Cell Free Synthesis of Lactic Acid

An Analysis on the Sustainability Marketing and Policies of Plastic Companies

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Chemical Engineering

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Fall 2023

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction:

Plastic is one of the biggest contributors to waste in the world. About 275 million pounds of plastic waste is produced every year (Ritchie & Roser, 2018). This waste populates the ecosystem, creating environmental hazards for both humans and wildlife. Organisms can get trapped in the plastic or ingest it, resulting in a higher mortality rate (Welden, 2020). It also does not naturally degrade. As a result, the negative effects of plastic waste continually affect the environment. Plastics can be broken down into microplastics. These microplastics are difficult to remove and can accumulate rapidly. Microplastics may also poison the organisms who accidentally consume it, causing them to have detrimental health effects (Okafor, 2023). Overall, the amount of plastic waste continues to grow every year and has long lasting negative effects on the environment.

A common solution to plastic pollution is to utilize a more sustainable alternative in bioplastics. One type of bioplastics that has been used is polylactic acid, or PLA. PLA can be used in the same applications as plastic, is able to be broken down naturally by algae or bacteria, and is made from biologically based ingredients such as corn (Ranakoti et al., 2022). The main ingredient of PLA is lactic acid. Lactic acid is commonly produced through fermentation of food waste (Kwan et al., 2018). This makes it more sustainable, as it reuses discarded biological material and does not require fossil fuels. However, because fermentation uses cells, an extensive purification process is needed to fully separate the lactic acid from the organic matter (Ojo & de Smidt, 2023). Using this process takes more resources and energy than producing plastics made from fossil fuels, which reduces the overall sustainability and profitability. The goal of my technical project is to reduce this cost by utilizing a cell-free reactor and a cheaper purification process to produce lactic acid.

Another solution to plastic pollution is to reduce the waste of plastic companies. Companies that produce and use plastic are one of the biggest contributors to the growing plastic waste problem. In fact, 20 companies are responsible for more than half of the world's throwaway plastics (Meredith, 2021). To combat this pollution, these companies have adopted sustainability policies and have used it in their marketing. The goal of my STS project is to analyze how plastic companies use sustainability in their marketing and policies to promote their brand.

Technical Project:

Many industries are dependent on large quantities of biocommodities to continuously run their biochemical processes. Biocommodities, the cheap raw materials essential for almost every chemical and biochemical process, are inexpensive compared to high-value products. The cost is heavily reliant on the feedstock cost which accounts for 30%-70% of production expenses (Zhang, 2010). One of the most versatile biocommodities in the current market is lactic acid which has applications in the pharmaceutical, cosmetic, food and beverage, and biodegradable plastics industries ("Lactic Acid Market", 2022). All of these industries are vital to standard products in American life. This already sophisticated market is expected to grow at a rapid rate. Lactic acid production was a $3.46 billion industry last year and is projected to double by 2031 ("Lactic Acid Market", 2022). In order to be competitive in this market, a new well-designed process with cheaper production costs must be used.

One of the cutting edge methods to cheaply produce biocommodities is cell free fermentation. In 2010, cell-free synthetic (enzymatic) pathway biotransformations (SyPaB) were shown to increase product yield, improve process flexibility, and hasten reaction rate which will decrease the time required to produce commodities like lactic acid (Zhang, 2010). These enzymes are also recyclable (Wee & Ryu, 2009) without the downside of cell glucose consumption. Results from anaerobic cell catalysis experimentation find that 10% of the feedstock is lost from the feed stream (Zhang, 2010) with more unconverted feedstock being consumed in recycle streams. By removing cell consumption of feedstock in both the initial and recycled streams, the cost is decreased as the efficiency increases making cell free catalysis a viable alternative to cell fermentation. Cell free biotransformation along SyPaB also decreases the amount of waste products because other enzymes within the cell can be removed before reactions are performed if enzyme selection is effectively performed (Zhang, 2010).

