Executive Summary

Production of medium-chain carboxylic acids (MCCAs) from acid whey under different conditions.

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Renewable energy has attracted widespread attention worldwide because of its green, low-carbon, environmental protection, and other benefits (Wang et al., 2019). Biomass energy, wind energy, solar energy, and other new energy sources are considered reliable alternative energy sources. On the other hand, agriculture generates significant waste every year. These agricultural and food industry wastes cause serious disposal problems. In the agricultural product processing industry, the production of dairy products generates wastewaters with whey as the main polluting by-product of milk processing.

Recently, among the products of anaerobic fermentation of biological wastewater, another more valuable product, the medium-chain carboxylic acids (MCCAs) were generated by a bio-refinery technology called chain elongation. MCCAs refer to linear monocarboxylates with 6-12 carbon atoms, including caproate, heptanoate, and so on (Wu et al., 2019). Caproate was mainly studied in this internship. MCCAs have more advantages such as wider application and higher market value than methane and can be widely applied in agriculture and industry (De Groof et al., 2019). MCCAs can replace many fossil fuel-based commodities to help alleviate the chemical industry's dependence on fossil fuels (Wu et al., 2020).

For this internship, we used four strategies including feedstock selection, methanogenesis inhibition, pH control, and addition of ZVI (zero-valent iron) to evaluate the production of

MCCA. The sludge used in this research was obtained from an anaerobic digester of a municipal wastewater treatment plant. Figure 1 shows the process of filtering sludge. Acid whey was used as a substrate and was provided by "OSU Beaver Classic™ Cheese" (Corvallis, Oregon, USA). Figure 2 shows the collected acid whey. 35 ml of the filtered sludge and 70 ml of diluted acid whey (5 times dilution of acid whey) were added to these batch reactors. Figure 3 shows the batch reactors.

Figure 1. The process of filtering sludge.

Figure 2. The Collected acid whey

Figure 3. The batch reactor.

In this internship, I used the anaerobic fermentation approach to the acid whey, which will help manage the wastewater (acid whey) generated during the cheese production process.

Rather than dumping directly in the drain in the past, we can collect this whey and use it to produce MCCA. From the experimental results, we know that acid whey has a high potential in the production of MCCA. Maintaining a buffered pH can also contribute to the fermentation process, so we need to add a buffer to help stabilize the pH and establish a steady state.

Furthermore, the appropriate concentration of ZVI can help increase the production of MCCA. The experimental results suggested that 0.41 g/L MCCA was produced under the 0.1mol/L buffer. With the addition of zero-valent iron (15g/L), this study obtained currently highest MCCA production (0.65 g/L), while the high the concentration of ZVI (30g/L) has the potential to inhibit the MCCA production (0.36 g/L) (Figure 4).

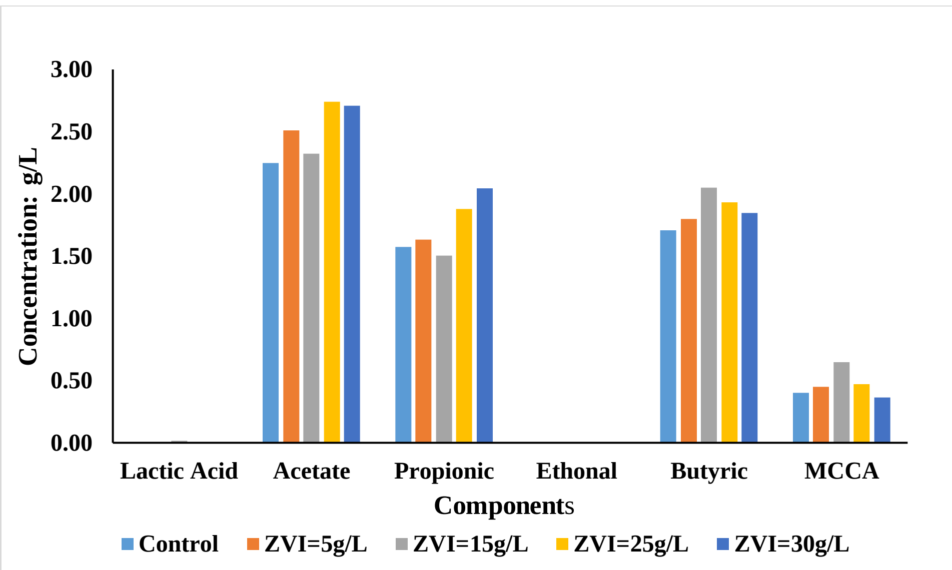

Figure 4. The final concentration of medium chain carboxylate compounds after adding ZVI addition on day 12.

