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Production of Lactic Acid from Orange Wastes

Cyrus Aseibichin
Chemical/Petrochemical Engineering, Rivers State University.

Abstract
Considering the ***production of lactic acid from Orange wastes,*** *its specific objectives are to determine the yield of lactic acid produced from each substrate at different pH and temperature. To compare the yield of substrate used and determine the one with highest yield. To characterize the substrate that produces more lactic acid than the others.*

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I. Introduction

Lactic acid is a versatile chemical compound with a wide range of applications in the food, pharmaceutical, and chemical industries. It is a natural fermentation product of carbohydrates and can be produced from various sources, including food wastes. In recent years, there has been an increasing interest in using food wastes as a sustainable and low-cost feedstock for lactic acid production. This chapter provides a background of the study on the production of lactic acid from food wastes.

Food waste with high organic matter concentrations (volatile solids/total solids [VS/TS]: 0.8–0.9) and moisture content easily spoils and stinks, and large amounts could seriously affect people's physical health and the cityscape (Ren, Y *et al*., 2018). Presently, food waste is reused in the following processes: anaerobic digestion for biogas production, composting, bio-ethanol production, and feed production for insects and animals. Food waste contains approximately 30–60% starch, 5–10% protein, 10–40% fat and some trace elements, which are nutritious and suitable for the growth of LA bacteria (Ren, Y *et al*., 2018, Zhang, S. *et al*, 2021 and Ma, X *et al*., 2022). To establish a highly efficient LA production system from food waste without exogenous enzyme supplementation, co-fermentation of food waste and corn straw was first performed to obtain glucoamylase (1838 $U \cdot g^{-1}$) with Aspergillus niger UV-60. Further, this kind of crude glucoamylase was found to have good acid resistance, with optimum pH of 4.2–4.9, and that relative enzyme activity at pH 3.0 can still reach 83.5% [21]. Subsequently, LA fermentation was carried out in a simultaneous saccharification fermentation mode with crude glucoamylase (142 $U \cdot g^{-1}$, dry basis) addition and 6% ($v \cdot v^{-1}$) Lactobacillus rhamnosus inoculation in food waste medium. Finally, 58.40 $g \cdot L^{-1}$ (0.58 $g \cdot g^{-1}$ food waste, dry basis) of L-LA was obtained after SSF at 38 ◦C for 48 h (Journal of Applied Bacteriology, 23(1), pp. 130-135).

II. Literature Review

In the pharmaceutical industry, lactic acid is used in implants, pills, dialysis, surgical sutures, and controlled drug release systems. In the cosmetic industry, lactic acid is used in the manufacture of hygiene and aesthetic products because of its moisturizing, antimicrobial, and rejuvenating effects on the skin. It is also used in oral hygiene products (Castillo Martinez *et al*. 2013).

New applications for lactic acid have been developed, such as the production of biodegradable and biocompatible PLA polymers (Abdel-Rahman *et al*. 2013), solvents, and oxygenated chemicals. Polymer production accounts for the largest portion of lactic acid demand (39%). In polymer applications, water is removed from lactic acid (CH CHOHCOOH) in the presence of acid catalysts to form lactides (C6H804), as shown in Eq. 1:

$$2CH_3CHOHCOOH \quad C_6H_8O_4 + 2H_2O \longrightarrow \qquad \text{.....(1)}$$

Lactides are polymerized to obtain the biodegradable thermoplastic polymer, PLA. There is a growing demand for PLA derivatives to substitute conventional plastic materials, as well as for use in materials for medical devices (Gao *et al*. 2011). L(+)-Lactic acid provides a high yield of lactide, which in turn yields polymers with a high molecular weight, high degree of crystallinity, and high tensile strength. These polymers are transparent, which is important for packaging applications; have long shelf lives because they slowly degrade by hydrolysis (which can be controlled by composition and molecular weight adjustment); and their characteristics are similar to polymers generated from fossil carbohydrates. Other desired properties can be obtained by copolymerization with other oxygen monomers.