Process:

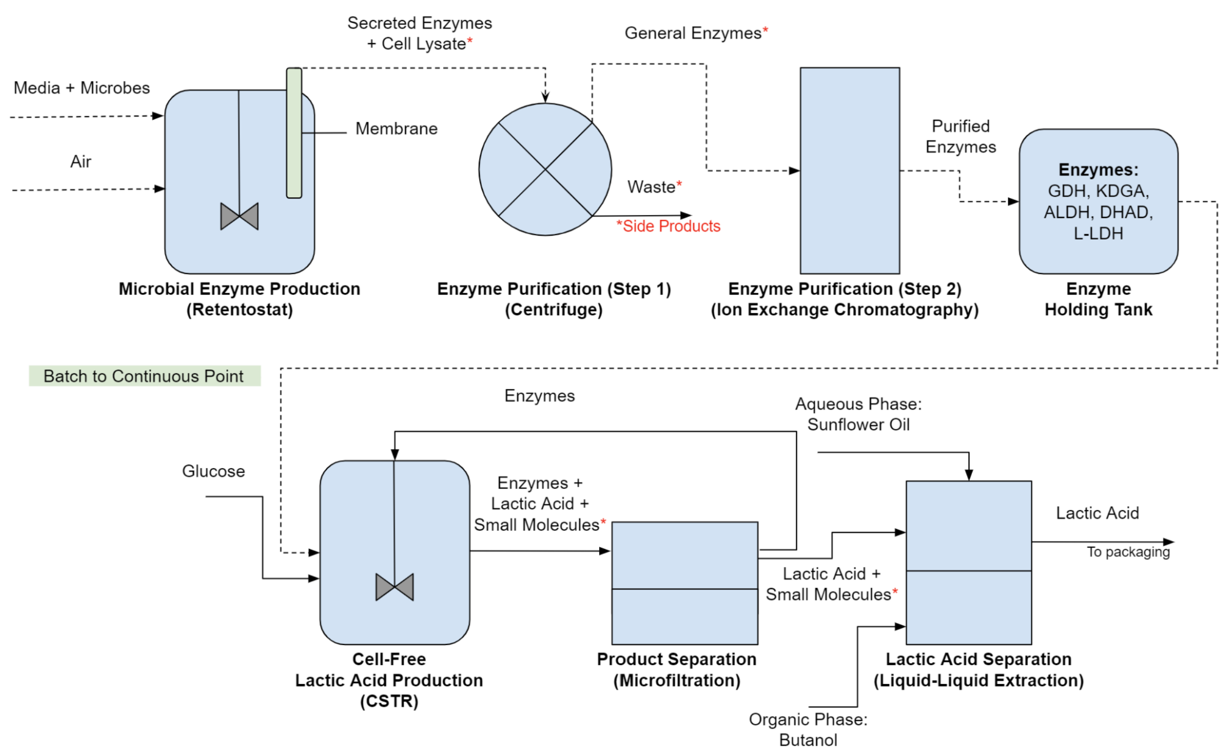

Fig. 1. Process Flow Diagram of Cell Free Synthesis of Lactic Acid

Various unit operations will be employed to create lactic acid from a cell-free reactor and the process is outlined in Figure 1. First, we will ferment *bacillus subtilis* in a retentostat using

LB broth as a growth media (Cruz Ramos et al., 2000). This microbe is capable of secreting enzymes which will help increase the purity of the system from the beginning (Abedi & Hashemi, 2020). However, the specifics of the genetic engineering required to produce such a cell line are out of the scope of this project. Next, a disk stack centrifuge will be used to remove any cellular debris and to separate the cells from the secreted enzymes (Phanthumchinda et al., 2018). The supernatant containing our target enzymes and other small secreted molecules will then undergo ion exchange chromatography to isolate our target enzymes based on engineered peptide tags that will be selected in the column (Sullivan et al., 2016). The enzymes of interest are GDH, KDGA, ALDH, DHAD, and L-LDH. The purified target proteins will be transferred to a holding tank until they are needed for the reactor, concluding the batch portion of the process. Enzymes and glucose from food waste will be fed into a continuous stirred tank reactor (CSTR) where the cell-free synthesis of lactic acid will occur (Hodgman & Jewett, 2012). The output will be various small molecule intermediates mixed in with the lactic acid product which will then be purified via microfiltration, with enzymes being recycled back into the reactor (Phanthumchinda et al., 2018). The small molecules and lactic acid remaining will undergo liquid-liquid extraction with butanol and sunflower oil as solvents (Kumar & Thakur, 2019). The remaining output stream will be purified lactic acid which will then be packaged and sold in a liquid solution.