In this internship, chloroform did not play a very good role in promoting MCCA production. When the chloroform concentration was 0.2%, the MCCA concentration was 0.22g/L lower than the control group, and when the chloroform concentration was higher, no MCCA was produced in the reactor (Figure 5). This shows that chloroform has an inhibitory effect on the production of MCCA. However, because when the concentration of chloroform is too high, it may not be dissolved at room temperature, which means that a part of the high concentration of chloroform may not be dissolved in the solution. Therefore, in future research, the effect of chloroform on MCCA can be further studied by increasing the solubility of chloroform in the reactor.

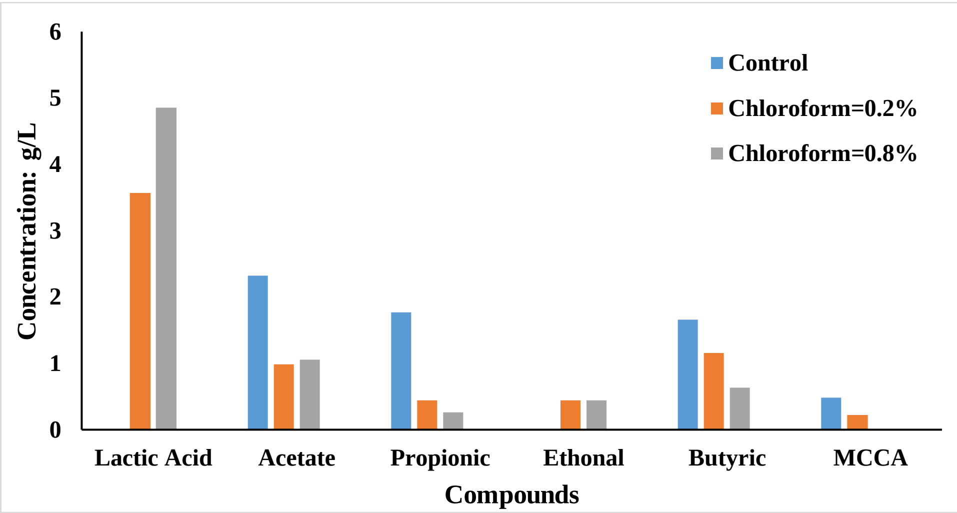

Figure 5. The final concentration of medium chain carboxylate compounds after adding chloroform on day 12.

At present, the MCCA production is in the experimental stage, and more research is still needed to improve the efficiency of yield and make the production process more profitable (De Groof et al., 2019). The development of MCCA's production scale from laboratory to commercial production and industrial level still needs to overcome many challenges and carry out more research. The main steps can be divided into the following aspects (Wu et al., 2020).

(1) It is necessary to explore a large number of available and reasonably priced waste biomass resources as feedstock. A comprehensive evaluation of the MCCA production performance and the total utilization cost of each potential raw material is required.

(2) A complete collection and storage network needs to be established to meet high demand. This process requires the government to implement some policies to sort, collect, store, and transport usable waste biomass.

(3) Technical improvements are needed to maintain excellent MCCA production performance. It is necessary to focus on the formation of a high-efficiency microbiome and maintaining the functional flexibility of them, which will help increase the yield and purity of MCCA.

(4) Research on the system for timely extraction of MCCA should be carried out. For the large-scale production of MCCA, the product extraction system is also very important.

On the other hand, considering the integration of acid whey fermentation in a biorefinery is also very promising. Biorefinery is a new concept in recent years, which refers to the sustainable processing of biomass into a series of saleable products and energy. The biorefinery focuses on using biomass to replace the original fossil energy as feedstock and produce chemicals through different conversion technologies. The biological waste such as acid whey mentioned in this internship can be used as a renewable biomass feedstock to replace fossil energy. In this way, the waste stream can be utilized to maximize the use of waste resources, thereby promoting a circular economy.

This internship made me realize that another way to deal with water quality is to focus on the reuse of these wastes. In the past, my study of wastewater treatment mainly focused on removing harmful pollutants and high organic loads in wastewater. However, we can now reuse the wastewater with a high organic load before it is discharged. In this way, not only the discharge of waste can be reduced, but also the recovery and recycling of waste can be carried out to generate new energy, so as to continue sustainable development. During the period of experimental work, I conducted multiple experiments, collected a large amount of data, and summarized the findings, which provided a more theoretical basis and data support for the production of MCCA using acid whey as a substrate. In addition, this internship and degree study also deepened my understanding of scientific research. In the future, I will continue to do research related to water quality and continue to contribute to environmental protection.

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