Lactic Acid Production using Food Waste

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Abstract **- Lactic acid is a naturally occurring acidhaving hydroxyl group adjacent to carboxyl group making it AHA (Alpha Hydroxy Acid). Lactic acid has variety of uses in various industries like, cosmetics, pharmaceuticals, chemical, food and various medical. Lactic acid can be produce by various methods like fermentation of sugars and food waste. In this way lactic acid is eco-friendly product that grab a lot of attention towards it in recent years. Keeping in mind the importance of lactic acid the following study introduces the recent work being done on production of lactic acid using different types of food wastes from restaurants, university kitchen and biomass from agro-industrial waste. Different processes were used for lactic acid production like simultaneous saccharification, solid submerged fermentation and hydrolysis. For down-streaming and purification latest approaches are used such as distillation, Nano-filtrations, ultra-filtrations, micro-filtration, bipolar and mono polar electrophoresis and separations using anion-cation exchange resins. In future, more focus needs to be given upon attaining maximum productivity and yield. Purification processes must be efficient enough to achieve higher rates of productivity and less product loss.**

Keywords: Lactic acid; Poly Lactic Acid PLA; Fermentation; Food waste; Green Biotechnology

INTRODUCTION

A huge quantity of food is wasted at global level every year. This creates difficulty to find a perfect way for the management of huge amount of food to convert it into useful product or to recover essential components that can be extracted from the food. Research in Germany says that 18 million tons of food is wasted every year, from which 10 million tons of food is avoidable (by changing the habits of consumers). If we consider that this 10 million tons of food is dumped in 2.6 million hector of arable land this will generates 2.18 million ton of CO_2 [1]. This finding makes the development of an efficient process to convert wasted food into useful product is a serious concern.

Wasted food consist of various components depending on type of the food e.g. noodles, vegetables, fruits and most important meat. Waste food utilization processes are commonly biotechnology based[2]. Most of the processed food is first hydrolyzed by hydrolytic enzymes i.e. amylase and protease or most of the time microorganisms such as *Aspergillus awamori* and *Aspergillus oryzae* are used that secrete hydrolytic enzymes for bioconversion of food waste[3]. This secreted hydrolysate is rich in fructose, glucose (sugar monomers) and various amino acids, free amino nutrients and phosphates. This nutrients can be used in production of microbial biomass such as long chain polyunsaturated fatty acids, production of energy rich contents, production of succinic acid[7], production of lactic acid[4]and production of biogas[5].

Hydrolysis process can be made faster by using various commercial enzymes but processing large amount of food waste using different equipment and huge amount of commercial enzymes can be costly. There is a need to make the process cost effective for the areas where the food wastage is high i.e. urban areas [4].Most commonly, wasted food is utilized to produce biogas that involves many processes like mathanogenesis, acidogenesis, disintegration and hydrolysis and many other simple processes. These processes considered as simple steps even for incorporation in urban environment [6]**.** These anaerobic processes for biogas production are not very efficient methods to utilize waste food. The efficient way to utilize waste food is production of pure fermentative organic acids to be used in chemical industries.

In SSF approach wasted food is degraded with help of enzymes and lactic acid is produce in this process. Lactic acid is preferred over other compounds because lactic acid is basically used in various cosmetics, pharmaceuticals, chemicals and food industries. High market level polylactic acid can also be produced [8]**.**

Different ratios of solid to liquid are usually used at lab scale to check different level of lactic acid production. At industrial scale, this production is carried out under different conditions (non-sterile conditions) to check the productivity rate of lactic acid in these conditions. Down streaming is one of the most important steps that effect the end yield of product which may consists of ion-exchange chromatography, filtration and distillation**.** The current review will focus on simple way to directly produce lactic acid from organic matter without hydrolysis that allows us utilization of organic matter.

LACTIC ACID PRODUCTION

Lactic acid has many commercial uses and due to its importance in different industries, special focus has been given on improving lactic acid production. Lactic acid can be produced by chemical synthesis or by fermentation. But since chemically synthesized Lactic acid is way more expensive we chose the process of fermentation to produce Lactic acid which is both cheaper and eco friendly. Fermentative lactic acid is produced in two forms either L+ Lactic acid or D Lactic acid, or as a racemic mixture. But only L+ Lactic acid is consumable by humans therefore has more importance commercially and economically [8]**.** Fermentation can be of two types, solid state fermentation and solid submerged fermentation. Both methods are suitable and mostly employed for large scale production. The idea to choose biomass from food waste, animal feed, and agricultural waste and agro-industrial residues to produce lactic acid is so that we can design an environment friendly process that is cheap and affordable.

