

Original Article

Production of ethanol and value added product (biofertilizer) from algae for sustainable development

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Manuscript ID:
RIGJAAR-2025-0204016

ISSN: 2998-4459
Volume 2
Issue 4
Pp. 78-83
April 2025

Submitted: 10 Feb 2025
Revised: 20 Feb 2025
Accepted: 05 Apr 2025
Published: 30 Apr 2025

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Quick Response Code:



Web: <https://rlgjaar.com>



DOI:
10.5281/zenodo.16198062

DOI Link:
<https://doi.org/10.5281/zenodo.16198062>



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Abstract

The present study was carried out in the coastal region and freshwater bodies in the year of 2021 and 2024 in Maharashtra state, India. The macro and micro algae were collected in the month of September. Algae have high growth rate and can be sustain in extreme condition, which result in high ethanol production rate. The production of bio- energy is dependent on different composition of algal species, environmental factors, and growth rate. The focus of the present research was to study diversity of algal species in coastal and fresh water for production of bioethanol (biodiesel) and production of biofertilizer from the residual fermentation substrate with floral waste. The aim of research was to enrich the soil quality and to reduce the solid waste and water pollution, produced due to disposal of floral waste in water bodies. Average ethanol production from algae was in the range of 9.21 % to 19.72 % on the basis of type of algae. The maximum production of ethanol was from algal species of *Nannochloropsis* and *Chlorella*, under optimum laboratory conditions. The mineral content in the algal biomass were in the range of 0.11 to 18.1 mg/L, which produce high quality biofertilizer.

Keywords: algae, algae identification, solid waste, floral waste, biodiesel production, and biofertilizer

Introduction

India is depending upon petroleum resource, other than all renewable or natural resource. To reduce the burden on non renewable resource, algal biodiesel will be best alternative, to produce high amount of natural fuel (Bajhaiya et al., 2013). Fossil fuels and biofuel originate from biomass, but the difference is, biofuel is renewable carbon and fossil fuels are sequestered carbon compound (Köpke et al., 2011). Algae are the produces biodiesel and biofuel, which will be the best renewable energy source for next generation (Natalia et al., 2017). The second renewable source of biofuel is seeded plant such as jatropha seed which can produce high concentration of oil (Masjuki et al., 2013). Algae have high growth rate and can be sustain in extreme condition, which result in high ethanol production rate (When comparing algae and oil producing seeds, the algae was produced high quantity of oil (Smita et.al). Methanol can be produced from renewable and non renewable sources (Natalia et al., 2017). In renewable energy biofuels are produced from different types of biomass, industrial waste and algae (Janda et al., 2012).

Algae cell wall high amount of cellulose and polysaccharides which have high potential of ethanol production. The cell wall of algae is easily broken down by either acidic treatment or with the enzymes. Other than ethanol the remaining part of algae can be used for production of value added products. From ancient time of evolution algae was play a important role in the environment.

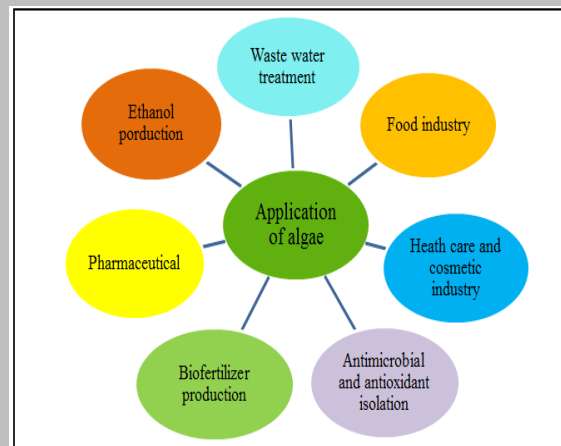


Figure no.1 Application of algae in the in the field of science

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How to cite this article:

Pore, S. M., & Dhulap, V. P. (2025). Production of ethanol and value added product (biofertilizer) from algae for sustainable development. *Royal International Global Journal of Advance and Applied Research*, 2(4), 78–83. <https://doi.org/10.5281/zenodo.16198062>

The evolution was triggered through the blue green algae and responsible for evolution of all eukaryotes along with human (Russell Leonard Chapman.2013). Production of biofertilizer is a step toward sustainable development to increase soil fertility and to increase the production rate of agriculture sector. Native microorganisms increase the soil fertility by decomposition of organic waste (Esraa E. Ammar et.al 2022).

