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Process and technoeconomic analysis of bioethanol production from residual biomass of marine macroalgae *Ulva lactuca*

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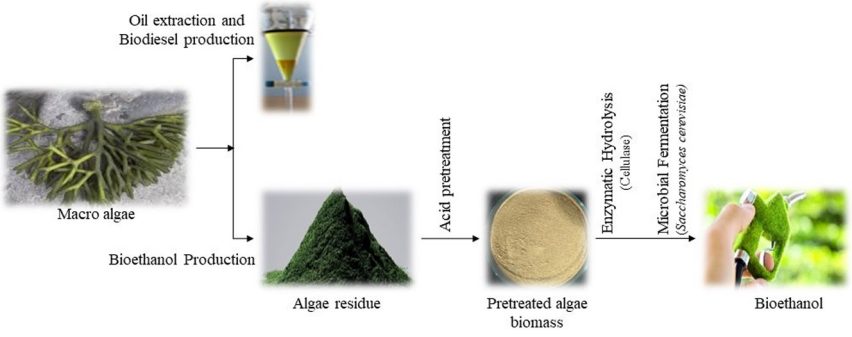
HIGHLIGHTS

- Pretreatment of algal residue was optimized to improve the availability of carbohydrates.
- Enzymatic hydrolysis and fermentation of algal biomass were optimized.
- Bioethanol produced under optimized conditions was characterized using GC–MS
- Techno-economic analysis of bioethanol production was studied.
- The minimum selling price of bioethanol was 0.47 $/kg.

GRAPHICAL ABSTRACT



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ABSTRACT

In the present work, the residual biomass of the green seaweed *Ulva lactuca* was chosen as feedstock to undergo separate hydrolysis and fermentation process to produce bioethanol. The hydrolysis process was optimized for cellulase, biomass, temperature, and time conditions. The maximum yield of fermentable sugars was 13.48 mg/mL. The recovered hydrolysate was subjected to fermentation using *Saccharomyces cerevisiae*. The bioethanol produced was subjected to gas chromatography coupled mass spectrometry analysis to determine the presence of ethanol. The technical performance and economic feasibility of the bioethanol production from *U. lactuca* were evaluated using the lab-scale data obtained for optimized conditions. The plant capacity was 10 MT/day of bioethanol production. The plant's capital investment and annual operating cost were 3.18 M$ and 0.86 M$ respectively. The total annual revenue of the plant was 1.41 M$. The minimum selling price of bioethanol was 0.47 $/kg. The ROI, payback period, IRR and NPV of the plant were 16.99 %, 5.89 years, 11.57 % and 291,000 $ respectively. The utilization of residual biomass for biofuels helps to develop an economic and environmentally sustainable plant.

1. Introduction

The economic development of many countries depends on fossil fuels consumption in transportation sector, industrial industries, and many other uses. In addition to the limited availability of resources, these fuels

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threaten the environment by emitting harmful greenhouse gases. Fossil fuel accounts for 75 % of global greenhouse gas emissions (Osman et al., 2022). The replacement of fossil fuels with renewable energy helps in carbon neutralization (Chen et al., 2022). Therefore, several countries have focused on bio-based fuels to protect the environment and resolve its related issues to have a safe and healthy environment. In global renewable energy, 70 % is produced from biomass feedstock and waste (Liu et al., 2022). Many pieces of research have been carried out earlier, but the current world has focused its search on sustainable resources which should not compete with the feed for livestock and minimum or no usage of arable land (Banerjee, 2022).

Algal-based fuel is one of the alternatives and found to be advantageous over the earlier generation fuels, both microalgae and macroalgae are used for producing fuel such as biodiesel, bioethanol, and biogases. Marine algae can be found in freshwater, brackish water, seawater, and some soil sediments near ponds and rivers. Freshwater is mostly beneficial and used for its growth and to fight nutrient levels of the microalgae. Algae can be characterized under various conditions such as membrane structures, and pigment colors without a uniform taxonomical classification (Foo et al., 2022). Macroalgae as an alternate fuel feedstock is a promising future that attracts most researchers and the public. Algae feedstocks are rich in 3 major components proteins, carbohydrates, and natural oil/ lipids. The post-oil extraction of the algal biomass can be used as animal feed or other valuable by-products.

In bioethanol production, feedstock selection is an important factor in developing a sustainable and economically feasible process (Chong et al., 2020). The feedstock cost is a major position of the operating cost (Nazemi et al., 2021). Low-cost bioethanol production is critical for commercialization and market stability. The integrated process and production of multiple products from a single source help to reduce the minimum selling price (MSP) of the products (Naveenkumar and Baskar, 2021). In the present study, the oil-extracted residual biomass of *Ulva lactuca* was used as a source for bioethanol production. The extracted oil is used for biodiesel production (Kalavathy and Baskar, 2019).

A complete survey on the bioethanol production from macroalgae reveals that not just the type of macroalgae depends on them but also the careful selection of steps in the bioethanol production process (Gengiah et al., 2020). The cellulolytic enzymes that are currently available for hydrolysis are mostly suitable for starch-based biomass and lignocellulosic not for macroalgae. Algae have complex carbohydrate structures. Also, the key factor for limiting bioethanol yield during the fermentation process is the lack of appropriate fermenting microorganisms (Ahmed et al., 2021).