Different studies have been conducted so far which help in understanding the optimum pH, temperature, type of media, solid to liquid ratios and best microorganism suited for inoculum giving the highest productivity and yield for Lactic acid. Table 1 reveals different studies about the types of microbial strains which are being used to produce lactic acid by using different food sources. It also shows the yield and productivity rate of different microbes that are being used for lactic acid production.

Table 1 Different Raw material sources, microbial strains and their productivity for Lactic Acid

Sr.No	Types of Food Waste	Source of Food Waste	Microorganism	Productivity	References
1.	Noodles, meat, sauce, potatoes, vegetable, rice, fruit.	Canteen located at the leibniz institute foragriculturalenginee ring and bioeconomy	Lactobaccilus thermophillus specie strains A28a, A59, & A211 and one streptococcus mesophillic specie strain A620 is used.	Lactobacillus species strain showed productivity of 0.27-0.53g/L/h whereas streptococcus sp. Strain showed higher productivity of 2.16 g/L/h	[9]
2.	Biomass and waste	agricultural and agro-industrial residues	*Lactobacillus amylovorus* ATCC 33622	Productivity of 20 g l^{-1} h^{-1} was seen for lactobacillus amylovorous ATCC33622. A maximum of 35 g l^{-1} h^{-1} was reported using a high cell density of *L. helveticus*	Rojan P. John et al., 2007
3.	cassava bagasse and sugarcane bagasse,	Agroindustrialwaste	*Lactobacillus delbrueckii*	A maximum of 249 mg/gds L-lactic acid was obtained after 5 days of fermentation	[33]
4.	Kitchen food waste and sophoraflavescens residue	Food waste was collected from the dining room of University of Science and Technology of Beijing. SFR was from a traditional Chinese pharmaceutical factor in Shanxi Province, China	Lactobacillus casei	The highest L-LAC concentration reached 67.5g/L at the SFR ratio of 1.5:1.	[29]
5.	Coffee mucilage	Coffee industry	*Bacillus coagulans*	Using mucilage and 5 g L^{-1} yeast extract as additional nitrogen source, more than 40 g L^{-1} lactic acid was obtained. Productivity and yield were 4–5 g L^{-1} h^{-1} and 0.70–0.77 g lactic acid per g of free sugars	[10]

SOLID SUBMERGED FERMENTATION

Solid submerged Fermentation requires a specific solid to liquid ratio. According to a research, when the food waste solid to liquid ratio was increased to 20% there was greater availability of carbon, nitrogen and oxygen sources which consequently lead to increased productivity of Lactic acid. Thus it can be concluded that greater solid to liquid ratio greater the yield and productivity of Lactic acid.

Recent studies on Fermentative lactic acid production showed that Lactic Acid Bacteria (LAB), which are a broad range of microbes, includes several genera which are proven to be the best microbes to choose for lactic acid production on large scale. The following table shows the productivity and yield of different LAB analyzed so far.

The Table 2 shown below refers to the commercially important lactic acid producing bacteria, their rates of productivity and product yield.

Table 2 Commercially Important strains of LAB and their productivities regarding Lactic Acid Production

Sr. No.	LAB sp. Strain	Productivity/Yield	References
1.	Lactobaccilus thermophillus specie strains A28a, A59, & A211	Lactobacillus species strain showed productivity of 0.27-0.53g/L/h	[9]
2.	*Lactobacillus amylovorus* ATCC 33622	Productivity of 20 g l^{-1} h^{-1} Was seen for lactobacillus amylovorous ATCC33622. A maximum of 35 g l^{-1} h^{-1} was reported using a high cell density of *L. helveticus*	[28]
3.	*Lactobacillus delbrueckii*	A maximum of 249 mg/gds L-lactic acid was obtained after 5 days of fermentation	[33]
4.	Lactobacillus casei	The highest L-LAC concentration reached 67.5g/L at the SFR ratio of 1.5:1.	[29]
5.	Streptococcus mesophillic specie strain A620	streptococcus sp. Strain showed higher productivity of 2.16 g/L/h	[9]
6.	*Bacillus coagulans*	Using mucilage and 5 g L^{-1} yeast extract as additional nitrogen source, more than 40 g L^{-1} lactic acid was obtained. Productivity and yield were 4–5 g L^{-1} h^{-1} and 0.70–0.77 g lactic acid per g of free sugars	[10]
7.	*Enterococcus mundtii* QU 25	the strain produced 964 mM L-(+)-lactate from 691 mM xylose, with a yield of 1.41 mol/mol xylose consumed and an extremely high optical purity of ≥99.9%	[31]
8.	*Enterococcus faecalis* RKY1.	*E. faecalis* RKY1 efficiently produced lactic acid with 2.6 g/l h of lactic acid productivity	[11]