Review of literature

Arun Lal Srivastav said that, in India due to human activities and social behavior maximum amount of waste was generated per day, which causes the problem of solid waste which results in environmental degradation. For environmental conservation management of organic waste was very important to maintain environmental and public health. The traditional method of waste disposal and management causes environmental pollution, so new and ecofriendly techniques should be adopted, such as biofertilizer production from organic or biodegradable

waste. Raphael Slade, Ausilio Bauen 2012, studied carbon dioxide emissions associated with algal biomass production were estimated by multiplying the external energy inputs to the process by the default emissions factors described in the EU renewable energy directive. During harvesting of algae maximum energy is utilized for oven during of micro and macro algae, which increases the cost of biodiesel production. The emissions associated with algal biomass production in raceway ponds are comparable with the emissions from the cultivation and production stages of rape methyl ester biodiesel.

Material and methodology

1. Study region

The present research was carried out in the coastal and fresh water region of the Maharashtra state of India. Marine Macro and micro were collected from different beaches of Ratnagiri and Sindhudurg district and Fresh water algae samples were collected from the fresh water lakes and river from Solapur district.

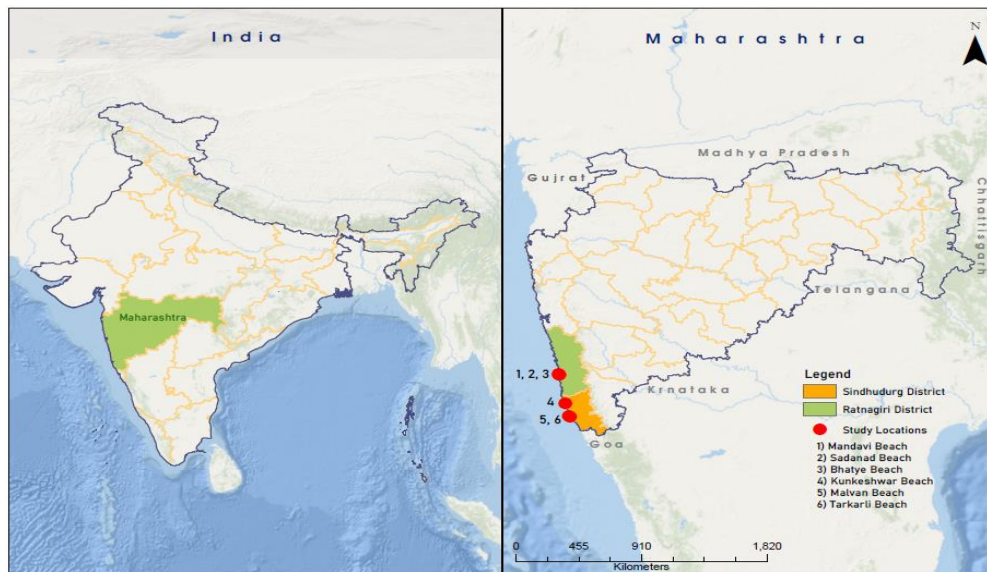


Figure No.2 Map of study region (India and Maharashtra)

Algae collection

The algae and water samples were collected in 2021, 2022 and 2023 during the period between the month of September Sindhudurg and Ratnagiri district, and fresh water from Solapur district of Maharashtra. Plastic container or bottles were suitable for micro algae collection

(Smita et.al 2023). A 5 ml capacity pipette was used to collect samples of micro algae, and a sharp object was used to remove attached algae on substratum. Matured macro algae were removed easily with knife. Manual and mechanical removal was required for collecting large quantities of wild or cultivated macro algal stocks. (Stefania Rocca et.al. 2015).