Technoeconomic analysis (TEA) helps to find the economic sustainability of the process and find the MSP of the products, which helps to find the critical factors and develop a cost-effective process. In TEA, the capital investment, operating cost, profitability factors, and minimum selling price of the products are investigated. Chong et al. (2020) produced bioethanol from macroalgae cellulosic waste and the MSP of bioethanol was 0.54 $/kg, and the payback period was 8 years with an internal rate of returns of 23.17 % (Chong et al., 2020). The waste feedstock helps to reduce the overall operating cost and MSP of the product (Rajendran and Han, 2022).

Novelty of the present research work is to find the critical factors in the production of bioethanol from residual algal biomass and economic feasibility analysis. The present study helps to find the optimum process parameters to improve the bioethanol yield and find the economic barriers and critical factors in the process. The present study investigates a biorefinery approach including pretreatment, enzymatic hydrolysis, and fermentation of the oil-extracted biomass (residual biomass) of the macroalgae *Ulva lactuca* was used to optimize the bioethanol yield, and its technoeconomic feasibility was assessed with Superpro software.

2. Materials and methods

2.1. Biomass

The *Ulva lactuca* samples were purchased from the R.K. Algae project centre, Mandapam, Ramanathapuram District, Tamil Nadu, India. The project centre collected the samples in May 2018 at the location Mandapam (9°16′09.3"N 79°07′09.4"E), Tamil Nadu, India. The macroalgal biomass was subjected to oil extraction and the residual biomass was used in the present work to produce bioethanol using separate hydrolysis and fermentation process (Kalavathy and Baskar, 2019). The solvent used for oil extraction from macroalgal biomass was n-hexane at the ratio of 6:1 (solvent: biomass) with 99 % purity which was purchased from SRL Pvt. Ltd., Mumbai, India.

2.2. Pretreatment of macroalgae

1 g of the algal biomass residue of *U. lactuca* after algal oil extraction was taken and acid was added, and the mixture was kept in a water bath. The acid was added to disrupt the structure of cellulosic biomass and to make cellulose more accessible to the enzymes. The mixture was centrifuged (Model R-8C, Remi Sales and Engineering Ltd., Mumbai, India) at 5000 rpm for 20 min (Helwani et al., 2009). After pretreatment, the residual biomass was washed with distilled water. The pretreatment process of residual biomass was subjected to the optimization of various parameters. Residual biomass was first optimized for acids used for pretreatment using nitric acid, diluted sulfuric acid, and hydrochloric acid. The effective acid was identified and its concentrations were optimized (1 to 5 %). Along with these, other parameters such as temperature (80 to 120 °C) and reaction time (5 to 60 min) with intervals of 5 min were optimized and the reducing sugar concentration was determined. The total carbohydrate in the sample was analyzed using the Anthrone method (Plummer, 1990). All the experiments are conducted triplicate and the mean values are reported in the results.

2.3. Enzymatic hydrolysis

The 1 g of the pretreated residual biomass was mixed with 20 mL of sodium acetate buffer of pH 4.8, and then cellulase enzyme (4 FPU/mL) was mixed and maintained at 50 °C and 150 rpm for 48 h. After that the mixture was centrifuged at 5000 rpm for 15 min, the supernatant was separated, and the reducing sugar was estimated. The supernatant was collected for the fermentation process to convert into bioethanol. The enzymatic hydrolysis of pretreated residual biomass was optimized for the following conditions biomass concentration (1–5 %). Cellulase enzyme (1–5 %) loading: 4 FPU/mL dry substrate, incubation temperature (20, 30, 40, 50, 60 °C) and incubation period (24, 48, 72, 96, 120 h). The presence of reducing sugar was estimated using 3,5 dinitrosalicylic acid (DNSA) method by taking 1 mL of sample and to which 3 mL of DNSA reagent was added and kept in a boiling water bath for 15 min. The absorbance was noted at 540 nm in the UV–Visible spectrophotometer after cooling the mixture to room temperature (Miller, 1959). The concentration of glucose in the sample was estimated by mixing 20 μL of sample with 2 mL of Glucose oxidase peroxidase (GOD-POD). The mixture was incubated at 37C for 10 min, the absorbance was noted at 505 nm in the UV–Visible spectrophotometer (Meiattini, 1975). All the experiments are conducted triplicate and the mean values are reported in the results.

2.4. Fermentation of hydrolysate

After hydrolysis of the residual biomass at the optimized conditions, the mixture was centrifuged. After centrifugation, the supernatant was collected as algal hydrolysate and its pH was adjusted to favor fermentation. The collected supernatant was subjected to fermentation with 0.5 g of *Saccharomyces cerevisiae*. The fermentation process was optimized for the following conditions such as pH (3–7), temperature (10–40 °C), and for time (24, 48, 72, 96, 120 h). Finally, samples were filtered and analyzed for ethanol content (Cherian et al., 2015). All the experiments are conducted triplicate and the mean values are reported in the results.