RAW MATERIAL, MEDIA SELECTION, TEMPERATURE AND PH CONDITIONS

The raw material we choose must be rich in carbon, nitrogen and oxygen source. Latest research work focuses on utilizing biomass for production of Lactic acid. Biomass from agricultural waste, agro-industrial residues, food waste, feed stock and mucilage from coffee was found to be a great source of raw material for lactic acid production.

Fermentation media must constitute of

- Glucose, fructose, sucrose or any fermentable sugar
- Nitrogen source
- Yeast Extract
- Salts like NaCl
- NaOH for balancing the pH
- Phosphate source
- Potassium source K_2SO_4
- $CaCl_2$. $2H_20$
- $MgSO_4$

Media rich in nitrogen and carbon source is the most suited as it helps to promote growth of microbes [30].

Conditions for Fermentation are different for each industrial method but are usually in the range of 45–60 °C having a pH of 5.0–6.5 for Lactobacillus delbrueckii and 43 °C with a pH of 6.0–7.0 for Lactobacillus bulgaricus. The reason to choose slightly acidic pH is because our product is itself an organic acid and a pH value that is slightly acidic will keep our product intact and prevent it from degradation. [12].

PURIFICATION/ DOWN-STREAMING PROCESS:

Purification is an important step for further processing. There are different approaches and techniques which can be used for down streaming and purification such as:

- Distillation
- Nano filtration
- Ultra-filtration
- Micro-filtration
- Bipolar and Mono polar electrophoresis
- Separations using anion-cation exchange resins [10].

Flow sheet diagram (fig.1) represents a general process for lactic acid production by fermentation and down streaming process.

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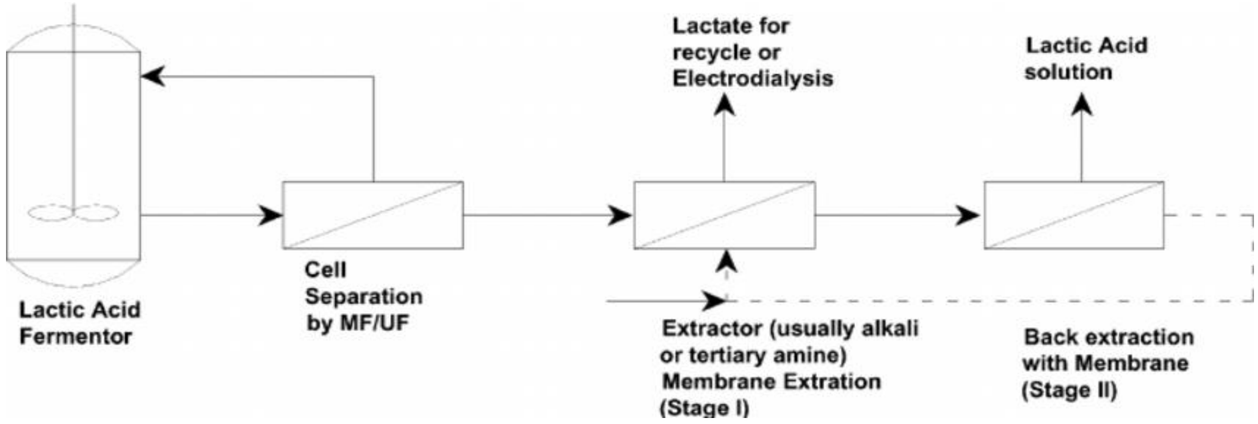

Fig. 1. General process of Lactic Acid production.

Commercial Applications

Lactic acid mostly classified as generally regarded as safe (GRAS) product by Food and Drug Administration. Lactic acid is first acidic product that was produce by fermentation. Lactic acid has variety of applications and commercial uses. Some of Commercial uses are summarized in given table (Table No.3) and explained below.

