Study of lactic acid production from invert sugar with ion exchange membrane electrodialysis

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Abstract.

Lactic acid is an important raw material for biodegradable production. This work was studied to lactic acid production from invert sugar. First step, the invert sugar was reacted with sodium hydroxide by alkaline degradation. Semi-batch reactor was used because it can controlled concentration of raw material and temperature. The yield of lactic acid from semi-batch was higher than batch reactor. It can produce high yield of lactic acid about 60%. Second step, the product from alkaline degradation was used for raw material for electrodialysis. For this experiment, the sodium lactate from alkaline degradation was changed to lactic acid with this technique. The constant voltage was applied at 4, 6 and 8 volts. When cation exchange membrane was used and voltage increased, the recovery of lactic acid decreased. It could recover about 50% lactic acid. Moreover, it can recycled sodium hydroxide for alkaline degradation.

Keywords.-

1. INTRODUCTION

The problem of waste in the world, mostly it due to plastic waste which made from petroleum industry. The campaign, stop the use of plastic, occurred. However, people still need plastic for many applications such as packaging. An attractive material which was alternative and can used to replace plastic called biodegradable plastic. Polylactic acid (PLA) was an interested biodegradable plastic. Polylactic acid was produced from polymerization of lactic acid. Lactic acid (CH3CHOHCOOH) was monomer of polylactic acid. It can produced from renewable resource such as corn, cassava, sugar. It can produce from either fermentation or chemical synthesis. The fermentation can got high yield, more than 90% depend on fermentation process or type of microorganism [1]. However, fermentation is difficult to control microorganism and takes a long time to ferment. Lactic acid from chemical synthesis got lower yield than fermentation. But it is easy and does not take a long time reaction. In the past, alkaline degradation of sugar was studied by many researcher. This process was simple to produced salt of hydroxy acid and the main product was sodium lactate that can changed to lactic acid [2-4].

Many techniques can be used for convert sodium lactate to lactic acid such as adsorption, reactive distillation, and electrodialysis [5-7]. Electrodialysis is the technique which ion-exchange membrane can change from salts to acid under the driving force of electrical potential. The electrodialysis is an interested method because it was friendly environment and it didn’t produce waste. This research study the feasibility of lactic acid production from invert sugar. First, study the alkaline degradation from invert sugar after that convert sodium lactate to lactic acid by using electrodialysis technique with ion exchange membrane.

2. MATERIAL AND METHODS

2.1. Material

Sucrose was purchase in supermarket in Thailand. After that, it was hydrolyzed with sulfuric acid at 65°C for 6 hours to invert sugar. Sodium hydroxide (NaOH) and sulfuric acid were analytical grade.

2.2. Method

2.2.1. Sodium lactate production from alkaline degradation

For semi-batch reactor, invert sugar was periodically added in desired sodium hydroxide solution in in-house double jacketed glass reactor. The temperature of solution in the reactor was controlled by flowing of water from circulating bath at 50°C. Sodium lactate was the main product from alkaline degradation was produced. Sample was analyzed in the percentage of lactic acid yield with High Performance Liquid Chromatograph (HPLC). After that, repeated experiment was study in batch reactor.

2.2.2. Electrodialysis

The single-state in-house electrolytic cell was use for convert sodium lactate to lactic acid. It consisted of power supply, pump and container with cation exchange membrane or anion exchange membrane. The membrane with the effective area of 144 cm2 was set in the middle of cell between catholyte and anolyte. The type of cation and anion exchange membrane was CSO and AMV respectively from AGC Engineering Ltd, Japan. The two electrodes were made of stainless steel.

Sodium lactate which was produced by alkaline degradation was added with CO2 until pH 8-9. After that it was added in anode side and low concentration of sodium hydroxide were added in cathode side for cation exchange membrane. The voltage was supplied and the sample were taken for analysed. The reaction will stopped when pH of anolyte was lower than 2.5.

After that the experiment was set up with anion exchange membrane. The sodium lactate and low concentration of lactic acid were added in catholyte and anolyte, respectively. Repeated the same experiment as before.

2.2.3. Analytical procedure:

The sample of sodium lactate was taken and acidified until pH about 2. After that lactic acid concentration was analysed by HPLC of Thermo Spectra SYSTEM with Platisil 5 µm ODS column using UV-VIS detector at 210 nm. The mobile was 5 mmol sulfuric acid at flowrate 0.8 ml/min. The concentration of sodium hydroxide was analysed with titration with 0.01 M hydrochloric acid.

3. RESULTS AND DISCUSSIONS

3.1. The study of alkaline degradation of sodium lactate

When the invert sugar was added into sodium hydroxide, the salt of hydroxy acid was produced. The main product from this reaction was sodium lactate. The reaction of alkaline degradation was studied in batch and semi-batch reactor at temperature 50°C. The results showed in Table 1.