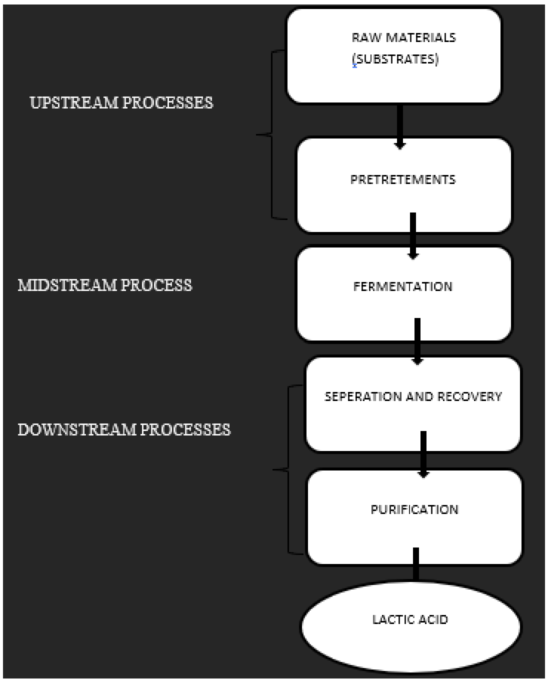
The use of lactic acid in the manufacture of green solvents, which are environmentally friendly solvents, is another area for potential growth. In particular, using lactate esters from alcohols with low molecular weights in the formulation of pesticides (Sasson *et al*. 2005; Baur *et al*. 2008) and other bioactive components because of its low toxicity has a high potential for growth.

Oxygen chemical derivatives from lactic acid are widely produced, and include propylene glycol, propylene oxide, acrylic acid, and acrylate esters (Datta and Henry 2006). Although there is a wide range of applications, the use of lactic acid is still limited by the final production costs associated with the downstream processes, which are responsible for 30% to 40% of total production costs of lactic acid (Lopez-Garzon and Straathof 2014)

Table 3: Application of lactic acid in various fields

FIELD	APPLICATIONS
Food Industries	Preservatives Acidulants
Pharmaceutical Industries	pH regulator Dialysis solution Mineral preparation
	Prosthesis
	Surgical Sutures
Chemical Industries	Cleaning agents
	Descaling agents
	pH regulators
	Green solvents
	Neutralizers
Cosmetics Industries	Moisturizers
	Humectants
	pH regulator
Poly Lactic Acid	Food containers
	Protective clothing
	Thrash bags
	Rigid Containers

Method



Fermentation Process
Fermentation Process

In Solid State Fermentation (SSF), 20g each of the substrate powders (orange peels) were taken separately into 250mL Erlenmeyer conical flasks moistened with 50 ml of sterile distilled water, the media were fortified using 0.5g of Lactose, 0.3g of MgSO4 and 0.5g of yeast extract. The pH was also adjusted to different ranges using diluted Sulfuric acid (H_2SO_4) and Sodium hydroxide (NaOH) of 6, 6.5 and 7.0 respectively.

The media were then sterilized by autoclaving at 121°C for 15 min. After cooling at room temperature, The flasks were inoculated with the isolated Lactobacillus Delbrueckii, 5 ml of sterile distilled water was added to the bacterial pure culture to make a suspension and was then added to the orange peel medium respectively and was allowed to ferment for incubation time of 48 hours all through.

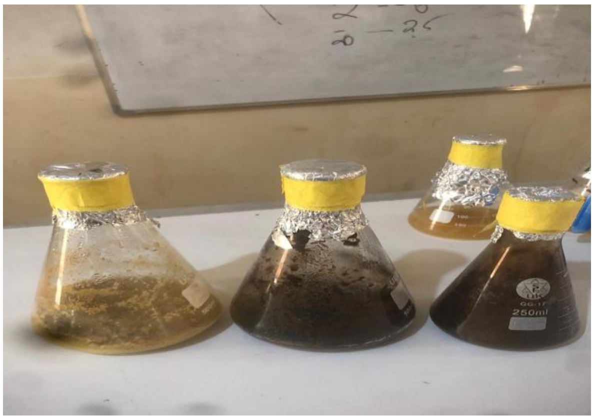


Fig 5: Fermentation Experimental Set up

Nutrient Requirement for Lactic Acid Fermentation

All lactic acid bacteria require a source of nutrients for metabolism. The fermentative bacteria require carbohydrates, either simple sugar such as glucose and fructose or complex carbohydrates such as starch or cellulose. The energy requirements of lactic acid bacteria are very high. Limiting amount of available substrate can stop their growth. It is necessary to supplement the fermentation media with sufficient nutrients for rapid lactic acid production. If small amounts of other nutrients were supplemented to the process, then the efficiencies of lactic acid fermentation would be improved significantly (Boontawan, 2010).