2.5. Characterization of bioethanol

The produced bioethanol was characterized using gas chromatography coupled mass spectrometry (GC–MS). Identification of bioactive compounds and mass spectra comparison were analyzed using the NIST Ver.2005 MS data library. GC–MS (Shimadzu: QP2010S) was equipped with Rxi-5Sil MS capillary column at the temperature of 200 °C at the front inlet. Helium gas was used as a carrier at a constant flow rate of 1 mL/min. 1 μL sample was injected along with methanol and chloroform at a ratio of 3:1. The temperature of the ion chamber was at 250 °C and the oven temperature was programmed to raise from 70 °C to 280 °C at 7 °C/min withhold for 2 min at 260 °C and 5 min hold at 280 °C. The sample was injected in splitless mode with flow control mode as linear velocity and total pressure was maintained at 61.5 kPa. The total flow was at 104 mL/min and the column flow was 1 mL/min with a linear velocity of 36.7 cm/s and purge flow of 100, the split ratio was 100. The interface temperature of gas chromatography was 250 °C. For the MS, electron impact ionization was carried out at 70 eV; the scan range was found to have 50 to 600 amu. The bioactive compounds were identified, and their mass spectra were compared and analyzed using the NIST Ver.2005 MS data library.

2.6. Technoeconomic analysis of bioethanol production

2.6.1. Process description

The TEA of bioethanol production from residual marine macroalgae *U. lactuca* was performed using SuperPro software (Version 11.2). The optimized data obtained at the lab scale were used in the technoeconomic simulation and analysis. The TEA simulation model of bioethanol production from residual biomass of *U. lactuca* was developed. The plant capacity was 10 MT of bioethanol production. The residual biomass that was obtained after oil extraction was utilized to produce bioethanol. In the first stage, the residual biomass was pretreated by acid wash under optimum conditions. Commercial cellulase enzyme (4 FPU/mL) was used to hydrolyse pretreated biomass and the mixture was passed to centrifuge. The supernatant separated from the centrifuge was subjected to fermentation with yeast in the stirred reactor. The crude fermented product was filtered, and the crude extract was distilled to separate the bioethanol produced. The complete process design for bioethanol production is shown in Fig. 1.

2.6.2. Economic analysis

Capital investment and operating costs are the two major components of industrial fabrication costs. The primary capital investment is composed of direct fixed costs, working capital, start-up, and validation. The direct fixed cost includes equipment, piping, installation, creating construction, electricity, engineering works, and other facilities (Rajendran and Han, 2023). The detailed capital cost calculations were shown in Table 1. Operating cost includes raw materials, labour, facility-dependent, laboratory expenses, consumables, and utilities. The facility-dependent cost which is composed of maintenance, depreciation, insurance, tax expenses, and other laboratory expenses are some of the important components of economic distribution. The lifetime of the plant was 20 years (Rajendran et al., 2022). The raw algae biomass was obtained from local vendors and the solvents used for the production are all industrial grade procured from dealers, the price of all raw materials and chemicals was determined by the Indian market in 2021. 25 % income tax will be charged on all Indian-based companies. The residual biomass cost of *U. lactuca* was assumed to be 0.11 $/kg, sulfuric acid cost was 0.07 $/kg, and sodium acetate cost was 0.80 $/kg, and the equipment, labour, and other operational prices were included as stated by the firms and consultancies (Naveenkumar and Baskar, 2020).

3. Results and discussion

3.1. Pretreatment of biomass

The biomass is composed of 58.1 % of carbohydrates (Rasyid, 2017). The cell wall of seaweed mainly comprises carbohydrates and its average content on the algal residue was found to be 3.9 ± 0.2 g/L. The pretreatment process conditions such as type of acid, acid concentration, temperature and time were investigated. The 15 % of algae biomass was treated with 1 % of HNO_3, H_2SO_4, or HCl, at 100 °C for 30 min. The maximum carbohydrate yield of 10.25 ± 0.54 mg/mL was obtained for 1 % H_2SO_4 (Fig. 2(a)).”

The maximum yield of carbohydrates in the presence of H_2SO_4 is due to its increased accessibility toward cellulose compared to HNO_3 and HCl. Moreover, the degradation of materials and production of inhibitors may be accounted for the lower estimate of cellulose in the case of nitric acid pretreated materials (Kim et al., 2011). As it was determined that sulfuric acid has shown promising results in the pretreatment process, it was further optimized at various concentrations (1–5 %) for improved carbohydrate yield (Alam et al., 2017). From the results, it was shown that the lower acid concentration has not shown any higher yield in carbohydrates due to its low depolymerization effect. However, the yield increased with an increase in the concentration of acid to 4 % and diminished with further increase and the highest amount of carbohydrate was achieved at 4 % H_2SO_4 concentration 10.52 ± 0.35 mg/mL (Fig. 2 (b)).

