production cost and the risk of contamination by harmful microorganisms. The relationship between consumed sugar and produced alcohol determines the yield, and for an industrial yeast it is essential that it be high (ALACARDE, 2017).

In alcoholic fermentation processes, most of the microorganisms used (belonging to the species *Saccharomyces cerevisiae*) only have the ability to convert hexoses (sugars composed of 6 (six) carbons, as an example of glucose) in ethanol, ie, can not convert xylose (sugars composed of 5 (five) carbons, ie pentose), the

type that is obtained from hemicellulose. But some years ago researchers from the Federal University of São Carlos - UFSCar, have the strategy of transforming xylose into a molecule that yeast can ferment, in this case xylulose, through a process called isomerization (transformation of a substance into one of isomers) through the action of an enzyme called xylose isomerase (EMBRAPA, 2014; MIRANDA, 2011).

The wine obtained through fermentation has in its composition 7 (seven) at 10 ° GL (% by volume) of ethanol, in addition to other components, such as water with contents of 89% to 93% by volume, glycerol, higher homologous alcohols, furfural, acetic aldehyde, succinic and acetic acids, among others, in smaller quantities. There is also the presence of solids, such as bagasse, yeast and bacteria, non-fermentable sugars, mineral salts, albuminoids and others, and gases that are dissolved, mainly CO₂ and SO₂ (PEREIRA, 2015).

Centrifugation

The most widespread industrial process of alcoholic fermentation (by *Saccharomyces cerevisiae* yeast), called Melle-Boinot (characterized by the recovery of yeast by centrifugation) is discontinuous. However, the distillation process is continuous, so a coupling between them is necessary. This connection is made through the fermentation tank, where storage of the delugurated (centrifuged) wine occurs (SILVA, 2012).

As soon as the sugar in the must (sugary liquid that can be fermented) runs out in the fermentation, the wine is pumped from the fermentation tank to the separation centrifuge, in which two streams are separated and come out, one from the yeast milk, which goes to the treatment vats, and the other from the aged wine, with concentration of between 7 (seven) and 10% by mass, which is stored on the fermentation tank, which feeds the distillery (ALACARDE, 2017; DIAS, 2008).

The yeast milk sent to the vats (tanks) undergoes a water and acid treatment so that the yeast can be reused in the process. With this reuse of yeasts in subsequent fermentations, cell multiplication is minimized and, consequently, the sugar that would be consumed for this purpose can be used for alcohol conversion activity (LEMONS; TANCREDO, 2010).

Distillation

Distillation is a unitary operation of component separation or component mixtures that is based on the volatility or vapor pressure difference. At this stage, the ethanol separates from the fermenter output stream (DUARTE, 2006; MIRANDA, 2011).

Industrial-level ethanol distillation has a series of distillation columns, the amount of which varies depending on the type and quality of the alcohol desired (SILVA, 2012).

In the process of alcohol distillation of Brazilian mills, a configuration consisting of five (5) columns is often used: A, A1, D, B and B1. Column A is known as the wine depletion column, A1 of wine eparation and D the concentration column of alcohol of second, which concentrates the most volatile components that could cause hydrous alcohol contamination. The set of these three (3) columns is called the distillation column. Column B is the rectification column, and column B1 is the depletion column. The set formed by these two columns is called the rectifying column, where you can get the Fuel Hydrated Ethyl Alcohol - AEHC, and this process can be seen in Fig. 4 (DIAS, 2008):

