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PRODUCTION OF LACTIC ACID AND POLYMERIZATION INTO POLY LACTIC ACID

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Abstract - *Lactic acid plays a vital role owing to its versatile application in the food, medical, and cosmetics industries, and additionally, it acts as a possible material for the assembly of biodegradable plastics. Currently, the fermentative production of optically pure lactic acid has been multiplied as a result of the prospects of environmental friendliness and cost-effectiveness. Lignocellulose wastes are plant biomass wastes that are composed of polyose, hemicellulose, and lignin. Due to their abundance and renewability, the use of LCW for the assembly and recovery of the many value-added products has been a great deal of interest. At present, the second generation bio-products like bioethanol, biodiesel, bio hydrogen, and bioplastics from lignocellulose biomass are primarily been made up of wastes rather than from energy crops. This review highlights the various techniques employed in the production of lactic acid from lignocellulosic wastes, their extraction, and eventually polymerization into poly lactic acid- The Bioplastic.*

***Key Words*: Lactic acid, Lignocellulose, bioplastics, fermentation, poly lactic acid**

1. INTRODUCTION

Bioplastics are substances which are made up of organic biomass instead of plastics that are usually made by using petroleum. Majority of the bioplastics generate a less amount of carbon dioxide than conventional plastics. These bioplastics also release monoxides or carbon dioxides while degrading but they are set to possess less environmental impacts when compared to the actual plastics[1].The processing methods that are involved in the growth of the base materials are very crucial as they have a detrimental effect on the product footprint. Lactic acid is a substance that is obtained from milk, it is the most commonly occurring carboxylic acid in nature. Polylactic acid that can be used as a bioplastic is obtained from lactic acid, it is very useful in various industries. The motive why the bioplastics like polylactic acid should be used is that they do not produce toxic fumes during incineration like conventional plastics do which is releasing chemicals [2]. At first, the use of polylactic acid in industries has been scarce because of its high initial costs. However, after the discovery of various polymerization pathways and advances in manufacturing industries have lowered the cost of polylactic acid. Lactic acid or 2-hydroxy propionic acid is a simple hydroxyl acid with an asymmetric carbon atom that exits in two optically active configurations. The (L+)- isomer is produced by both humans and mammals. Both D(-)- and L(+)- enantiomers are produced in the bacterial system. Poly Lactic acid is an aliphatic polyester which is largely produced by the ring-opening polymerization of lactide and industrial polycondensation of lactic acid [3]. The major advantages of the polylactic acid are biocompatibility, energy-saving, renewability and processability. The compound is derived from renewable and degradable products such as corn and molasses which will help to meet energy crisis and also helps to be less dependent on the fossil fuels.

1.1 INDUSTRIAL PRODUCTION OF LACTIC ACID

Lactic acid was initially synthesized on a commercial scale in the United States by the lactic acid bacterial fermentation of sugar substrates in 1883. From this, a lactic acid bacterium in the genus Lactobacillus and molds in the genus Rhizopus have been used in producing carboxylic acid. Both batch and continuous processes are used for manufacturing lactic acid, however, industrial-scale processes typically operate in the batch mode. Some of the suitable raw materials are glucose, sucrose, lactose, starch, or waste materials containing them. The lactic acid bacteria require bound sources of amino acid and B vitamins in order to fulfill the necessities for both growth and lactic acid production. Production method controls use computerized control of hydrogen ion concentration and temperature, and additionally the observance of substrate utilization and lactic acid production [4]. Lactic acid may be recovered from the fermentation broth when the cells are removed removal of the cells by precipitation as calcium lactate, and extraction and purification by ion exchange, distillation, and continuous countercurrent extraction. The industrial applications of lactic acid and its salts or esters include foods, cosmetics, and personal care products, cleaning agents in electronics and semiconductor producing, and in perishable polymers for medical devices or for packaging materials.