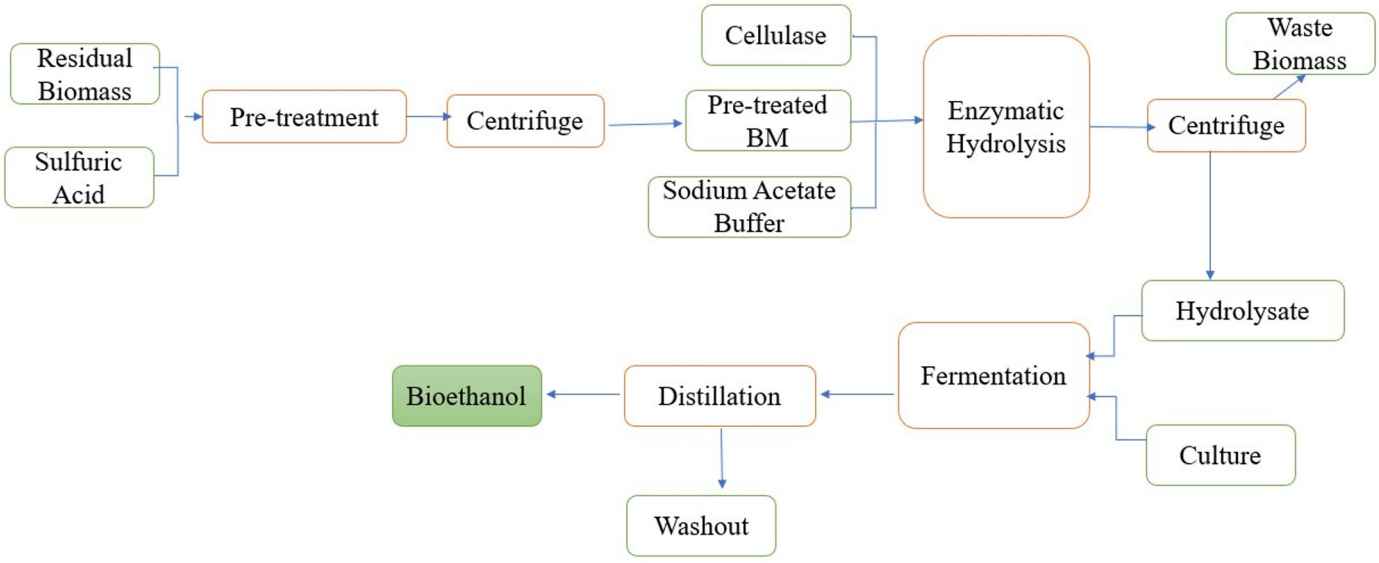

Fig. 1. The overall process design of bioethanol production from *U. lactuca* biomass residue.

Table 1
Total capital investment calculation.

Total capital investment	
Direct fixed capital (DFC)	
Direct cost (DC)	
Piping (A)	0.25 × PC
Instrumentation (B)	0.30 × PC
Insulation (C)	0.03 × PC
Electrical facilities (D)	0.10 × PC
Buildings (E)	0.25 × PC
Yard improvement (F)	0.15 × PC
Auxiliary facilities (G)	0.25 × PC
DC = PC+ installation +A + B + C + D + E + F + G	
Indirect cost	
Engineering cost	0.10 × PC
Construction	0.10 × PC
Other cost	
Contractor's fee	0.05 × PC
Contingency	0.05 × PC
DFC = DC + IC + OC	
Working Capital (WC)	
30 Days of labor, raw materials, utilities, waste treatment	
Startup and validation cost (SVC)	
0.5 % × DFC	
Total Capital Investment = DFC + WC + SVC	

The effect of temperature on the pretreatment of algal residue to increase carbohydrate yield has shown a great impact. The effect of temperature varying from 80 to 120 °C was studied with 4 % of H_2SO_4. The quantity of carbohydrate yield has steadily raised to 100 °C and then dropped, this may be due to saturation in the pretreatment (van der Wal et al., 2013). The maximum carbohydrate yield of 11.31 ± 0.30 mg/mL was obtained (Fig. 2 (c)). The effect of reaction time on the pretreatment of residual biomass was studied at various time intervals. The higher carbohydrate yield of 11.3 ± 0.40 mg/mL was obtained at 60 min (Fig. 2 (d)) and a further increase in time reduces the reducing sugar yield, this may be due to the degradation of sugar molecules at a higher exposure time (Karray et al., 2015).

3.2. Optimization and enzymatic hydrolysis of residual biomass for bioethanol production

Residual pretreated biomass was hydrolyzed at various biomass concentrations, enzyme loading concentrations, temperatures, and time to improve the conversion of higher sugars into glucose. The effect of residual biomass concentration on the hydrolysis of sugars was studied at various concentrations of algal residues (Dry mass) such as 1, 2, 3, 4, and 5 (g/100 mL) in the presence of cellulose enzyme. From the experimental results, it was observed that the yield increases with an increase in the biomass concentration to 4 %, where the maximum yield was found to be 11.8 ± 0.40 mg/mL (Fig. 3(a)). However, a significant reduction in reducing sugar was observed later on further increase in biomass concentration, which may be due to a

