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Production of Bioethanol from Brown Algae

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Mini Review

Aspen Plus software was used to model steady state ethanol generation from brown algae Saccharina japonica based on dry feed. On the basis of experimental works found in the literature, models of various process units, such as saccharification, fermentation, and purification, were developed [1]. In this simulation, acid thermal hydrolysis, concurrent saccharification, and fermentation were used and modelled. To create ethanol, ethanol was recovered from the raw fermentation broth using distillation columns and molecular sieves. This simulation enables economic analysis of the first large-scale ethanol generation from macroalgae in the literature. Because of things like rising oil prices, the need for greater energy security, and worry about greenhouse gas emissions from fossil fuels, biofuels are receiving more public and scientific attention. It can be acquired from sources that are renewable and contain starch, sugar, or cellulose, such as grains, potatoes, maize, corn cobs, and stalks. Using crops or wood as feedstock has the major drawback of directly affecting agriculture prices and causing forest damage [2]. Seaweed or macroalgae have so recently been proposed as a remedy for this issue. Utilizing seaweed as feedstock has some benefits, such as easy cultivation and potential productivity. Additionally, it has a better capacity to fixate CO2 and a simpler production procedure [3]. These benefits encouraged academics to publish a significant amount of experimental work demonstrating the feasibility of producing ethanol from seaweed. However, no comprehensive simulations have been created to date to look at the possibilities of industrialising the procedure [4]. On the other hand, purely experimental researches are unable to fully investigate all the significant characteristics and variables of such a process.

For the study, design, and economic assessment of the individual process units as well as for contrasting and optimising various process alternatives, computer simulation is a priceless instrument. Computer simulations are a technique used in the planning and evaluation of investigations; they cannot, of course, completely replace experimental studies. In the oceans and coastal waterways of the world, brown algae, a type of seaweed, are abundant and diverse in evolutionary terms. Tons of naturally occurring and produced seaweed are expected to be harvested annually by the seaweed business globally. Seaweed is mostly utilised in human dietary products. Due to its high concentration of quickly biodegradable carbohydrates, brown seaweed holds potential as a raw material for the manufacture of liquid fuels. Brown seaweed's primary sources of carbohydrates include alginate, laminaran, mannitol, fucoidan, and cellulose, which are also present in trace levels [5].

Alginate, which makes up the majority of the brown algal cell wall's structural elements, mostly comprises of D-mannuronic acid and L-guluronic acid units [6]. Alginates are crucial substances used as thickening, gelling, or stabilising agents in a variety of industrial applications (McHughA) linear glucose polysaccharide called laminaran has little branching at the glycosidic bonds and ends with D-mannitol [7]. One of the primary sugar components of brown seaweed is mannitol, a sugar alcohol generated from mannose. Mannitol. Numerous cosmetic and pharmaceutical products contain mannitol because of its moisturising and anti-oxidant qualities. It takes some time to ferment mannitol. Mannitol dehydrogenase converts it to fructose by an oxidation process that releases NADH. Oxygen (active electron transport chain) or transhydrogenase, which changes NADH into NADPH, are needed for NAD+ regeneration. As a result, many microbes cannot completely ferment mannitol in anaerobic conditions [8]. Brown algae contain the sulphated polysaccharide known as fucoidan, which contains significant amounts of l-fucose and sulphate ester groups. Despite numerous investigations looking into the fine structure of the fucoidan, very few instances of regularity were discovered. Because of the strong differences in monosaccharaides' linkages, branching, sulphate locations, and composition, there is no clear correlation between their structure and biological activity. Aspen Plus software was used in this experiment for simulation. Determining chemical components, establishing a thermodynamic model, selecting appropriate operational units, and setting up input conditions are the primary steps in the process simulation process. The three main components of the ethanol production process that we simulated: pretreatment of the feed, simultaneous saccharification and fermentation, and purification. The method for calculating the properties of the non-random two-liquid model was chosen. Feed composition, anticipated conversions for this simulation, and the three simulation units will all be detailed in the following sections. It is crucial to highlight that algae biofuel technology is still being developed at the lab size or at the very early pilot stage. This study makes an effort to model a brown algae-based ethanol manufacturing facility. Since the precise structure of fucoidan was unknown, we chose to divide its components equally among ash and laminarin since the sugars galactose and fucose, which are constituents of fucoidan, create the same amount of ethanol as glucose. Additionally, only half of the fucoidan will react, leaving a solid that we classified as ash. This is a sound supposition for this scenario. The chemical makeup of brown algae typically varies greatly between species, over the course of the year, and different habitats. When exposed to seasonal fluctuations, brown algae typically store mannitol and laminaran during the light season and eat them during the dark season. The characteristics and close examination of various seaweed the makeup envisioned for this simulation. Additionally, various algae can have distinct structures for fucoidan. According to Zhang et al., Laminaria japonica has total sugar content, fucose content, and sulphate content, which are the chemical components of fucoidan. Fucose and galactose were discovered through gas-liquid chromatography investigation of neutral monosaccharides. In the area of saccharification and fermentation of brown algae, there are various studies and experimental works as well

