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UTILISATION OF INDUSTRIAL ENZYMES TO PRODUCE BIOETHANOL FROM AUTOCHTHONOUS ENERGY CROPS

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Abstract

The present paper presents the data necessary to introduce and to extend at the industrial scale the utilization of a new generation of STARGEN enzymes to produce bioethanol from energy crops. In the case of Romania we can mention corn and even wheat. The effective production of the bioethanol using as raw-materials energy crops involves three main principles: 1. Utilization of one or more autochthonous renewable agricultural raw-materials specific for the location of the bioethanol plant; 2. Decreasing as much as it possible of the energy consumption both for the sweet mash producing and for the distilling and drying of the bioethanol and performing of higher ethanol yields; 3. Utilization of all wastes and by-products resulted from the bioethanol technology, in our case CO_2 and cereals spent-grains. In order to decrease the energy consumption in the mashing and saccharification steps specific industrial enzymes were created that require temperature no more than 30 – 32°C for corn and 55°C for wheat. In this way the energy consumption for the heating of corn mash till 90°C for 45 minutes and for the heating of wheat mash till 75°C for 45 minutes is considerable reduced.
Keywords: *bioethanol, energy crops, renewable energy, industrial enzymes, starch degradation.*

Introduction

Bioethanol is a renewable fuel made from starch or sugar from plants including crops like corn, wheat, rice, barley, sorghum, rye, tapioca, sugarcane, sugar beet. Grains store carbohydrate as starch, which is enzymatically converted into fermentable sugars by yeast to produce ethanol and carbon dioxide.

Taking into account the harmonization with the EU directives regarding the partial replacing of fossil fuels with renewable fuels or with fuels produced from autochthonous renewable agricultural raw materials (mainly cereals, especially maize), the technological solution to produce bioethanol was elaborated using different cereals specific for Romania (maize, wheat, barley) and was tested at industrial scale.

Interest in ethanol as a clean-burning fuel is stronger than ever before. Ethanol is a high-octane fuel that provides superior engine performance and its use is cost-effective for consumers. Environmentally acceptable scenarios exist in which bioethanol is a major energy carrier for a sustainable transport sector.

The Romanian Government Decision 1844/2005 concerning the biofuels and renewable fuels for transport transposes within the national legislation the Directive 2003/30/EC for the promotion of the utilisation of the biofuels and renewable fuels for transport. In this respect, the decision promotes the substitution of the gasoline and diesel, in order to fulfil objectives like as the achievements regarding the climatic changes and the safety for a supply compatible with the environment.

Accordingly with the Government Decision 1844/2005 the Romanian Ministry of Economy and Commerce gives priority to the promotion of these biofuels that provide a very good balance price – benefit for the environment, taking into account of the competitiveness, the safety for a supply and the influence of the biofuels on the environment (HG 1844/2005).

Experimental

Taking into account the impact of the integration in European Union on the agriculture, it is necessary to develop and increase the yield of the renewable agricultural raw-materials in order to produce biofuels and bioenergy.

Applying efficient technologies to produce bioethanol represents a guarantee for more work places and also to increase the local budget within the Romanian rural area.

We are looking for to approach and solve in effective and efficient manner the technological and technical aspects of performing energy using autochthonous renewable agricultural raw-materials.

The agricultural raw materials can be carried out to produce liquid fuels such bioethanol and to reduce CO_2 emissions from the combustion of fossil fuels, hence its impact on climate.

The effective production of the bioethanol using as raw materials energy crops involves three main principles:

1. Utilization of one or more autochthonous renewable agricultural raw materials specific for the location of the bioethanol plant;
2. Decreasing as much as it possible of the energy consumption both for the sweet mash producing and for the distilling and drying of the bioethanol and performing of higher ethanol yields;
3. Utilization of all wastes and by-products resulted from the bioethanol technology, in our case CO_2 and cereal spent-grains.

Ethanol is produced from starch crops like corn, barley, sorghum and wheat. The starch from these grains is converted by industrial enzymes to fermentable sugars, which are then converted to alcohol by yeast. The energy crops taking into consideration to produce bioethanol in Romania are the cereals specific for the region, such as corn, possibly the wheat. We also consider using the saccharate sorghum and sorghum grains. We don't exclude the utilisation of barley as alternative raw material, but we are moderate regarding the negative effects of the husks on the technological processes development (on the fermentation).