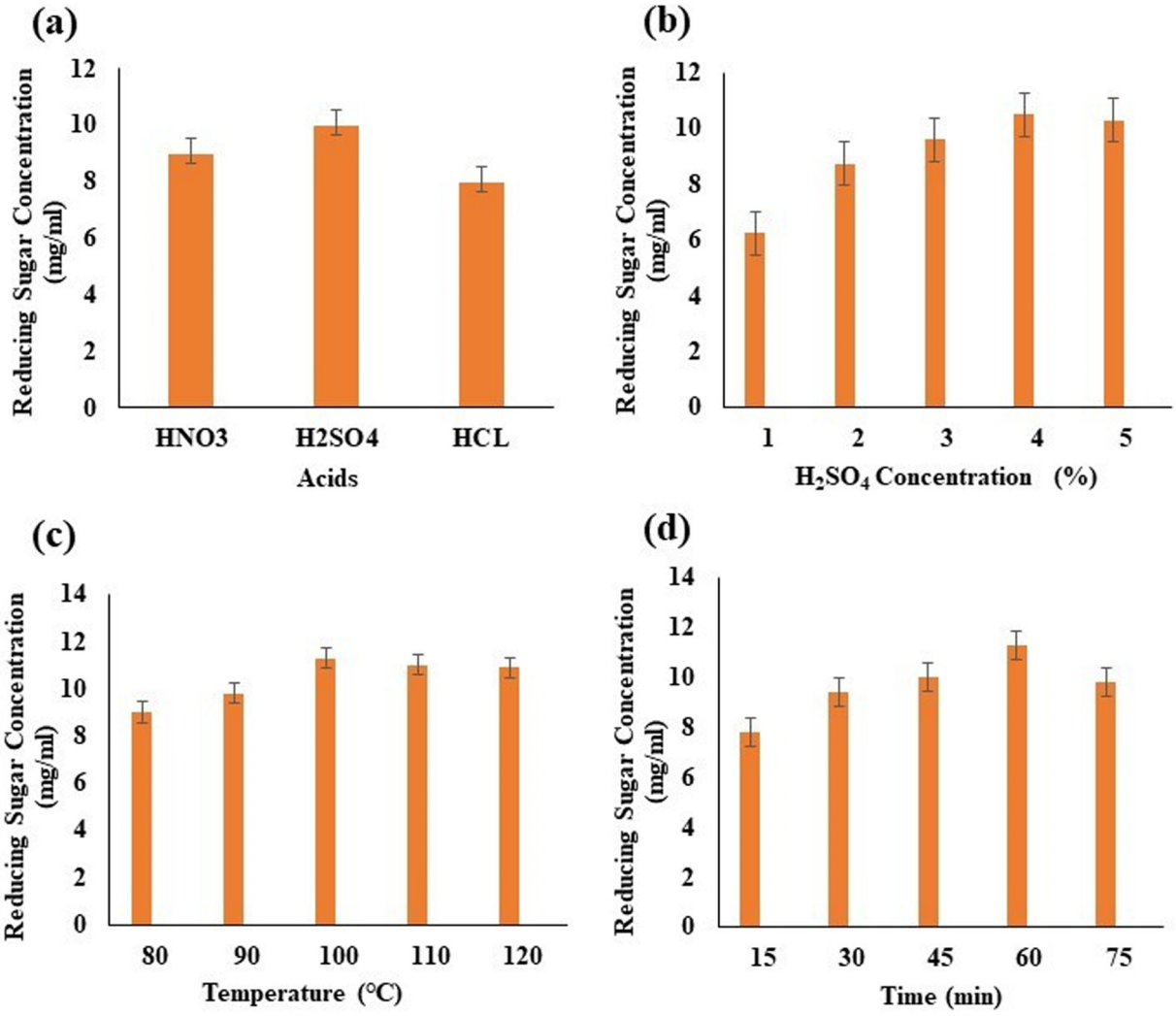

Fig. 2. Optimization of pretreatment of biomass, the effect of (a) different type of acids, (b) acid concentration, (c) temperature, and (d) time.

decrease in the inaccessibility of the cellulase enzyme and thus more agitation for more substrate concentration is required (Cripwell et al., 2015). Even at higher agitation speed to improve circulation, no significant increase in yield was noted, this may be because of decreased activity of the enzyme at the higher agitation speed. The cellulose conversion in the enzymatic hydrolysis step depends greatly on the cellulase activity. Thus, the presence of a sufficient amount of cellulase is important in obtaining a high glucose yield in the biomass-to-ethanol process. The effect of varied cellulose enzyme concentrations (1, 2, 3, 4, and 5) (mL/ 100 mL) on the residual biomass to hydrolyze cellulose into sugar molecules was studied. The yield of reducing sugar was found to increase with increased enzyme concentration up to 4 % with a maximum yield of 12.8 ± 0.40 mg/mL (Fig. 3 (b)). However, higher concentrations of enzymes do not show a considerable increase in the yield. This may be due to the unavailability of active sites in the biomass for the enzyme to bind and the saturation point might have reached as well (Borines et al., 2013).

The effect of temperature on the hydrolysis of biomass to reducing sugar was studied in the range of 20 to 60 °C. From the experimental result, it was observed that a higher yield of reducing sugar was obtained at a higher temperature of 50 °C. *maximum* reducing sugar of 15.1 ± 0.17 mg/mL was obtained (Fig. 3 (c)). On further increase in temperature, the yield was decreased as higher temperature might degrade the activity of the enzyme and inhibit hydrolysis (Tan and Lee, 2014). The effect of time on the hydrolysis of residual biomass was studied between a range of 24 to 120 h. The highest glucose yield was obtained at an optimum time of 48 h as 13.5 ± 0.21 mg/mL (Fig. 3 (d)). Prolonged hydrolysis has not shown a good yield of fermentable sugars ever after 120 h, this may be due to a decrease in the activity of the enzyme and saturation of active site binding (Singhania et al., 2015).

3.3. Optimization and fermentation of hydrolysates for bioethanol production

The fermentation of hydrolysate was performed to convert monosaccharides (glucose) to bioethanol in the presence of yeast (*cerevisiae*). The growth of *Saccharomyces cerevisiae* and its fermentation were optimized for various parameters such as pH, temperature, and time. Due to the strong influence of pH on the growth of yeast and its fermentation of sugars into bioethanol, their effect has been studied at a pH range of 3 to 7. From the results, it can be observed that the fermentation of sugars into bioethanol was found to increase up to pH 5 and falls on further increase in pH. At pH 5, the growth of yeast was found to be optimum and thus fermentation was at a higher rate with an increased ethanol yield of 1.89 ± 0.05 mg/mL (Fig. 4(a)). An increase in pH has been found to inhibit the growth thus reducing the ethanol yield (Gawande and Patil, 2018). Microbial cultures are highly temperature sensitive, so the temperature is one of the key factors in the fermentation process. The effect of temperature on yeast growth was