Collection and Pretreatment of Substrates

The collection and preparation of the substrates are essential to ensure the quality and purity of the raw materials. Orange 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.

Moisture Content

The peels were pre air dried at room temperature and ground into powder. A sample of 5g is accurately weighed into crucible and dried in an air oven at 110ºC for about 3 hours. The sample was then cooled and weighted. The moisture content was calculated according to equation below:

$$\text{Moisture content} = \frac{W1-W2}{W2-W} \times 100$$

Where: w = weight empty dish (g)
w 1 = weight dish and sample before drying (g)
w 2 = weight dish and sample after drying (g)

III. Results

The yield and quality of lactic acid produced using different substrates and production parameters used in 3.7 was analyzed. The data collected from the experiments were used to determine the yield and quality of lactic acid produced from potato, orange and yam peels.

Tables 4.1, 4.2 and 4.3 present the yield and quality of lactic acid produced from different substrates. The table shows the amount of lactic acid produced, the concentration, and the purity of the lactic acid. The substrates were compared based on their yield.

Table 5: Lactic acid from Orange peel powder (OPP)

Mass(g)	Water quantity(ml)	pH	Temp(ºC)	Time(hr)	Yield (%)
20	50	6.0	30	48	33.7
20	50	6.5	35	48	42.5
20	50	7.0	40	48	44.8

From table 5 above, the lactic acid produced from orange peels powder, the best yield occurs at the pH of 7.0 and a temperature of 40ºC

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

Substrates	Substrate conc. (g)	pH	Time (hr)	Temp (ºC)	Best Yield(%)
OPP	20	7.0	48	40	44.8

Several studies have been conducted on lactic acid production from agricultural waste, including orange peels. For example, a study by Hu *et al* (2014) reported a lactic acid yield of 32 g/L. 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	Orange peels
Protein	11.3
Crude fiber	7.3
Moisture	8.6
Ash	2.61
Carbohydrate	42.6

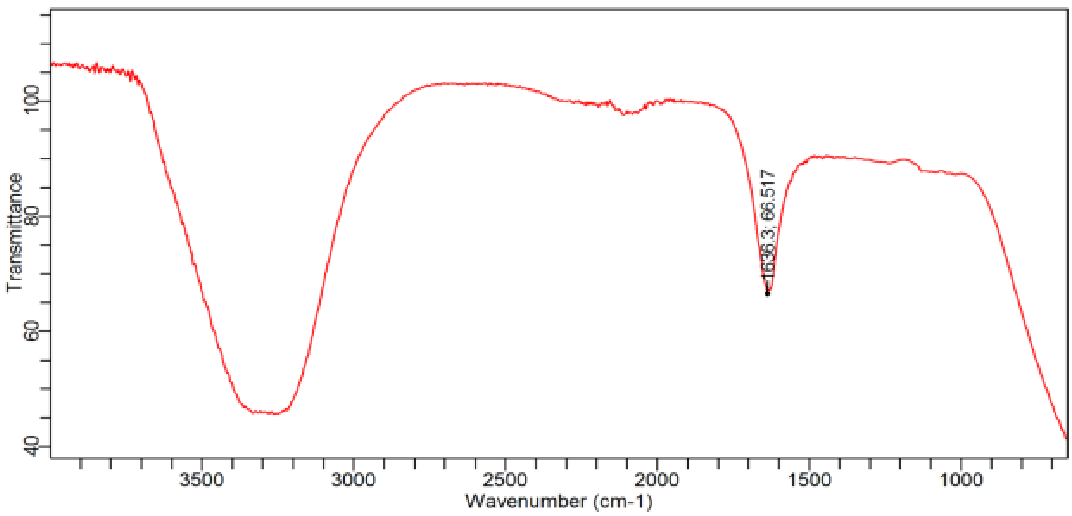


Fig10: OPP at 7.0pH, 30ºC

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.