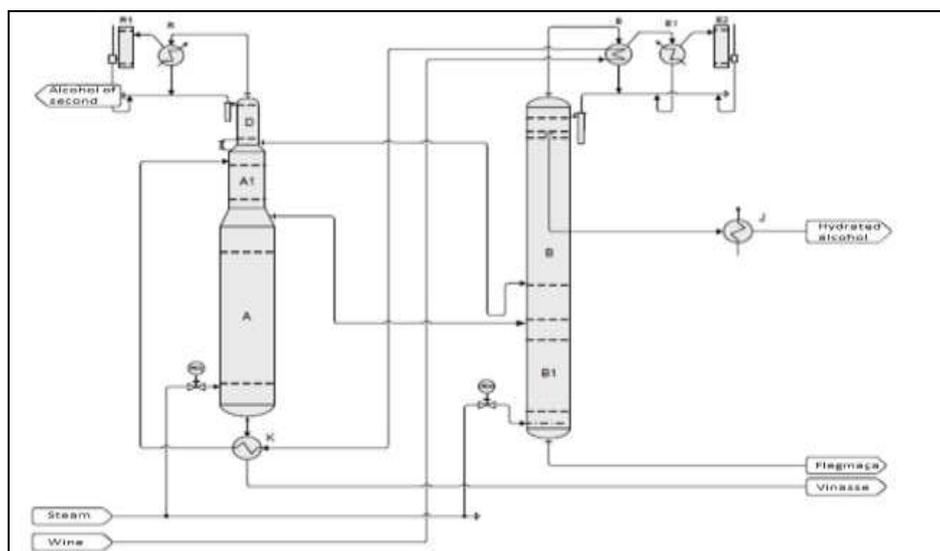


Fig. 4. Configuration of the industrial alcohol distillation process

Fonte: Paternina, 2011.

The distillation process begins when the wine grown from the fermentation tank passes through the condenser (E) in column B, is heated to 60 ° C and condenses the alcohol coming out of the top of this column. This warmed wine goes to the heat exchanger (K), exchanges heat with the vinasse (produced in column A), and is heated to 92 ° C, with the vinasse cooled to 85 ° C (MUNDO DA CANA, 2017; PATERNINA, 2011).

The wine that has been heated to 92°C feeds the column A1, and will suffer a concentration in the alcoholic production, where inside the column, there is an increase of the alcohol-rich vapors and a decrease of the alcohol-poor condensed liquid. This low alcohol liquid called vinasse (which may contain an alcohol content of 0.02% by mass), when it reaches the bottom of column A, goes to the exchanger (K), which is responsible for preheating wine, and after exchange, it must be removed and can be used as fertilizer in crops (PATERNINA, 2011).

These alcohol-rich vapors from column A1 divide for feed from purification column D and another part exits near the top of column A to feed column B at its bottom, in the form of a flegma vapor, which has a concentration of 50% alcohol by volume and 50% in water plus residues formed by higher alcohols, aldehydes, esters, among others. The columns are heated by the reboiler in column A (DIAS, 2008; MUNDO DA CANA, 2017).

In column D the most volatile wine products are concentrated, and the steam obtained at the top of this column is condensed in the heat exchanger (R) and the auxiliary condenser (R1), which uses water as a refrigerant. From the condensed vapor (liquid stream obtained), part flows back to column D and the other part is to be removed as alcohol of second, and sent for tanking. The bottom of column D is closed, and in this is obtained the liquid flegma current, which is fed to the bottom of column B just above the input of the vapor flegma current. (DIAS, 2008).

The flegma (product with impurities obtained from a first distillation of the fermentate) that is fed to column B will undergo a purification and concentration process. Almost all the steam produced at the top of this column is condensed on heat exchangers E, E1 and E2. These alcoholic vapors in these heat exchangers preheat the wine, and return as reflux to column B in the form of condensed vapor. And this preheated wine is subsequently heated in the heat exchanger (K), and promotes cooling of the vinasse at the bottom of column A1, and the heated wine is then fed into column A1, as explained at the beginning of process (PATERNINA, 2011).

At the side outlet of column B, just below the top and the backflow inlet, the hydrated alcohol 94° GL is withdrawn, cooled in the heat exchanger (J), moved to a metering tank, and then pumped to the storage tanks. This procedure enables better quality hydrated alcohol to be obtained (DIAS, 2008).

The bottom product of column B feeds the top of column B1. At the bottom of column B1 there is an aqueous liquid called flegmaça (which must contain less than 0.02% by mass of alcohol) which can be used for washing (asepsis) after a fermentative cycle and for cleaning exchangers. And if the flegmaça obtained has higher alcoholic content, it is recycled in column A1 for ethanol recovery (MELLO, 2012; PATERNINA, 2011).

In the lower lateral part of column B also occurs the removal of tall oils, such as esters, acetates; and low oils, such as fusel oil (composed of long chain alcohols such as isoamyl alcohol), which can be used in industry as solvents for paints and varnishes, among other applications (BARRA et al., 2011; MUNDO DA CANA, 2017).

Dehydration

Hydrated alcohol, the product obtained through the distillation process, is a binary mixture alcohol and water, which can reach 96 ° GL. These components cannot be separated in the distillation process due to the occurrence of the physical phenomenon of the formation of an azeotropic mixture (behaves as a pure substance as it has a constant boiling point). So this alcohol can be marketed this way, or it can go through the dehydration process to produce anhydrous alcohol (PEREIRA, 2015).

Among the existing dehydration processes, one of the most used is adsorption dehydration using molecular sieve (MIRANDA, 2011).