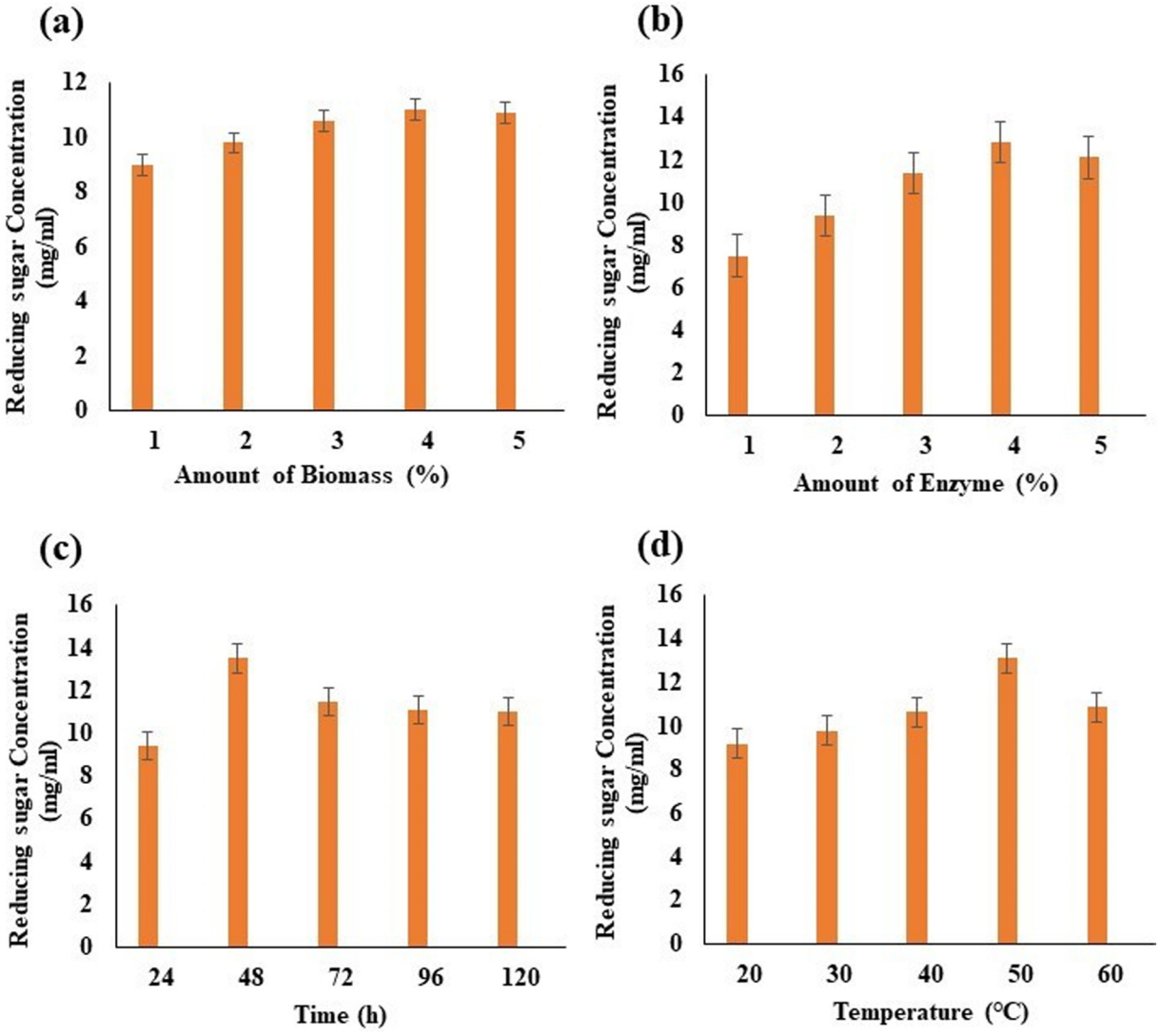

Fig. 3. Optimization of enzymatic hydrolysis of residual biomass, the effect of (a) biomass concentration, (b) cellulase concentration, (c) temperature, and (d) time.