The main steps of bioethanol process flow applied in this moment are the following:

- Cereal milling;
- Mashing – dextrinizisation – saccharification of starch at temperature depending on processed raw material, contained starch hardness, respectively;
- Alcoholic fermentation of sweet mashes;
- Alcohol distillation;
- Alcohol dehydratation passing the vapors through molecular sieves;
- By-products recovery (spent-grain and CO_2).

In order to decrease the energy consumption in the mashing and saccharification steps we used specific industrial enzymes that require temperature no more than 30 – 32°C for corn and 55°C for wheat. The liquefaction step is skipped and saccharification and fermentation are combined into one process. These enzymes are not yet used at industrial scale in Romania, because their destination is only for bioethanol production. There were samples of these enzymes tested at pilot scale with very good anticipated results. In this way the energy consumption for the heating of corn mash till 90°C for 45 minutes and for the heating of wheat mash till 75°C for 45 minutes is considerable reduced.

The bioethanol production process with STARGEN new generation enzymes for cereals consists basically of one step, on a continuous basis in a simultaneous saccharification and fermentation process. During the fermentation step STARGEN enzymes hydrolyses the granular starch and releases glucose, this being directly fermented in to ethanol and carbon dioxide by the yeast.

The STARGEN industrial enzymes include blends of enzymes that have synergistic activities on granular starch. The blend includes an alpha amylase and a glucoamylase, the combined activities catalyze the release of fermentable glucose continuously from granular starch under the yeast fermentation conditions (www.genencor.com).

There are some potential advantages of this technology:

- improved productivity;
- reduced energy consumption;
- higher ethanol yields;
- capital expense savings by reducing the number of unit operations.

The rebuilding and redesigning of an ethanol plant into a bioethanol production plant comprises two main modifications:

- the replacement of the refinement phase with the alcohol drying (elimination of water from the crude alcohol vapours);
- spent-grain drying and utilisation for the in order to perform the energetic independence of the production plant.

The rest of modifications don't involve modification of equipments or technological lines.

Enzymes can be found in all organisms: plants, animals, yeast, mould, bacteria, but the industrial enzymes are produced by biotechnologies, using appropriate culture media and specific micro-organisms.

Several benefits of industrial enzymes for bioethanol production are the following:

- energy savings;
- higher ethanol yields;
- capital expense savings by simplifying the technological flow.

Technological parameters such as pH, temperature, calcium ions concentration are the basis for selection of appropriate industrial enzymes for dextrinization – liquefaction – saccharification of starch.

Using STARGEN enzymes a single pH adjustment step is needed. This simplifies the operation and reduces costs as compared to the described present process, which requires dual pH adjustment because liquefaction (pH = 5 - 6) and saccharification - fermentation (pH 3.0 - 4.8) are typically conducted at different pH levels. Additionally, the conventional process may require the addition of calcium salts to stabilize the alpha amylase enzyme at high temperatures (www.genencor.com).

On the basis of our researches performed within ca. 30 ethanol factories in Romania and Republic of Moldavia we can assess that the calcium ions concentration does not require an adjustment if the technological water has a total hardness of 5 – 6 German degrees.

Non-starch polysaccharides such as cellulose, beta-glucans, pentosanes, increase the mash viscosity, this fact making more difficult the homogenization process, the heat exchange and the pumping time. Industrial enzymes have to solve these aspects of the technological bioethanol process.

Normally, the fermentation step lasts 72 hours, but this can be shorted up till 10 hours using the STARGEN enzymes.

Results and Discussions

Based on our experimental studies the conclusion is that the corn, a cereal with high starch content, is the most profitable raw material to be process for bioethanol (Stroia, 2004). Another advantage of corn in comparison with wheat and mainly with barley is the hardness of starch that in the case of corn is lower, because of the low content in beta-glucans.

We can assess that the highest yield in ethanol can be obtained in the case of corn, even when hybrid varieties are used.

Concerning the sorghum, this is a cereal studied from few time for ethanol production, but we estimate the appropriate results as in the case of the other studied cereals.

Applying the technology proposed by us the concentration of the resulted bioethanol is 99.8 % v/v.

Specific consumption for the main raw materials – cereals, enzymes and yeast – are presented in the tables 1 and 2 (Begea, 2006).