Figure no. 3 collection of algae from coastal region of Maharashtra

Cultivation of algae

The marine and fresh water micro algae were cultivated in the designed prototype photo-bioreactor in sterilized BG 11 liquid media. The optical density was measured at definite time interval (3 days) at optimum temperature, pH, photo period and salinity in case of marine micro algae. During cultivation of algae optimum temperature for the growth of algae was 32 to 35°C, at 7 to

7.5 pH and 34 gm /l salinity. The fluctuation in these parameters were affected the growth rate of algae and their survival rate also. To reduce the cultivation cost of micro algae, the CO₂ gas was supplied through anaerobic fermentation of yeast (*Scaromycease cerevisiae*) for photosynthesis of algae, which was ecofriendly and reduces energy cost. Micro algae, was able to fix atmospheric CO₂ up to 2 kg per 1 kilogram of algae biomass.

Sr. No.	Sampling location	Types of algae species	Environmental factors				Algal growth
			Temperature (°C)	pH	Photo period (Hr.)	Salinity (gm/l)	Optical density
1.	Mandavi Beach	<i>Lyngbya aestuarii</i>	29.4	7.1	12:12 Hr	35.8	2.07
		<i>Ulothrix flacca</i>	30	6.9	12:12 Hr	35.8	1.06
		<i>Nannochloropsis oculata</i>	29.6	7	12:12 Hr	35.7	0.97
		<i>Lyngbya bouillonii</i>	30	7.1	12:12 Hr	35.4	1.2
		<i>Nannochloropsis oceanic</i>	29	7.2	12:12 Hr	34	0.41
		<i>Batrachospermum antiquum</i>	29.6	7.2	12:12 Hr	34.1	0.89
		<i>Ulothrix aequalis</i>	29.5	6.9	12:12 Hr	34.9	0.65
2.	Are ware Beach	<i>Vaucheria conifer</i>	29	6.9	12:12 Hr	35.9	1.49
		<i>Ulothrix aequalis</i>	29	7.3	12:12 Hr	35.6	1.13
		<i>Diyocia pinnatifida</i>	29.6	6.8	12:12 Hr	35.8	2.01
		<i>Polysiphonia subtilissima</i>	29.4	6.9	12:12 Hr	35	0.99
		<i>Vaucheria sessilis</i>	27.3	7.3	12:12 Hr	35.8	1.99
		<i>Vaucheria stegeogonium</i>	27.2	6.9	12:12 Hr	35.8	1.22
3.	Bhate Beach	<i>Nannochloropsis oculata</i>	28	7.1	12:12 Hr	35.7	1.42
		<i>Ulothrix flacca</i>	27.9	6.9	12:12 Hr	35.4	0.72
		<i>Nannochloropsis oceanic</i>	27.2	7	12:12 Hr	34	1.82
		<i>Dictyosphaerium reniformae</i>	28	7.2	12:12 Hr	34.1	0.96
4.	Tarkarli Beach	<i>Micractinium conductris</i>	27.9	7.2	12:12 Hr	34.9	0.89
		<i>Batrachospermum antiquum</i>	27	7.3	12:12 Hr	35.9	1.2
		<i>Polysiphonia abscissa</i>	27.3	7.2	12:12 Hr	35.6	1.6
		<i>Phormidium bonheri</i>	27.2	7	12:12 Hr	35.8	1.03
5.	Malvan Beach	<i>Asterionella formosa</i>	28	6.9	12:12 Hr	35	1.12
		<i>Dictyosphaerium reniformae</i>	28.1	7.3	12:12 Hr	35.7	2.12
6.	Kunkeshwar beach	<i>Nannochloropsis oculata</i>	27.3	6.9	12:12 Hr	35.4	0.85
		<i>Batrachospermum antiquum</i>	27.9	7.1	12:12 Hr	34	1.65
		<i>microspora indica</i>	27	6.9	12:12 Hr	35	1.89

Table no. 1 Growth of marine algae in photo bioreactor

Downstream process of algae

• Filtration

In this method, the algae along with liquid media are transfer through Whatman filter with -pore size under

pressure. Different filtration techniques were available, but micro filtration method was suitable for algae filtration.

