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8. Nano-Technological Applications in Ethanol Production: An Insight Look

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8.1 Introduction:

It is widely known that the storage of fossil fuels is limited and depleted rapidly. The usage of the fuels by the large population is increasing day by day so as the demand for the fuels are also increasing. The primary source of energy (fossil fuels) is non- replenish able and also has environmental effects like pollution, global warming etc. So, the need of the hour is to think of an alternate energy resource which is renewable and has no or less effect on the environment. Biofuels poses a good option for replacing the fossil fuels and fulfilling the demand of energy. Biofuel production is an appropriate substitute of fossil fuels because it is a renewable source of energy and also gives solution to the environmental problems arises from the use of fossil fuels [10].

From the vision of Henry Ford who uses Bioethanol as a fuel, biofuels utilization becomes the future fuel. Biofuel production gain importance globally. Among the countries, Brazil and USA are the prime contributors in the production of bioethanol which totally provides -80% of the contribution in the production worldwide [2]. In some previous decades, various feedstocks or substrates has been used for the production of bioethanol as a fuel. Based on the feedstock used, it divides into three generation. First generation used food crops as a substrate, second generation uses non-edible substrate or biomass and the third generation uses algal biomass.

The most research emphasized on the selection of substrate which is cheap and renewable in nature. So, lignocellulosic biomass is an abundant, renewable and inexpensive source for the production of bioethanol. But, inspite of the availability of abundant resource, one can't be getting 100% extraction from it because of its complex structure of lignin, cellulose and hemicellulose. The other challenges which come in the production of biofuels are its cost and other technological barriers. Taking into the consideration of the required needs of this technology, the nanotechnology comes as a solution. Nanotechnology has been emerged as field of science that has extensive applications in distinct streams of sciences.

Nanoparticles attained much attention in the area of biofuel production due to its unique physicochemical properties. Nanoparticles can transform the biomass structure and also help in immobilizing the enzymes used in the production of bioethanol. The use of the magnetic nanoparticles in the production of the bioethanol has many advantages like they are recovered by applying magnetic field and recycled for reuse. The use of nanotechnology in the bioethanol production makes it more efficient and sustainable.

8.2 Nanotechnology in the Bioethanol Production:

The process of bioethanol production from lignocellulosic biomass contains following step- pretreatment, enzymatic hydrolysis and fermentation. The use of nanotechnology in each stage of bioethanol production has been discussed below.

8.3 Pretreatment:

Lignocellulosic biomass is a carbon source available in huge quantity and composed of lignin, cellulose and hemicellulose in a defined manner. Pretreatment is an unavoidable step in the bioethanol production that is needed to open up the structure of biomass into its constituents. It has extensive impact in the production cost i.e. accounts for 40% of the total cost (approximately) of the process. The use of nanoparticles in the pretreatment step can alter the biomass structure. The nanoparticles interact with the biomass components that release carbohydrates with less inhibitor generation [8]. In pretreatment step, the nanotechnology used by two ways- a) use of instrumentation at nanoscale b) use of nanocatalysers in the process. The nanotechnology instrumentation involves the usage of electron microsocopy i.e. SEM (Scanning Electron Microsocopy), TEM (Transmission Electron Microsocopy), and AFM (Atomic Force Microscopy). The use of electron microscopy in the pretreatment process can help to know the structure of biomass at molecular level prior to its pretreatment and afterwards. Secondly the use of nanoparticles in the pretreatment step is a promising and competent approach. The use of acid- functionalized nanoparticles catalyses the hydrolysis reaction. It is also known as the solid acid nanocatalyst and has similar effect like the mineral effect in the chemical pretreatment method. But it has an advantage over the chemical method is its recovery and reusability that reduces the cost of process by diminishing the downstream processing requirements. Nano- scale shear hybrid alkaline (NSHA) pretreatment is also one of the methods used for the pretreatment method. This method involves the combined effect of the high-speed shear and use of chemical along with the applications of mild heat. It needed a nanomixing reactor with the temperature control system [3]. Ji and Lee [4] added cationic polyelectrolyte in the Nano-shear hybrid alkaline pretreatment of corn stover. The results showed the modification in the lignin structure and enhancement in the yield of enzymatic hydrolysis.

8.4 Enzymatic Hydrolysis and Fermentation:

Enzymatic hydrolysis is the process that uses enzymes to convert the cellulose, hemicellulose in their monomeric units. The enzymes used in the process are cellulase and hemicellulases complexes. The expense of these enzymes is high which makes the production of bioethanol expensive. The cellulase use in the hydrolysis process constitutes about 18% of the cost of the plant in the 2G bioethanol production [1]. Immobilizing these enzymes in the substrate can increase the efficient and reduce the cost of the process.

