Production of Lactic Acid from Potato Wastes

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Abstract- Lactic acid is a natural organic acid. As such, its long history of application in the food, pharmaceutical, textile and chemical industries cannot be overemphasized. This study is focused on the production of lactic acid from food wastes (potato peels) with a view to evaluating the feasibility and potentials of using food wastes as renewable resources for industrial application.

I. INTRODUCTION

Lactic acid, or 2-hydroxypropionic acid (CAS 50-21-5), is the most widely occurring hydroxycarboxylic acid (Datta and Henry 2006). It is a natural organic acid with a long history of applications in the food, pharmaceutical, textile, and chemical industries (Ouyang *et al*, 2013). In recent years, the demand for lactic acid has increased considerably because of its use as a monomer in the preparation of polylactic acid (PLA) (Abdel-Rahman *et al*. 2013; Ouyang et al. 2013; Shi *et al.* 2015), which is a biodegradable and biocompatible polymer that is used in a wide variety of applications. Its uses range from packaging and fibers to foams (Abdel-Rahman et al. 2013) and applications in biomedical devices (Lasprilla *et al.* 2012). Lactic acid can be produced by fermentation or chemical synthesis. Production by the fermentation process has attracted interest because of its advantages, which are the production of pure isomers (L(+)- or D(-)-lactic acid), use of renewable and low cost raw materials, low energy consumption, and mild conditions required for operation.

Lactic acid is a versatile chemical compound that finds use in the food, pharmaceutical, and chemical industries. It is a natural carbohydrate fermentation product that can be produced from a variety of sources, including food wastes. In recent years, there has been a surge of interest in using food wastes as a low-cost and sustainable feedstock for lactic acid production. This chapter provides an overview of current research on lactic acid production from food wastes.

Food wastes such as potato, orange and yam peels are promising sources of lactic acid due to their high carbohydrate content and availability as byproducts of food processing. Potato peels are estimated to account for 20% of the total potato weight and are typically discarded as waste, while orange peels constitute up to 50% of the total fruit weight and are also commonly discarded. Utilization of these wastes for lactic acid production not only provides a sustainable solution for waste management but also reduces the dependence on conventional feed stocks and enhances the economic feasibility of lactic acid production.

II. LITERATURE REVIEW

Lactic (2-hydroxypropanoic) acid (LA) is a valuable organic chemical with both traditional and modern applications. It was widely used as a neutralizer, preservative, or acidulant in food and beverage, cosmetic, pharmaceutical, and other industries. Recently, lactic acid is applied as the building block for various biodegradable polymers or precursor for environmentally friendly solvents. The annual global market of lactic acid in 2020 is valued at USD 1.1 billion with an increasing tendency to double till 2025 (Lactic Acid Market by Application (Biodegradable Polymers, Food & Beverages, Pharmaceutical Products (2020)). The global market for lactic acid was 750.00 kilotons in 2017 and is projected to reach 1,845.00 kilotons by 2025 (Global Lactic Acid Market 2017- 2025 - Growth Trends, Key Players, Competitive Strategies and Forecasts - Research and Market 2017)

Lactic acid is a chiral compound with a carbon chain composed of a central (chiral) atom and two terminal carbon atoms (Fig.1.1). The optically active form of lactic acid is simply an equimolecular mixture of both and may be denoted as DL-lactic acid or racemic mixture. The optical composition does not affect many of the physical properties with important exception of the melting point of the crystalline acid.

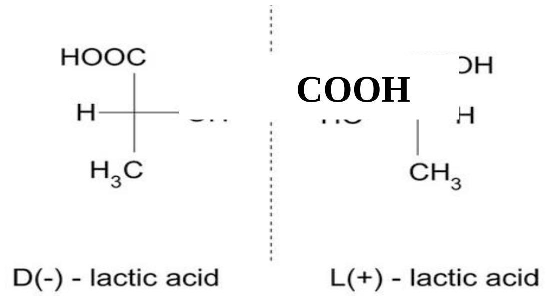

Fig1: Chemical structure of L-(+)-lactic acid and D-(-)-lactic acid

Table 1: Properties of Lactic Acid

PROPERTY	CHARACTERISTICS
Optical activity	Exists as L(+), D(-) and racemic mixture
Crystallization	Forms crystals when highly pure
Colour	None or yellowish
Odour	None
Solubility	Soluble in all proportions with water Insoluble in chloroform, carbon disulphide
Miscibility	Miscible with water, alcohol, glycerol and furfural
Hygroscopicity	Hygroscopic
Volatility	Low
Self-Esterification	In solutions of > 20%
Reactivity	Versatile; e.g. as organic acid or alcohol

Source: (Martin, 1996)

Uses of Lactic Acid

Once the lactic acid is ready, it can be used for various purposes as below.

i. Personal products and healthcare products
ii. Food preservatives
iii. Dairy products, like yoghurt
iv. Cleaning, laundry, and dishwashing products
v. Paint and coating additives
vi. Furniture care products
vii. Textile dyeing and leather tanni
viii. Pharmaceuticals

These activities of LAB can contribute to different sensory and quality characteristics of fermented food and can make protein ingested easily in the gastrointestinal tract of the host. For example, compounds resulting from breaking down casein (peptides, amino acids, and derivatives of amino acids) contribute to the formation of flavor and texture in fermented milk products.