Table 1 The yield of lactic acid in batch and semi-batch reactor

Experiment	Initial concentration of sodium hydroxide (M)	Time (hr)	Yield of lactic acid (%)
Batch	8.5	2	57.2
		4	57.4
		8	59.5
Semi-batch	3.5	8	48.1
	6.0	8	64.2
	8.5	8	64.5

From the result, it showed that the yield from the semi-batch reaction was higher than batch reactor. In the semi-batch reactor, the invert sugar was slowly added into the sodium hydroxide, in batch reactor the two solutions was mixed immediately. Therefore, the concentration of invert sugar in semi-batch reactor was kept lower than in batch all the time of reaction. On the contrary, the concentration of sodium hydroxide was high in semi-batch reactor. Low concentration of sugar and high concentration of sodium hydroxide will support the lactic acid yield and decrease other products such as acetic acid, formic acid and glycolic acid [8]. Moreover, the temperature in batch reactor will increased rapidly due to exothermic reaction. In this experiment, temperature increased from 50 to 58°C, while semi-batch can controlled temperature and the temperature of solution was not changing 1°C. Batch is not good for large scale, it will produce very high temperature, that it is not safety. Therefore, semi-batch was suitable for this reaction at high both concentration of raw material. The concentration of alkaline effected on the yield of lactic acid [8]. The initial concentration of sodium hydroxide at 3.5, 6 and 8.5 M was studied. When high concentration of sodium hydroxide was use the yield of lactic acid will increased. The yield were 48.1, 64.2 and 64.5% at 3.5, 6.0 and 8.5 M of sodium hydroxide, respectively. High initial concentration of sodium hydroxide improved lactic acid yield. From the result, 6M of sodium hydroxide was suitable for further study.

3.2. The study of electrolysis with cation exchange membrane/ anion exchange membrane

Sodium lactate from invert sugar was prepared. The invert sugar was reacted with 6 M sodium hydroxide at 50°C in semi-batch reactor. After that the solution was added with CO_2 and filter. The filtrate was added in single-stage electrolyzer with cation exchange membrane. Anolyte and catholyte was sodium lactate and sodium hydroxide, respectively. The results with cation exchange membrane were applied. The results were shown in the Figure 1

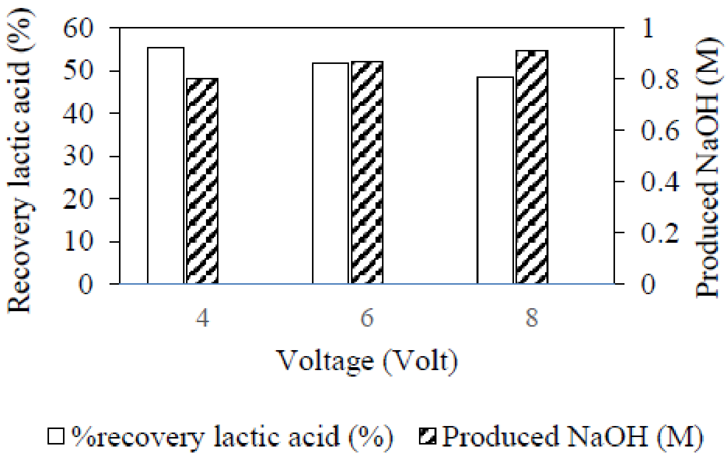

Figure 1 The recovery of lactic acid and produced sodium hydroxide at 4, 6 and 8 volts when using cation exchange membrane

When the voltage was applied, sodium lactate in anode side will dissociate and sodium ion (Na^+) was transferred pass cation exchange membrane to cathode. At cathode side the reduction occurred, H_2O received electron and the hydroxide ion (OH^-) and H_2 (g) was produced. Na^+ will change to sodium hydroxide at cathode side. Therefore the sodium hydroxide will increased as time increased. As voltage increased, sodium hydroxide were produce as 0.80 0.87 and 0.91 M at 4, 6 and 8 volts, respectively. At anode side the oxidation occurred, H_2O was oxidized to hydrogen ion (H^+) and O_2 (g). Lactate ion (La^-) in anode side will form with H^+ to lactic acid, so the lactic acid will increased at this side. The recovery of lactic acid were 55.5 51.7 and 48.6% at 4, 6 and 8 volts, respectively. The recovery of lactic acid at high voltage was lower than at low voltage. At high voltage lactate ion might be oxidized to proton and pyruvate ion, so the lactic acid yield was decreased and the recovery of lactic acid was decreased. After that the anion exchange membrane was used replace to cation exchange membrane. The sodium lactate was added in cathode side and low concentration of lactic acid was added in anode side. After voltage was applied, the yield of lactic acid was decrease with time as shown in Fig.2. It decreased more than 95%. These results showed that the lactic acid wasn't produced with single anion exchange membrane, lactate ion pass through membrane difficultly. While pH of solution at this side slightly increased, it showed that hydroxide ion (OH-) from cathode side may pass through membrane to anode side. Thus only single anion exchange membrane was not suitable for lactic acid production in this condition.