Table 1. Specific consumptions of the main cereals

Specific consumption UM/hl bioethanol	Cereals			
	Corn	Wheat	Barley	Sorghum
	300	321	338	465

Table 2. Raw materials specific consumptions

Specification	U.M.	Specific consumption UM/hl bioethanol
Dextrinisation - saccharification enzyme	litres	0.22944
Yeast	kg	0.020

The flow diagram for the bioethanol process is presented in figure 1. Using the STARGEN enzymes, the bioethanol production process for corn consists basically of one step: the saccharification – fermentation, so from mashing the slurry is directly saccharified – fermented. Fermentation is carried on using Saccharomyces *cerevisiae* yeast. The flow diagram and technological line are consistently shorted.

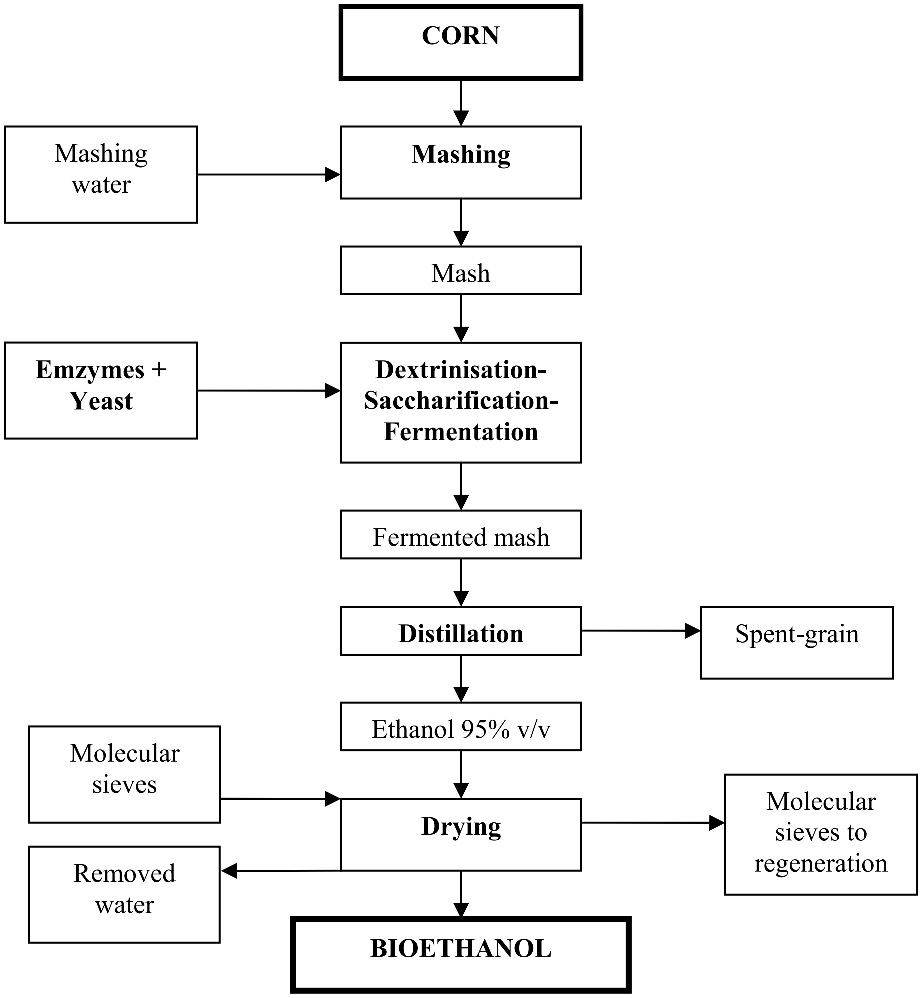

Figure 1. The flow diagram for the bioethanol process

Conclusions

Bioethanol became a very valuable and an environmental friendly fuel, reducing CO_2 emissions from the combustion of fossil fuels, hence its impact on climate. The main condition for bioethanol producing is to use cheap local renewable raw materials that ensure the economical efficiency, such as corn or wheat. Other raw materials such as lignocellulosic raw materials rise serious difficulties from the economical point of view and were no taken into consideration in present paper. Another important aspect is to produce bioethanol with law specific consumptions of raw materials and energy, performed through a technology using suitable industrial enzymes and yeast, and recovering all by-products. Bioethanol production ensures important benefits both for rural area where raw materials are harvested and for fuel producer.

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