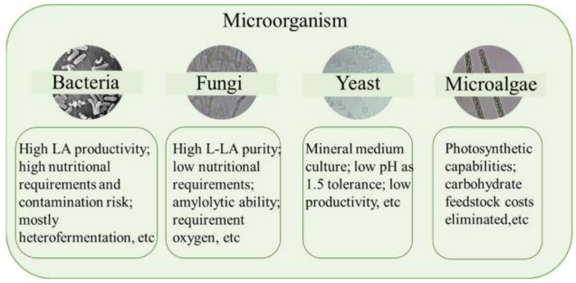

Figure 3: properties of different microorganisms for lactic acid fermentation (CrossRef)

III. METHOD

3.3.1 Collection and Pretreatment of Substrates

The collection and preparation of the substrates are essential to ensure the quality and purity of the raw materials. Potato, orange and yam peels were collected from local markets and restaurants. The peels were washed with distilled water, and air dried for 48 hours. Previous studies have shown that the quality of the raw materials significantly affects the lactic acid yield and quality (Cai *et al*., 2018; Lu *et al*., 2020).

Therefore, careful selection and preparation of the raw materials are crucial for successful lactic acid production.

3.3.2 Grinding

The dried peels were ground into a fine powder using a blender. The powder was sieved to remove any remaining large particles.

3.3.3 Storage

The fine powder was stored in a clean, dry, and airtight container at room temperature until further use.

3.3.4 Sterilization

The powders were sterilized in autoclave at 121°C for 20 minutes to eliminate any microbial contamination. This step is critical to ensure a sterile environment for the fermentation process and prevent contamination by unwanted microorganisms.

3.3.5 Inoculation

The sterilized substrates powders were inoculated with Lactobacillus delbrueckii, (a lactic acid bacteria). The inoculum size is an important factor that affects the fermentation rate and lactic acid yield.

3.4 Enzymatic Hydrolysis of Substrates

The substrates were treated enzymatically to obtain a glucose-rich hydrolysate from starch. This approach was preferred to acidic treatments in order to limit the formation of undesired inhibitory by-products like hydroxymethylfurfural. Sulfuric acid was used in the acid hydrolysis of the potato and orange peels to release the fermentable sugars. Calcium hydroxide was used to neutralize the acid solution after hydrolysis. Sodium hydroxide was used to adjust the pH of the fermentation medium.

3.5 Isolation of Lactic Acid Bacteria

Lactic Acid Bacteria (LAB), which can be found in curd, rice water, kimchi, garlic, and mango peels were isolated from a variety of fruits, vegetables, and dairy products. Samples were serially diluted up to 10^{-9} in distilled water for isolation, then spread plated on MRS agar plate and incubated anaerobically at 37ºC for at least 2 days. The isolated colonies were transferred to MRS broth and streaked three times on Nutrient agar to purify them. Further, the individual bacterial colonies were saved for the study.

IV. RESULTS

Table 4: Lactic Acid from Potato peel powder (PPP)

Mass(g)	Water quantity(ml)	pH	Temp(ºC)	Time(hr)	Yield(%)
20	50	6.0	30	48	42.3
20	50	6.5	35	48	72.6
20	50	7.0	40	48	51.8

From the table above, the lactic acid produced from potato peels powder at a pH of 6.5 and 35ºC gave the highest yield.

Table 7: Summary of substrate with the highest yield and optimum production parameters

Substrates	Substrate conc. (g)	pH	Time (hr)	Temp (ºC)	Best Yield(%)
PPP	20	6.5	48	35	72.6

From this study, it was observed that the highest yield of lactic acid was obtained from potato peels powder at 6.5 pH and 35ºC. This is because lactic acid fermentation performs best within the mesophilic temperature range, which is around 25 ºC to 37 ºC. Many lactic acid bacteria strains perform well within this temperature range, with optimal growth and lactic acid production occurring around 30 to 37 degrees Celsius.