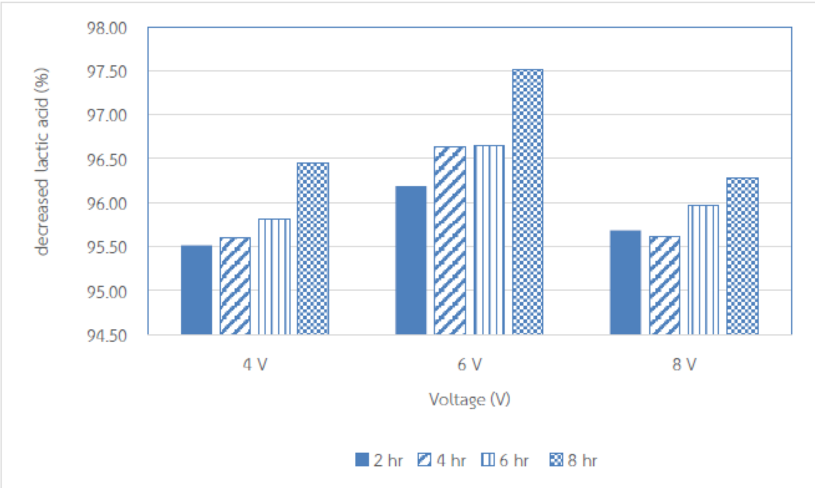

Figure 2 The decreasing lactic acid when using anion exchange membrane at 4, 6 and 8 volts

The lactic acid production from invert sugar with alkaline degradation and electrodialysis is advantage. Sucrose and sodium hydroxide were cheap and easy to found in Thailand. The process is easy and low temperature reaction was used and low energy cost too. Moreover, the yield was quite high.

After that, sodium lactate from alkaline degradation can convert to lactic acid by using electrolysis technique with cation exchange membrane. It can recovery lactic acid more than 50%, and it enable efficiency sodium hydroxide recycling as using raw material for alkaline degradation. This process was shown in Fig.3. This process was good for environment because no waste from this process and didn't used chemical. However, this process used only cation exchange membrane, so it took high energy consumption.

4. CONCLUSIONS

The semi-batch reactor was suitable for lactic acid production with alkaline degradation. When high concentration of sodium hydroxide was used, the lactic acid yield was high. For cation exchange membrane electrolysis, the voltage has effected on the recovery lactic acid and this process can got sodium hydroxide which can recycle for alkaline degradation. The recovery of lactic acid was about 50-55% and could produce 0.8-0.9 M sodium hydroxide at this conditions.

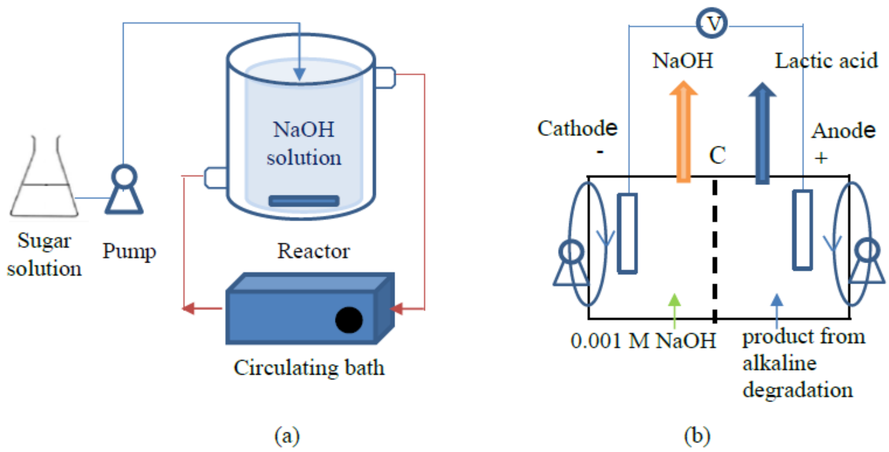

Figure 3 The process of lactic acid production from invert sugar with cation exchange membrane electrolysis (a) alkaline degradation (b) Electrodialysis with cation exchange membrane; C: cation exchange membrane

5. REFERENCES

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