- **Centrifugation:**

Centrifugation technique was commonly for separation of algal biomass from liquid media. After filtration immediately centrifugation was followed with the speed of 150 rpm (resolution per minutes) for 30 minutes. The pellets of algal biomass were collected and supernatant was discarded.

- **Drying**

Biomass drying was essential step for extraction of all phytochemical content from the algae for conversion of ethanol. The drying of both algae was carried out through sun drying for two days Followed by oven drying for 30 minutes at 70°C temperature for complete removal of water content from the algae.

Ethanol production

- **Fermentation Process:**

The fermentation process was carried with inoculation of 10 ml Yeast in 2 liter YEPD (Yeast extract potato dextrose) liquid media into the designed bioreactor. The optimum temperature was 30°C with 7 days fermentation duration in a bioreactor operating at 150 rpm.

- **Fermentation Medium**

Two liter of fermentation medium YEPD (Yeast extract potato dextrose) was prepared according to the requirement of *S. cerevisiae*, containing 20 g/l yeast extract, 40 g/l peptone and 40 g/l dextrose sugar dissolved in 2 liter double distilled water. The medium was sterilized in autoclave at 121°C at 15 psi pressure and the pH was adjusted to 5.

- **Fermentation Conditions for ethanol production**

The fermentation was carried out in a 5 liter capacity of fermentor, with a working volume of 2 liters. The 2 liter fermentation medium YEPD (Yeast extract potato dextrose) was inoculated with 100 ml inoculums. It was

carried out at 250 rpm and temperature of 30°C, at 5.2 pH. Samples were taken every 24 hours for the entire monitoring of fermentation process.

Value added products –biofertilizer

Macro algae have high content of minerals and high water binding capacity in the soil, which increases the fertility of soil with high supply of water and minerals. (Pulz and Gross 2004).

Result and discussion

In the research period from 2021 to 2023 different algae species were collected from the coastal and fresh water region of Maharashtra for ethanol production, seasonally. In month of September maximum variety of algae was observed as compared to month of April. The difference in species availability was depends on the environmental conditions. The September month was favorable for algae growth due to low temperature, neutral pH and maximum availability of nutrients for their growth. The production of bio- energy is dependent on different composition of algal species, environmental factors, and growth rate. From macro algae bioethanol was produced through the process of fermentation due to high concentration of carbohydrate than the lipid. The ethanol produced from micro algae were in the range of 14 to 18 g of ethanol / L of algal biomass. The maximum production of ethanol was from algal species of *Nannochloropsis* and *chlorella*, under optimum laboratory conditions. Enteromorpha intestinalis, Corallina officinalis, and Gelidium pulchellum biomass algae was mostly used in biofertilizer production due to high nutrient content and low heavy metal concentration (Fran Nekvapil et.al 2021).The sea weed contain high concentration of mineral ,which favors the production of biofertilizer from algae ,to enhance the soil fertility.