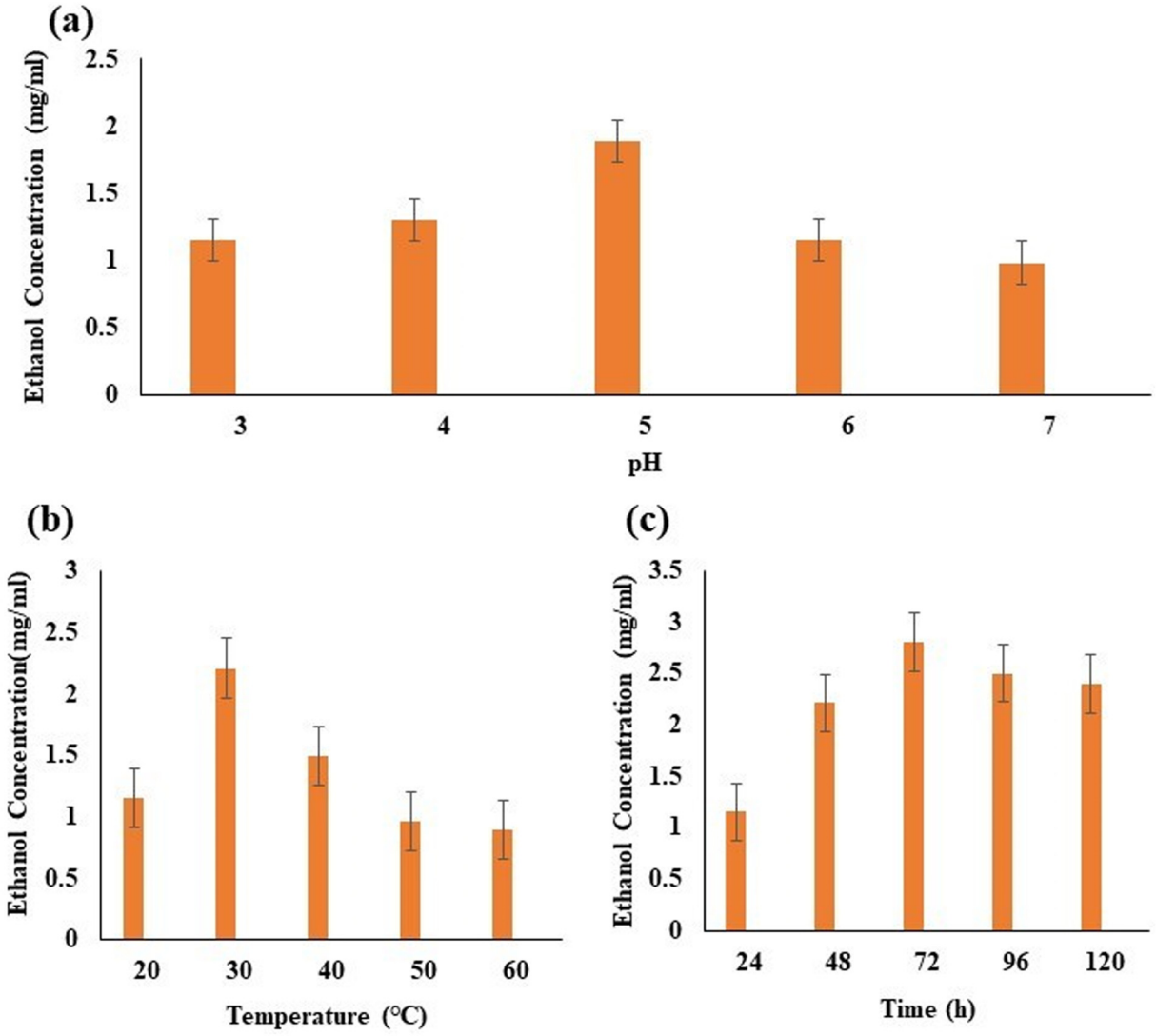

Fig. 4. Optimization of bioethanol production from hydrolysate of *U. lactuca* biomass residue, the effect of (a) pH, (b) temperature, and (c) time.

studied for a temperature range of 10 to 40 °C. The yeast growth was observed to gradually increase to 30 °C and at higher temperatures, it showed a decrease in ethanol production. Thus, the ethanol yield was found to be higher while incubating the yeast at 30 °C at 2.2 ± 0.17 mg/mL (Fig. 4 (b)). The effect of time on the fermentation of *S. cerevisiae* was studied for the time range of 24–120 h. From the experimental results, it was observed that the bioethanol yield was found to increase up to time 72 h, and then the yield was not significantly increasing. At the time of 72 h, the conversion of glucose to ethanol was found to be highest at 2.8 ± 0.12 mg/mL (Fig. 4(c)). After the optimum time, the yield was found to slightly decrease with an increase in time, this may be due to the usage of ethanol in another metabolic process by the *S. cerevisiae*.

3.4. Characterization of bioethanol using GC–MS

The produced bioethanol was confirmed using GC–MS as shown in Fig. 5. The results from the GC–MS analysis of bioethanol produced from *U. lactuca* residue showed different peaks of alcohol groups such as 1,2,3-Benzenetriol, Oxime-, methoxy-phenyl, Cyclotrisiloxane, hexamethyl, and Geraniol peaks were observed at a retention time of 3.61, 3.81, 4.41, 6.46, 8.6, 8.34 respectively. The peaks were compared with previous reports and confirmed (Dizhbite et al., 2011). The peak at 3.61 min confirms the presence of ethanol.

3.5. Technoeconomic analysis of bioethanol production from U. lactuca

3.5.1. Technical performance

The TEA of bioethanol production from *U. lactuca* was carried out under optimum process conditions. In this study, 9.74 MT of dried *U. lactuca* biomass was treated per batch. Annually 165 batches were processed. The residual biomass was pretreated with 14.22 MT/batch of 4 % sulfuric acid and the pretreated biomass was sent to a centrifuge and then sent to the dryer through a belt conveyor. The dry pretreated biomass was hydrolyzed with cellulase and then centrifuged to remove hydrolysate. To the recovered hydrolysate 0.11 MT/batch of yeast was pumped and the fermentation was carried out under optimum conditions. After fermentation, the reaction mixture was transferred to a rotary evaporator to separate bioethanol. Annually 1650 MT of bioethanol was produced.