Also, lactic acid production primarily relies on the fermentation of carbohydrates. Among the substrates used, potato peels contain higher amounts of carbohydrates compared to yam and orange peels. Potatoes are known to be relatively rich in carbohydrates, particularly starch, which makes up a significant portion of the carbohydrate content in potato peels. Therefore, the substrate with the highest carbohydrate content gives the highest yield.

Several studies have been conducted on lactic acid production from agricultural waste, including potato and orange peels. For example, a study by Hu *et al* (2014) reported a lactic acid yield of 32 g/L and a purity of 76% using potato waste as a substrate. Another study by Yu *et al* (2016) reported a lactic acid yield of 34 g/L and a purity of 83% using orange peel as a substrate.

Table 8: Proximate Analysis of Substrates

Parameter	Potato peels
Protein	7.8

Crude fiber	6.8
Moisture	5.2
Ash	4.56
Carbohydrate	89.3

Fourier Transformed Infrared (FTIR) Analysis

The Fourier Transformed Infrared (FTIR) analysis was used in this research to detect the presence of the functional groups of lactic acid from each of the substrate at different pH (6.0, 6.5 and 7.0) and temperature (30°C, 35°C and 40°C), and the purity of the lactic acid.

Lactic acid exhibits characteristic infrared absorption bands at specific wavenumbers in the FTIR spectrum, corresponding to its functional groups. The major functional groups present in lactic acid are the carboxylic acid (-COOH) and hydroxyl (-OH) groups. In the FTIR spectrum of lactic acid, the carboxylic acid group typically appears as a strong and broad absorption band in the range of approximately 3000-3500 cm^-1 (wavenumbers). This region corresponds to the stretching vibrations of the O-H bond in the carboxylic acid group. The hydroxyl group in lactic acid, which is associated with the alcohol (-OH) functional group, exhibits an absorption band in the range of around 3200-3600 cm^-1. This region corresponds to the stretching vibrations of the O-H bond in the hydroxyl group.

Below are the FTIR results of the samples analyzed:

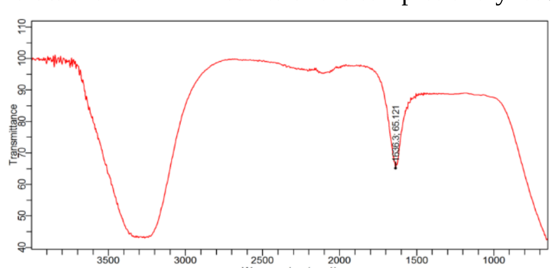

Fig7: PPP at pH 7.0, 30°C

The figure above illustrated the presence of lactic acid at the broad peak which falls between the wavenumber of 3000 to 3500. It also indicates the presence of minor impurities or other compound in the sample which is the narrow peak on the result.

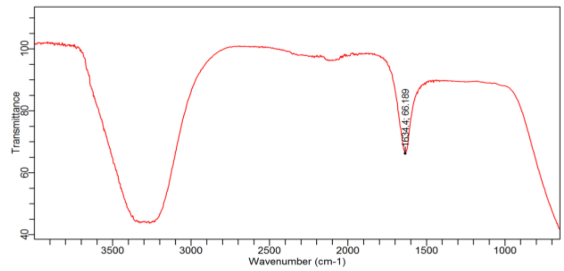

Fig8: PPP at 6.5 pH, 35°C

The figure above illustrated the presence of lactic acid at the broad peak which falls between the wavenumber of 3000 to 3500. It also indicates the presence of minor impurities or other compounds which is the narrow peak on the result.

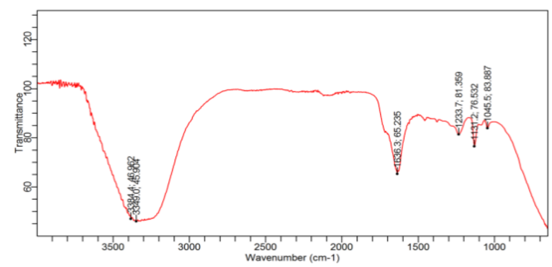

Fig9: PPP at 6.0 pH, 40°C

The figure above illustrated the presence of lactic acid at the broad peak which falls between the wavenumber of 3000 to 3500. It also indicates the presence of impurities and other compounds which is the narrow peaks on the result.

CONCLUSION

The study aimed to investigate the production of lactic acid from three different substrates which are; potato peels, orange peels and yam peels. The results show that all the food substrates can be utilized for lactic acid production. The optimal conditions for lactic acid production were found to be a pH of 6.5 a temperature of 35°C, and an incubation period of 48 hours.

The yield of lactic acid varied between the different substrates used, with potato peels producing the highest yield of 87 g/L. The quality of the lactic acid produced was found to be comparable to commercial lactic acid.

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