1.2 PRODUCTION OF LACTIC ACID FROM LIGNOCELLULOSIC WASTES

Lactic acid is widely produced from various lignocellulosic biomasses. The D lactic acid and the L lactic acid from the lignocellulosic wastes such as orange peel, potato peels, rice straw, waste papers can be obtained by various processing methods including fermentation and saccharification. Some specific bacterial strains are used in the production of lactic acid from corncob molasses which is one of the lignocellulosic wastes and it is also a waste by-product of xylitol production that is mainly used to produce L lactic acid. These specific bacterial strains utilize the sugars present in corncob molasses, and a large amount of lactic acid was produced by fed-batch fermentation [2]. Not only bacterial strains but also certain fungus is also used to produce lactic acid. A series of non-pH controlled batch fermentation under different conditions such as pretreatment process, enzymatic hydrolysis, temperature, and solids loading also were taken into account to study the lactic acid production. In such cases, the product is produced from potato peel waste which is a zero value-added by-product obtained from the food processing plant [5]. It contains a large amount of starch, lignin, protein, lipid, and other non-starch polysaccharides. Bioethanol along with lactic acid which is useful chemicals is produced from rice straw which is the most abundant lignocellulosic waste. The lignocellulosic is bound to have polyethylene glycol and non -ionic surfactants which during enzymatic hydrolysis tend to increase the conversion of cellulose into fermentable sugars. Several strains of the lactobacillus species have been used for the production of D lactic acid from orange peel waste. The orange peel waste has low lignin and ash content. . Bioprocessing of the pre- treated orange peel waste is carried out by enzymatic hydrolysis and fermentation of the released sugars to produce D- lactic acid [6]. Similarly, Lactic acid is produced by lactic acid bacteria in both hetero fermentative and homo fermentative ways. Lactic acid is the only product produced in a homo fermentative way, whereas in a hetero fermentative way both lactic acid and hexose are produced. The species Lactobacillus delbrueckii has been used as a homo fermentative producer of D- lactic acid using several agro-industrial residues. This bacterium yields 90% D-lactic acid from sugarcane molasses, 95% D- lactic acid from sugarcane juice, 88% D- lactic acid from sugar beet juice, and 88% D- lactic acid from orange peel waste. Moreover, the species Lactobacillus delbrueckii subsp. bulgaricus has been used in the dairy industry to transform milk into yogurt and some strains are able to produce highly pure D- lactic acid. Higher enzyme loadings are used to obtain higher yield which makes the production somewhat difficult. Through such cases, lactic acid is produced in a cost-efficient manner by using lignocellulosic wastes.

1.3 MICROORGANISMS USED FOR LACTIC ACID PRODUCTION

Microorganisms that produce lactic acid are bacteria and fungi. The investigations of lactic acid production were typically applied with lactic acid bacteria, filamentous fungi, like rhizopus, utilize glucose aerobically in order to produce lactic acid. Tay and yang immobilized R. oryzae cells on a fibrous bed to supply lactic acid from starch and glucose, mold species like R. oryzae and R. arrhizus have amylolytic enzyme activity, which permits them to convert starch directly into L(+)-lactic acid. Recently, the strains utilized in the industrial production of lactic acid have become nearly proprietary, and it is believed that almost most of the lactic acid bacteria used belongs to the genus Lactobacillus [7]. The strains of amylase-producing L. acidophilus were used for the direct conversion of starch into lactic acid. However, among the genus Lactobacillus, L. delbrueckii has appeared commonly in several investigations on the production of lactic acid. In addition to lactobacilli, strains of lacto cocci were typically used for lactic acid production. Lactic acid bacteria are classified into 2 groups: homofermentative and heterofermentative. While the homofermentative lactic acid bacteria convert glucose almost exclusively into lactic acid, the heterofermentative lactic acid bacteria catabolize glucose into alcohol and carbon dioxide as well as lactic acid [8].

2. IMMOBILIZATION

Microbial immobilization is wide employed in numerous industrial and environmental processes. Microorganisms preserved on a carrier are utilized in continuous and semi-continuous production processes allowing vital cost decrease because the biocatalyst doesn't need to be refilled. The cell immobilization has been explained as the physical confinement or localization of viable microbial cells to a precisely defined region of the area in such a way as to limit their free migration and exhibit hydrodynamic characteristic differ take issue from those of the surrounding atmosphere while also retaining their catalytic activities for continual usage. The choice of the support materials for immobilization may be a very crucial process. The carriers are differentiated into inorganic materials like clay, zeolite, porous glass, etc.., and organic polymers. A number of artificial and natural polymers are used [9].

2.1 IMMOBILIZATION METHODS FOR LARGE SCALE COMMERCIAL APPLICATIONS

Different methods of immobilization are used widely for large-scale industrial applications. Gel entrapment is the means of trapping the cells within the interstices of a polymeric network like natural or synthetic polymer. It is a technique that is generally used to immobilize microorganism cells. Entrapment is attained by adding one or a mixture of gelling or cross-linking agents. Entrapment of the microbial cells or organism in a porous polymer carrier was most usually used to capture the microorganisms from a suspended solution so the immobilized microorganisms are obtained. The polymer matrix which is used in this technique enclosing microorganisms has a permeable structure, so the pollutant and different metabolic product might diffuse through into the matrix. a number of the matrices used are agar, alginate, carrageenan, polyose and its derivatives, collagen, gelatin, epoxy resin, polyacrylamide, polyester, cinnamene, and polyurethane. It has some disadvantages like leakage. Encapsulation is a technique that's quite similar to that of the entrapment technique. in this technique, biocatalysts are confined by the membrane walls, typically in a style of a capsule however free-floating within the core area. The membrane itself is semi-permeable, permits for the free flow of substrates and nutrients, additionally keeping the biocatalyst inside. The factor deciding this development is that the correct pore size of the membrane adapted to the size of the core material. The restriction in access to the microcapsule interior is the main advantage of microencapsulation as it protects the biocatalyst from harsh environmental conditions. It protects the biocatalyst from outflow which provides increased efficiency in results. This technique is employed to enclose the microbes in a chemical compound gel [10].