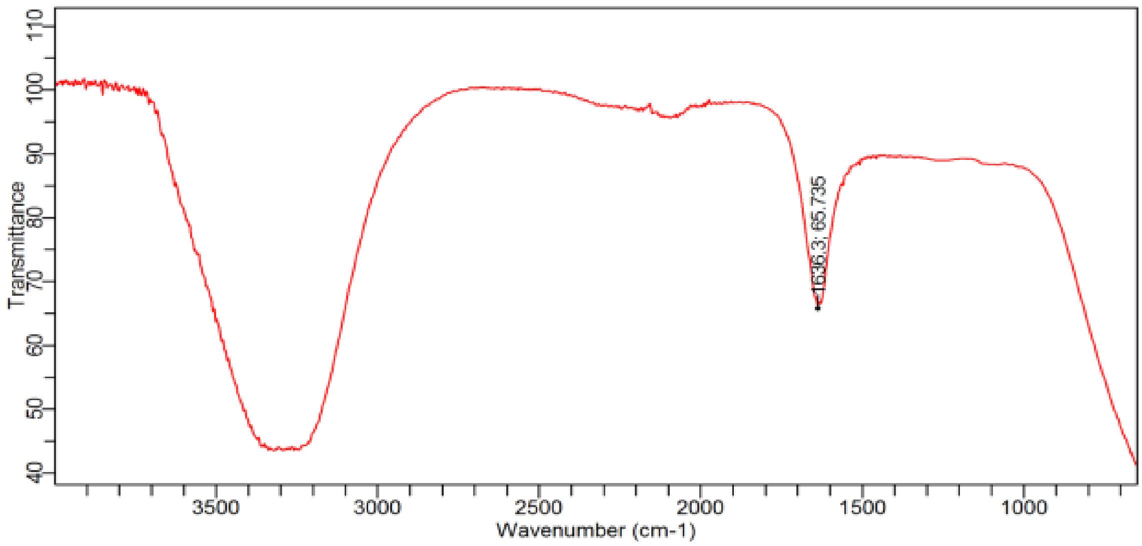


Fig11: OPP at 6.5pH, 35ºC

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.

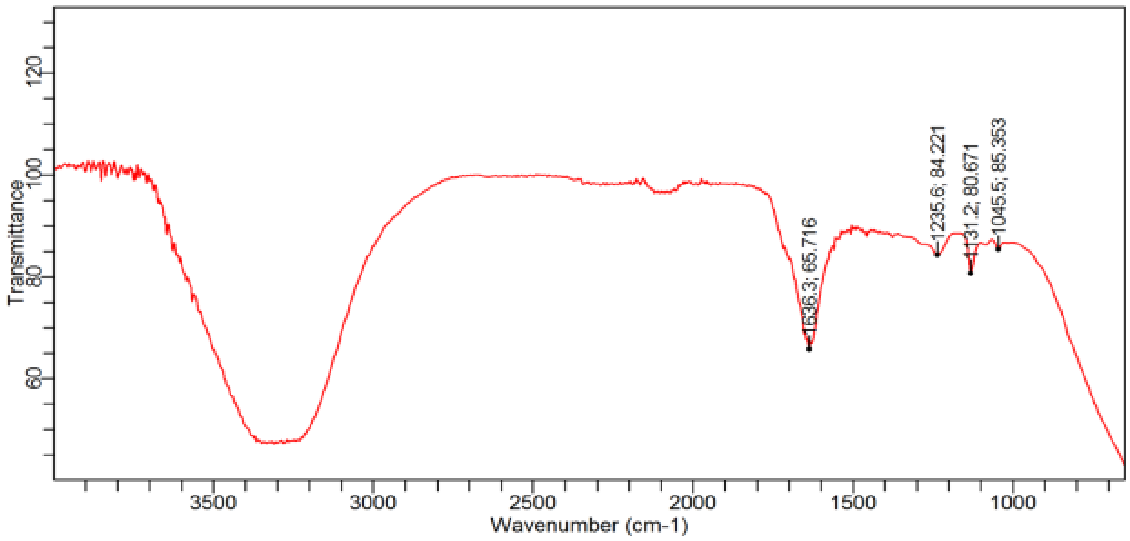


Fig12: OPP at 6.0pH, 40ºC

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 peak on the result.

IV. Conclusion

The pH and temperature conditions of 6.5 and 35 degrees Celsius were identified as optimal for lactic acid production from the selected substrates. These conditions likely provided an environment conducive to the growth and metabolic activity of lactic acid bacteria, leading to higher yields. It is important to note that the specific strains of lactic acid bacteria used in the experiment could also influence the optimal pH and temperature conditions for lactic acid production.

The results of this experiment highlight the potential of utilizing food waste sources, such orange peels for lactic acid production.n particular, demonstrated their potential as a valuable resource for lactic acid production, possibly due to their higher carbohydrate content.

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