Table 3: Applications of Lactic Acid in different industries.

Sr.No.	Applications	References
1.	Use in Cosmetics.	[13]
2.	Use in pharmaceutical.	[13]
3.	Biodegradable plastics which have compatibility of thermoplastic.	[14]
4.	Use to make Electro dialysis and bipolar membranes.	[15]
5.	Use in preparation of environmental friendly Green solvent.	[16]
6.	Use in chemical industry.	[13]
7.	Food preservation.	[17]

Some Applications are explained below:

Use in Cosmetics

Lactic acid has a major role in various cosmetic products. Lactic acid is used in the production of skin and hair products which are creams, shampoos, lotions etc. Various cosmetics cause detrimental effects on skin causing dryness, irritation or harshness. But using lactic acid in cosmetic helps to overcome these problems and also improves the condition of skin [13]. Lactic acid when combine with other constituents, enhance their favorable properties. Adding lactic acid to hair and skin products enhances their lubricity, smoothing and softening quality [18]. It also provides resistance and protection against drying effect of cosmetics. Cosmetics with lactic acid provide tactile oiliness due to vegetable oil present in cosmetics [19]. Treatment of the skin with lactic acid makes skin frim, thick, and wrinkle free. Lactic acid treatment of skin cause anti-aging effect on skin [20].

Use in pharmaceutical

Lactic acid is a very important factor in pharmaceutical industry. L+ lactic acid plays important role in pharma because D- lactic acid is not metabolized by human body. Lactic acids with different salts have many applications in medical field. They are able to supply energy and are helpful in regulating the ph. Lactic acid with different salt combination like calcium, sodium or iron exhibit anti-tumor activity [21].

The use of lactic acid in intravenous injections acts as bodily electrolyte which replenishes bodily fluids. Lactic acid is also used as a lactated Ringer's or Hartmann's solution in artificial kidney machines [22].

Polylactic acid has potential to work as drug releasing matrix. PLA is considered as most well suited biopolymer, because when PLA is applied or added to human body, PLA is easily hydrolyzed to its monomers (hydroxyl acid monomers) that can easily be metabolized in human body trough TAC (tricarboxylic acid cycle)[23].

Biodegradable Plastics

Polylactides or lactic acid polymers are aliphatic poly-eaters and widely used and researched for bioplastics or thermoplastic polyesters. PLA is made up of 2-hydroxy propionic acid and works as a building block in PLA. PLA is biodegradable and compostable thermoplastic which is derived from renewable plant sources 24]. These lactic acid polymers have ability to replace petrochemical polymers. PLA technologies stress on achieving mechanical, chemical and biological properties which are superior to petrochemical polymers [25].

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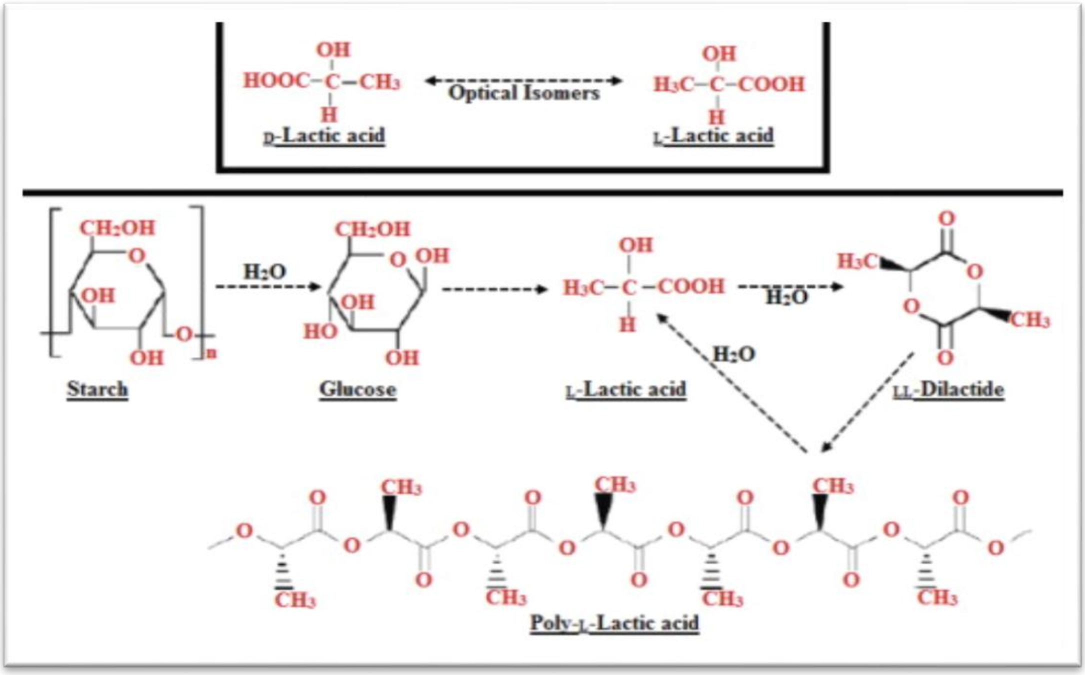