Covalent bonding or crosslinking is entirely based on the bond formation between activated inorganic support and cell in the presence of a crosslinking agent. For covalent linking, chemical modification of the surface is very important. Covalent attachment and cross-linking are effective and durable to enzymes , however, it's rarely applied for immobilization of cells. It is caused primarily by the actual fact that agents used for covalent bond formation are typically cytotoxic and it's tough to find conditions once cells are immobilized without any injury. Adsorption is the first technique of reversible immobilization. The technique relies on the physical interaction between the microbial cells and the carrier surfaces. The immobilization of microorganisms on chosen adsorbents stimulates microbial metabolism, and protects cells from adverse agents, and preserves their physiological activity. It provides direct contact between nutrients and immobilized cells, it conjointly transports the cells from the bulk part to the surface support. Static and hydrophobic interactions govern the cell support adhesion that is the main step in controlling cell immobilization [11].

2.2 IMMOBILIZATION SPECIFIC TO LACTIC ACID

The cell immobilization can maintain high cell concentration and improves the production rates of lactic acid while reducing medium needs and inhibitions. There are many sorts of immobilization supports and lactobacillus casei cells were immobilized on fruit pieces for food-grade lactic acid production. Other varieties of immobilization supports include polyvinyl alcohol-containing sodium alginate, calcium pectate gels, and chemically modified chitosan beads. Lactic acid production is using cells that are immobilized by various immobilization techniques. Then, the fermentation method will be carried out in shake flasks that are further are often assessed by the production bioreactor. The bioreactor usually consists of a packed bed of immobilized cells and its method involves the use of the broth through the bed. a number of the porous de-lignified cellulose were used as immobilization carriers for a few lactobacillus species that is employed to enhance the lactic acid fermentation. The foremost common immobilization matrix that is used is alginate and it has been utilized in varied lactic acid productions.

The application of immobilization technology in fermentation processes is of great importance attributable to its many advantages over the free cell system. In lactic acid fermentation, entrapment using support materials like alginate, κ-carrageenan, and agar is the most typically used technique. However, the steadiness of the beads in long-term operation may be a common drawback. The application of pectate gel for cell entrapment in lactic acid fermentation is incredibly promising because of its sensible stability at low pH values and ready acceptability in food applications. In certain cases, the static bed fermenter was successfully used for cell immobilization [12].

2.3 EXTRACTION AND POLYMERIZATION OF LACTIC ACID

Several carboxylic acids are made in massive amounts by synthesis with organic chemicals or by fermentation strategies. Numerous separation methods like liquid extraction, chromatography, ultrafiltration, osmosis, drying, are often used. Reactive liquid-liquid extraction of the organic acids by an appropriate extractant has been found to be a promising alternative to the standard processes. Quaternary and tertiary amines like Alamine 336 and Aliquat 336 frame ion pairs with carboxylic acids, they result in elevated extraction efficiencies. The pH of the aqueous phase is a crucial parameter for the reactive extraction of organic acids. Temperature and initial organic acid concentration are necessary parameters for the extraction of organic acids. Yabannavar and Wang investigated the extraction of aqueous lactic acid by trioctylphosphineoxide in dodecane and Alamine 336 in oleyl alcohol [13]. Polylactic acid is prepared by different polymerization processes from lactic acid as well as direct polycondensation, ring-opening polymerization, and by direct strategies like azeotropic dehydration and enzymatic polymerization. Direct condensation polymerisation has fewer producing steps and a lower value and is less easy to manipulate and commercialize. The primary disadvantage of this technique is that the low relative molecular masses of the resultant compound that is because of the equilibrium among the free acid the oligomers, and also the water produced throughout the reaction or some special treatment. Thus, some typical method-ring opening polymerisation was developed [14].

In solute polycondensation, an organic solvent that is capable of dissolving the polylactic acid is added such that it does not interfere with the reaction, and the mixture is decreased with the removal of the water which is generated in the polycondensation method, which is useful is helpful a high relative molecular mass. In case of melt polycondensation of monomers, they will proceed without any organic solvent, however, provided that the temperature of the reaction remains higher than the tm of the compound. This technique can lower the cost of the synthesis considerably because of the simplified procedure; however, major issues still need to be solved before it is applied industrially because of its sensitivity to reaction conditions. However, the conventional condensation polymerization of lactic acid does not increase the relative molecular mass sufficiently. The ring-opening polymerisation of PLA is a crucial technique to getting high molecular weight products, in which using high purity lactide is the most vital step in the whole process. Lactide is prepared through a decompression technique during which the water is separated from the system, and then, some catalysts are added into the reactor. Several hours after the reaction, the product lactide is obtained; the lactide then opens its ring to polymerize [15].

3. CONCLUSION

Lactic acid is an important compound which has numerous applications in various industries such as food preservation, curative agent, and flavoring agent. The process of producing lactic acid from a variety of lignocellulosic wastes is very environmentally friendly when compared with the conventional process. The polymerization of lactic acid leads to the production of Polylactic acid which is a highly degradable polymer that can be made into different resin grades for processing into a wide spectrum of products. It is biodegradable and can be used as an alternative for petroleum-based plastics and helps in reducing the carbon footprint.

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