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as issues to utilise them as a guide for modelling. Each study employs a distinct species of brown algae from a different region. As a result, it is not always possible to generalise conversion rates recorded for one kind of algae to others. For instance, polyphenols and divalent metal ions present in the tissue during anaerobic conditions may have a significant impact on alginate degradation. Additionally, employing other bacteria, microbes, or enzymes can make the issue more complex. Finding the conversion rates for each ingredient into the process is a different issue. Unless one single component is employed for the experiment, no experimental work has reported the conversion rate of each component in the mixture. For instance, tests on the conversion of mannitol to ethanol were conducted by Horn et al. They demonstrated that the bacteria could grow and create ethanol in a synthetic mannitol medium under oxygen-limited circumstances, with a yield that gives an overview of the conversion rates for saccharification and fermentation of brown algae. In this investigation, back calculations were made utilising literature data to determine conversion rates for each individual component. The majority of the feedstock's carbohydrates are hydrolyzed by the pretreatment process into soluble sugars. Provides a flowchart of this section's process. There are two steps to pretreatment. In the first step, the feed stream is heated by the addition of steam and ingredients for thermal acid hydrolysis. Using enzymes for saccharification in the second stage is followed by SSF. Seaweed slurry and enzymatic SSF have been identified as the optimal conditions for acid hydrolysis. 75% of the total carbs are saccharified under these circumstances. For the preheater and reactor to reach temperature, two steam flow rate adjusters were utilised. To keep a solid ratio at the pretreatment reactor entrance stream, a water adjuster was used. Sulfuric acid that has been dilute is used to catalyse hydrolysis reactions. Despite being significantly more expensive than lime, ammonia is more cost-effective than lime due to reduced sugar loss and lower capital costs. Because of ammonia's great miscibility, the entire hydrolysate slurry can be handled without undergoing the solid-liquid separation processes. A heat exchanger is used to get the slurry from the pretreatment stage up to the required temperature for fermentation and saccharification, which is 30°C. Slurry is sent to saccharification reactors for additional saccharification before being sent to SSF reactors. Unsaccharified carbs in slurry were given conversion rates from the second column of table 4. Products from these reactors are sent to an SSF reactor for simultaneous fermentation and saccharification, where sugars are converted to ethanol at rates listed in table 4. The fermentation broth is divided into solids, anhydrous ethanol, and water in the purification phase. To extract ethanol from the initial fermentation liquid and create ethanol, two processes are used: distillation and molecular sieve adsorption. Two columns are used for distillation. The dissolved CO_2 and the majority of the water are removed by the first column, referred to as the Water remover column. The ethanol from the first column is concentrated into a nearly azeotropic composition in the second column, which is known as the Azeotropic column. An overview of the process in this region is shown. The ethanol product exits the azeotropic column and undergoes vapour-phase molecular sieve adsorption for further hydration. A stream of low-purity ethanol is produced during regeneration of the molecular sieve adsorption and is recycled back to the Azeotropic column for recovery column. Based on literature data and design goals, aspen plus was used to simulate the production of ethanol from brown algae on a dry feed basis for 100,000 tonnes per year in this study. This simulation represents many stages of the process, such as pre-treatment, SSF, and recovery. The ethanol production produced a weight-per-weight and ton/year of ethanol that is comparable to a benchmark ethanol titter that was recently reported and was derived from the fermentation of lignocellulose biomass using S. cerevisiae simulation. This allowed for the examination of feed composition sensitivity analysis. The impact of composition change on yearly ethanol output was investigated. This research makes it possible to create techno-economic models, which can then be used to examine and improve the economics of a seaweed-based ethanol manufacturing facility. The Ministry for Food, Agriculture, Forestry, and Fisheries provided funding for this project.

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