Fig.1. Production of Poly Lactic Acid (PLA) [32].

LACTIC ACID IN FOOD

Lactic acid has a wide range of uses in food industry. Lactic acid is used as an emulsifier in baking food industry, for baking purpose industry require heat stable emulsifier that can be produced synthetically[34]. It is also used in the manufacturing of rye bread. Lactic acid is used in food preservation because lactic acid is slight acidic in nature that inhibits bacterial growth on food[26]. Lactic acid also helps in increasing shelf life of poultry and fish products during packaging[27].

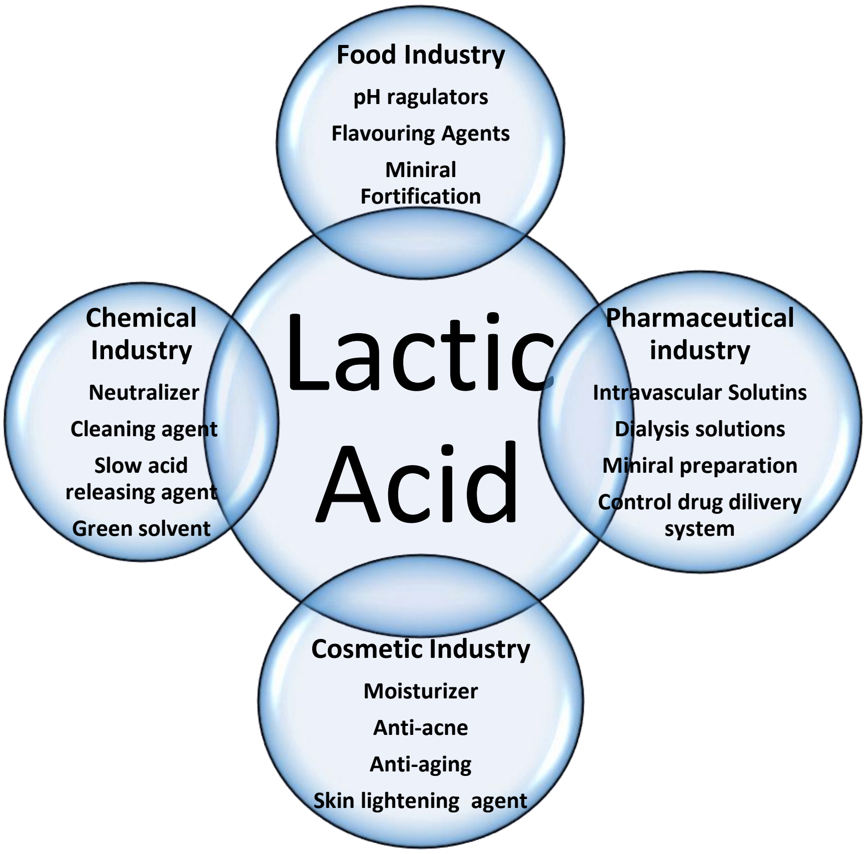

Fig.2. Range of Commercial Applications of lactic acid and its salts [35].

CONCLUSION

Increasing demand of lactic acid and research on eco-friendly poly lactic acid production has made it necessary to develop a sustainable and conventional method for lactic acid production by fermentation. It is reported that under controlled conditions like at controlled pH the productivity of lactic acid by fermentation can be increased. Lignocellulosic material can be obtained from food waste, agriculture waste for large scale fermentation of lactic acid. This raw material, obtained as a waste product, received great attention for the lactic acid production in recent years. However, due to an increasing demand of lactic acid, there is still need to improve fermentation technology to produce lactic acid commercially at low cost. There is also a need to produce high performance microbes or to improve their activity by genetic modification to produce lactic acid on large scale.

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