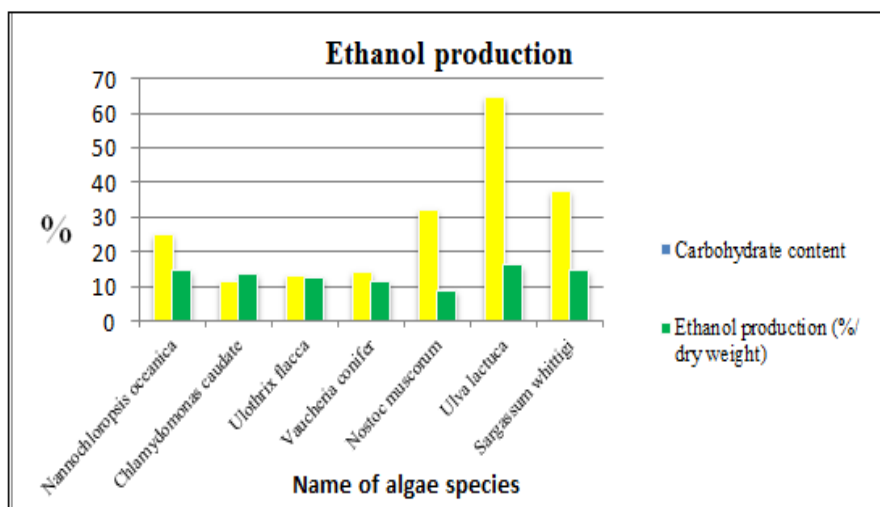


Figure no. 4 ethanol production from algae and carbohydrate content

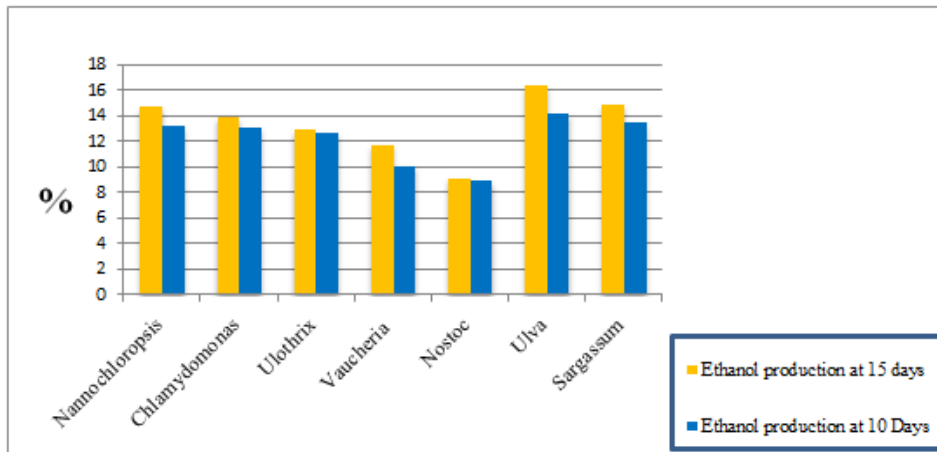


Figure no. 5 ethanol production from algae at 10 and 15 days of fermentation

Sr. No.	Name of mineral	% of mineral in algal biomass
1	potassium	1.6 mg/L
2	copper	2.9 mg/L
3	manganese	1.6 mg/L
4	sodium	1.8 mg/L
5	magnesium	18.1 mg/L
6	cobalt	0.11 mg/L
7	iron	0.61 mg/L
8	zinc	1.55 mg/L

Figure no. 6. Physico chemical analysis of algal extract for fertilizer production

Conclusion

The results reveal that the species of micro algae, their carbohydrate content and pretreatment of algal biomass affected the production efficiency of ethanol. The favorable conditions for the growth of algae were at pH 7, temperature 32°C with 12 hrs photo period. The results showed that the species which had carbohydrate above 30%, with acid pretreatment at 20%, and fermentation duration 15 days enhancing the productivity of algae-based biodiesel production. In PBR, minimizing CO₂ supply costs and improving environmental control, ensures higher growth rates while reducing operational expenses, making biodiesel generation more economically viable and sustainable. The present research focused on the cost effective production of ethanol and biofertilizer for sustainable development and ensures the zero discharge into environment to conserve our environment and nature.

Acknowledgment

The authors would like to express their sincere gratitude to Punyasholk Ahilyadevi Holkar Solapur University Solapur for providing the necessary facilities and support to carry out this research. We also thank Dr. V. P. Dhulap sir research guide for their valuable guidance and insightful suggestions during the course of this study.

Special thanks are extended to School of Earth sciences, Department of environmental science for their assistance with data collection, analysis, and administrative support.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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