Immobilization on nanoparticles can increase the thermo stability of the enzyme and also provides greater surface are for the enzyme loading. The reusability is one of the factors of using nanoparticles in the enzymatic hydrolysis [7]. Khoshnevisan et al. [5] uses superparamagnetic nanoparticles for the immobilization of cellulase. The cellulase is immobilized by physical adsorption (ionic bonding) and the results showed the increased stability and activity of the enzyme.

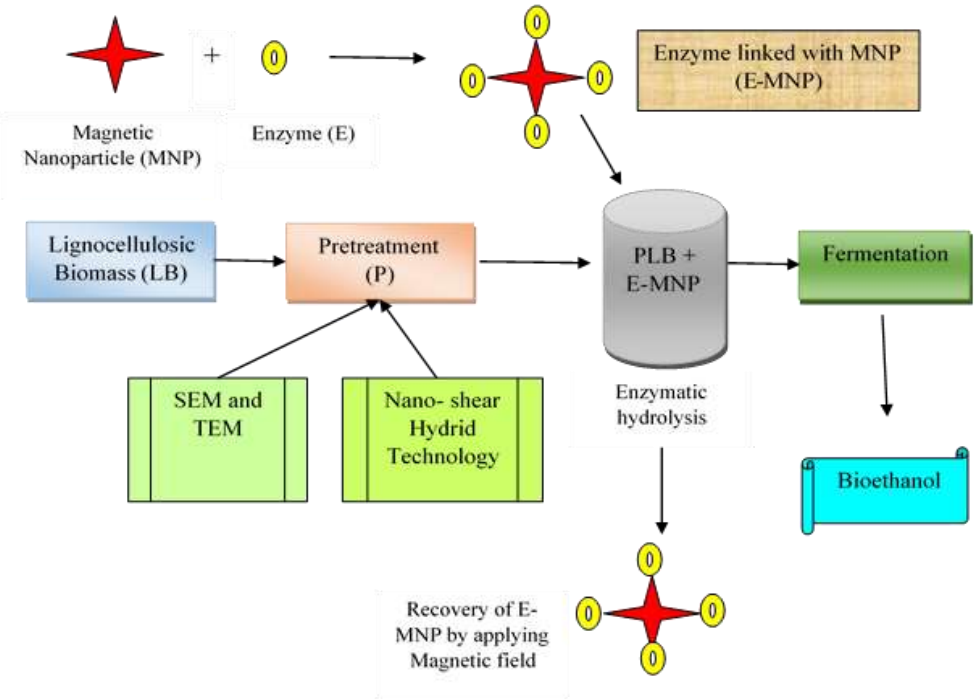

Fig.8.1: Figure shows the use of nanotechnology in different stages of bioethanol production

Sanusi et al. [9] studied the impact of metallic oxide nanoparticles on bioethanol production by Saccharomyces cerevisiae BY4743. The enhanced ethanol production was shown by use of Fe2O3 nanoparticles with 99.95% of the glucose utilization and 51% fermentation efficiency. It has also been shown that the production of ethanol can be decreased if nanoparticles are used in above concentration of 0.02 wt%. Kim and Lee [6] investigated the effect of two types of the nanoparticles (Methyl-functionalized silica and methyl-functionalized cobalt ferrite–silica) on production of ethanol in syngas fermentation by clostridium ljungdahlii. The ethanol production has been increased by the use of CoFe2O4@SiO2–CH3 nanoparticles and also enhances the syngas mass transfer. The nanoparticles have been recovered and reused five times and it has been shown that the capability of the nanoparticles was maintained. Although use of nanotechnology in bioethanol production has made the process more efficient but still there are many more aspects which need to be considered in further research. The main points which have to be kept in mind is its interaction with the microorganism, cost of nanoparticles and their impacts on the environment and human health for its applicability at industrial scale.

8.5 Conclusion:

Nanotechnology has promising applications in bioethanol production. The nanoparticles are used as a biocatalyst in the enzymatic hydrolysis process by immobilizing the enzyme on the nanoparticles through the following processes-encapsulation, ionic bonding, entrapment and adsorption. Nanotechnology (SEM, TEM) helps in finding out the changes that occur in the lignocellulosic biomass after pretreatment. The use of nanocatalyst improves the efficiency of the saccharification process and gives better yield. The magnetic nanocatalyst has an advantage over the conventional catalyst is its recovery by applying suitable magnetic field and reusability after many cycles. Many studies have been conducted by the researchers on the nanoparticles use in the bioethanol production process which showed the increased glucose utilization and improved productivity and yield. Much more detailed research is needed to use this technology at pilot scale and at industrial level.

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