3.5.2. Economic performance

The total capital investment in the bioethanol production process was estimated at 3.18 M$ and the yearly operating cost was 0.86 M$/yr. In operating costs, 60.74 % was covered by raw materials. Reducing the biomass price and utilization of chemicals helps to reduce the operating cost. The revenue generated from the process can be subdivided into main revenue, revenue generated by by-products, and savings. Revenue generated by the process was calculated on yearly basis. The bioethanol produced from

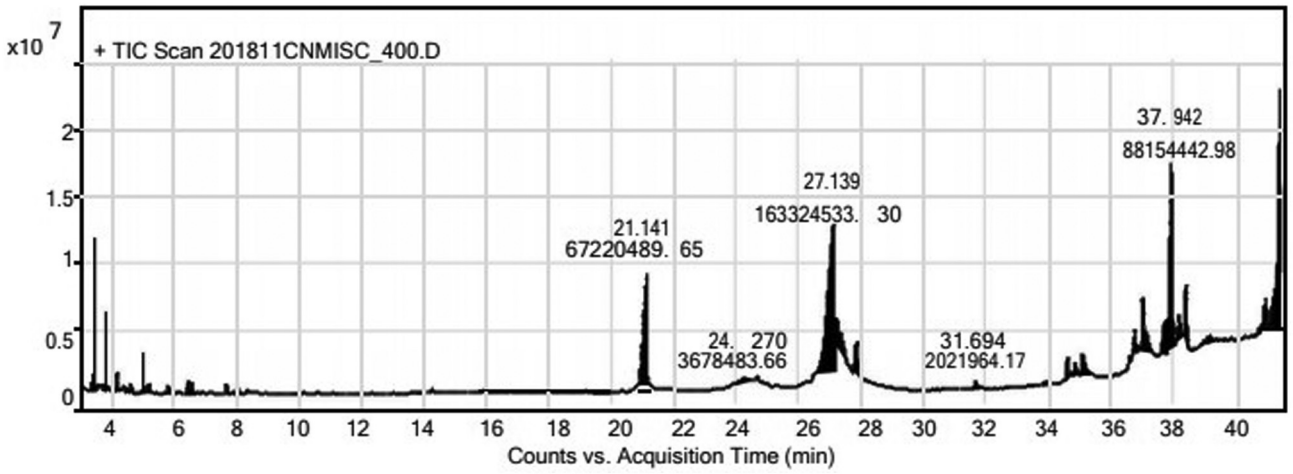

Fig. 5. GC–MS analysis of bioethanol produced from *U. lactuca* biomass residue.

residual biomass has generated 1.24 M$/yr as the main revenue and along with this leftover residual biomass which can be used as feedstock for animals or used as organic manure has generated revenue of 0.18 M$/yr. The total revenue generated out of bioethanol production was found to be 1.41 M$/yr. Around 55,440 $/yr was obtained from the heat integration process. The minimum selling price of the bioethanol was 0.47 $/kg. The ROI, payback period, IRR and NPV of the plant were 16.99 %, 5.89 years, 11.57 % and 291,000 $ respectively. Advanced processes and large-scale plants increase economic sustainability (Table 2).

3.6. Limitations and future scope

In sustainable biofuel production, feedstock selection is a very important factor. In biofuel production, raw materials comprise 50–70 % of operating costs. In the present study, residual biomass was used for bioethanol production which reduced the overall raw material cost as well as the operating cost. Low-cost feedstock and reduction of acid and chemical utilization helps to develop low-cost bioethanol process. The advanced integrated process and low toxic chemical utilization reduces the overall cost and reduce the environmental impacts. The present work was focused on process and economic analysis, the life-cycle assessment (LCA) to find the accurate environmental feasibility can be studied in future. The combined TEA and LCA help to develop an economic and environmentally friendly process.

4. Conclusions

An attempt was made to utilize the residual biomass effectively to produce bioethanol. The maximum yield of fermentable sugars was 13.48 mg/mL. The bioethanol conversion was found to be highest at 2.8 ± 0.12 mg/mL. The annual revenue generated by bioethanol was found to be 1.41 M$/yr. The capital investment and annual operating cost of the bioethanol production plant were 3.18 M$ and 0.86 M$ respectively. The minimum selling price of the bioethanol was 0.47 $/kg. The utilization of residual biomass reduced the overall bioethanol production cost and minimum selling price of bioethanol. The integrated process of biodiesel and bioethanol production from algae helps to reduce capital investment and economic risk.

Table 2
Economic summary of the bioethanol production plant.

Description	Value
Total capital investment ($)	3,180,000
Operating cost ($)	857,000
Savings (due to heat recovery) ($)	55,440
Main revenue ($)	1,237,000
Other revenues ($)	176,734
Total revenues ($)	1,414,000
Batch size (kg)	10,000
Cost basis annual rate (Kg)	1,650,000
Net unit production cost ($)	0.47
Gross margin (%)	43.3
Return on investment (%)	16.99
Payback time (Yr)	5.89
IRR (after taxes) (%)	11.57
NPV (at 10.0 % interest) ($)	291,000

CRediT authorship contribution statement

Kalavathy Gengiah: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft. **Naveenkumar Rajendran:** Investigation, Validation, Writing – original draft, Writing – review & editing. **Khalid A. Al-Ghanim:** Software, Writing – review & editing. **Marimuthu Govindarajan:** Resources, Writing – review & editing. **Baskar Gurunathan:** Conceptualization, Software, Supervision, Writing – review & editing, Project administration.

Data availability

No data was used for the research described in the article.

Declaration of competing interest

The authors declare no conflict of interest.

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