Logistics:

This project will be done by a group of four people (Gavin Estrella, Clare Cocker, Collin Marino, and Ethan Coleman). The initial design will be created in the Fall semester for CHE 4474 and the project will be finished in the Spring semester for CHE 4476. The work will be split amongst the group as follows: Estrella and Cocker will be designing the lactic acid reactor and downstream processes needed to purify the lactic acid, Marino will be designing the bioreactor used to produce the necessary enzymes and purification of the enzyme product stream, and Coleman will be researching and analyzing the economics behind the entire process. Every week, the team will meet up to discuss findings and report progress. All of the data needed for the material balances, operating conditions, and economic costs will be obtained from literature review. Aspen Plus V14 will be used to model the process and simulate its conditions. Matlab will be used to calculate individual material balance equations on each reactor.

STS Project:

Plastic companies make many valuable commodities that consumers use daily. In 2015, over 322 million tons of plastic was produced to create these products (Beckman, 2022). After being used, these items are thrown away in landfills. This results in much of the pollution that can be seen today. Plastic also requires a lot of energy and resources to produce, which makes the product even more unsustainable. Because they make and sell these products, plastic companies are responsible for much of the world's waste.

In order to curb this problem, plastic companies have been adopting sustainability policies. These include using more sustainable ingredients, reusing and recycling plastic, and developing more optimized processes to lower energy consumption (Bocken et al., 2014). By using these policies, companies aim to reduce their waste and make their process more environmentally friendly. These companies also incorporate sustainability into their marketing. They tout their products as the “green” alternative and invest in environmentally friendly initiatives. One example of a company doing this is Lego. They have utilized recycled plastic to create their headquarters in Denmark (Hobson, 2022). This has helped promote their idea of sustainability and show that it is possible to reduce plastic consumption. By using both sustainability policies and marketing, plastic companies aim to solve the issue of plastic pollution.

The main reason I am examining plastic companies' marketing and policies is because the companies can influence the public’s ideals. Companies promote their own idea of society and sell this idea to the public so that they buy the companies’ products (Sadowski & Bendor, 2018). In the case of plastic companies, they are able to market their plan of making the world more sustainable through their product. This causes the public to support the goal of reducing their own plastic waste and investing in sustainable projects. By analyzing how companies advertise their sustainability, I will be able to determine their priorities and figure out what makes these companies adopt environmentally friendly solutions.

Research Question and Methods:

The research question my thesis will aim to address is as follows: How have companies that produce or use plastic in their products changed their policies and marketing to promote their idea of sustainability?

Two methods will be used to answer the research question: discourse analysis and literature review. For discourse analysis, I will be looking at three significant plastic companies: Lego, Dow, and ExxonMobil. These companies were chosen because they have been around for decades and are some of the biggest plastic companies in the world. For each of these companies, their sustainability reports will be compiled and analyzed to determine their major policies. Their advertising will also be examined to find out how they promote their products. This will allow me to determine how the companies with the most influence use their presence to promote their vision of a sustainable future. For literature review, I will be compiling the findings of papers that have investigated the sustainability policies and marketing of these companies. I will then analyze the compiled data to determine the most common trends. This will show what the industry standard is when it comes to approaching the idea of sustainability.

Conclusion:

Plastic waste will continue to be an environmental problem until solutions are enforced to reduce it. My technical project will utilize the cell free synthesis of lactic acid to cut down on production costs and make the process more sustainable. This will help promote the use of PLA as a viable alternative to plastic. My STS project will utilize discourse analysis and literature to determine how plastic companies use sustainability in their policies and marketing. This will show what these companies value and give us an understanding of how they approach sustainability solutions.

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