Adsorption dehydration uses in its interior a material consisting basically of micro-pore-containing aluminum hydrosilicate, called zeolite, and popularly known as molecular sieve. The alcohol to be dehydrated is initially vaporized and overheated before being sent to the dehydration columns. The micro-pore network absorbs water and allows the passage of alcohol vapors, which are subsequently condensed as anhydrous alcohol (approximately 99.3 °GL) and sent to storage tanks (DIAS, 2008; PEREIRA, 2015; SALLES, BARROS, AGUIAR, 2012).

The periodic regeneration of the zeolite should be performed, through the passage under vacuum of alcoholic vapors which will then be distilled to recover the alcohol present in them. (PEREIRA, 2015).

Environmental aspects

Ethanol (2G) is considered 8 (eight) times more sustainable than ethanol (1G), and the expansion of its use may result in a reduction in greenhouse gas emissions (GHG) and, consequently, avoid climate change, and use of fossil resources (CATOLICO et al., 2015; RAIZEN, 2018).

The use of ethanol (2G) has lower environmental impacts compared to fossil fuels, and the main impacts generated in its production cycle is the local atmospheric pollution caused by the burning of its production residues in boilers (as an example of unhydrolyzed bagasse), for the generation of steam and electricity, and also for the use of ethanol (2G) as fuel, which together emit particulate matter, carbon monoxide, methane, nitrogen oxides and aldehydes (BACOVSKY, 2013; CATOLICO et al., 2015; MONTES, 2017).

With the use of ethanol (2G), 50% more fuel can be produced in the same planted area, because the raw material used is a co-product of the ethanol (1G) production cycle. This avoids soil degradation and land loss through extensive use of sugarcane crops, as well as reducing the application of pesticides and fertilizers, the destruction of the ecosystem, among others (BNDES, 2016; CATOLICO et al., 2015; RAIZEN, 2018).

In the production of ethanol (2G) sugarcane can not be harvested by the traditional way (burned), and mechanized harvesting is used. With this, there is an environmental gain, since one of the main environmental impacts of sugarcane cultivation is related to burning of straw. This practice can contribute to worsening global warming, affect the soil, change its physical characteristics, change gas concentration, decrease soil fertility and moisture, and cause the soil to lose volatile nutrients and be exposed to erosive effects (CATOLICO et al., 2015; RAIZEN, 2018).

In addition to environmental effects, burning at harvest has numerous consequences for humans due to the risk of accidents, and breathing problems that can be caused by inhalation of smoke and soot (CATOLICO et al., 2015).

The use of mechanized harvesting in the production of ethanol (2G) allows the residual straw to be deposited in the soil and form a cover that reduces erosion and makes it possible to develop a biological community to act on the decomposition of the straw and to help in control of weeds (ANDRADE, 2013; CATÓLICO et al., 2015).

In contrast to sugarcane, which must undergo processing immediately after harvesting, agricultural residues from the production of ethanol (1G) can be stored and used at a later time in the off season when the plants are at a standstill. The use of these materials is also viable for ethanol production in regions and countries where sugarcane cultivation is scarce or inadequate (BNDES, 2016).

III. CONCLUSION

Second generation ethanol (ethanol (2G)) is an alternative, given the need to replace the use of petroleum derivatives and the existing limitations to increase the production of first generation ethanol (ethanol (1G)). However, because the waste from the production of ethanol (1G) is used as raw material, a pretreatment of this material should be performed during its production process, which makes its generation not economically viable in relation to conventional ethanol.

In addition, the production of ethanol (2G) by using sugarcane bagasse as one of its raw materials can impact energy cogeneration, which uses this material to produce electricity, and which is also of great importance in our current context, due to the fact that the country has undergone a restriction in economic and social development, due to the rationing of electricity.

And after analyzing the description of the production process of second generation ethanol, the existing challenges, and the environmental aspects involved, it is concluded that the combination of first and second generation ethanol production if consolidated in the country, will allow a greater amount of fuel by keeping constant the volume of raw material cultivated and the area of plantation.

However, there is a great need for incentive in policies and research programs in universities and large companies, in the search for technological advances and the emergence of better production routes, to improve the treatment and control of the biomass used, especially in the stages of pre-treatment, hydrolysis, and pentose fermentation. Thus, it will be possible to reduce the expenses involved in its generation, and consequently boost the development of new ethanol plants (2G), due to the higher return on investment. This will result in an environmentally favorable and commercially competitive end product.

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