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Assessing Bio-Economic Potential of *Enteromorpha instestinalis* for Sustainable Aqua-Farming in Climate Vulnerable Coastal Areas of Indian Sundarbans

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ABSTRACT: Algaculture in trapped waters of inundated coastal areas in the Indian Sundarbans can be a sustainable aquafarming practice for marginal farmers who have lost their land due to sea level rise and salt water intrusion. The present paper tries to assess the bio-economic potentials of algaculture as a sustainable aquafarming practice by analysing the biochemical components of one of the best grown macro algal species, *Enteromorpha intestinalis.* Perusal of results show that the species is rich in protein and has considerable amount of carbohydrates to deem it fit as an alternate source of food feed and fodder, whereas almost 95% of the available oil can be converted to biodiesel that confirms the standard specifications of EN-24124 in regard to fatty acid methyl esters and linolenic acid contents. This also qualifies the species as an alternative energy crop augmenting its bio-economic potentials.

KEYWORDS: *algaculture, sustainable aquafarming, bio-metabolites, climate impacts, coastal Sundarbans*

Introduction

Coastal Sundarbans in eastern India harbours natural resources of halophytic mangrove forest, rich biodiversity and ecosystem that form an extraordinary environment of the globe. It is also one of the most ecologically threatened areas of the planet (Choudhury & Choudhury, 1994). The available brackish water environment of Sundarbans provides favourable substratum for algal communities (Naskar & Naskar, 2010). *Enteromorpha intestinalis*, *Ulva lactuca* and *Catenella repens* are the dominant macroalgae found in the Indian Sundarbans of which Chlorophyceae (*E. intestinalis* and *U. lactuca*) are present in higher levels compared with *C. repens* (belonging to Rhodophyceae) zonation. It is noteworthy that in marine ecosystems, macroalgae are ecologically and biologically important and provide nutrition and an accommodating environment for other living organisms. There is mention of their polysaccharides being used in industries such as food, cosmetics, paint, crop, textile, paper, rubber and building industries. In addition, they are used in medicine and in areas of pharmacology for their antimicrobial, antiviral, antitumour anticoagulant and fibrinolytic properties.

Reports on studies on brackish water algae in and around the Sundarbans are available in the work of Naskar et al. (2008a, 2008b, 2008c), and Naskar (2011a, 2011b). Impact of seasonal variation on the biochemical compositional variation of the green weeds has also been reported by some authors (Mitra, 2009). However, there is a lack of information on research activities for the commercial exploitation on green algae of the Sundarbans. At the international level, research activities on the nutritional evaluation of the seaweed have been conducted and evaluation of the varied species for multiple industries reported (Wong, 2001).

Under the aegis of APN's CAPaBLE programme, a community-based sustainable aqua-farming initiative was taken to promote alga-culture in three coastal villages of the Sundarbans. Through community capacity building, on-field demonstration and scientific interventions, it has now become a multi-stakeholder endeavour. Perusal of results from follow-up interventions show that *E. intestinalis* shows promising growth in saline water-infested inundated areas (Maity & Dey, 2014) and development of processes for commercial exploitation of this algal flora may not only bring relief to thousands of impoverished families living in the belt, but also might create a position in the global market. Hence, the present study involves determination of the bioactive components of *E. intestinalis* that has nutritional significance and as well as potential for alternative energy sources. An extension of this preliminary work would entail developing and establishing the production processes for a range of products in the food and pharmaceutical sector and create alternative sources for biodiesel.

Methodology

Algal samples were collected in each month in pre-monsoon (March to June), monsoon (July to October) and post-monsoon (November to February) seasons of the year, from 2012 to 2014, from their natural habitat of coastal beaches from Sagar (21^{0}48'N, 88^{0}5'59.9"E), Jhorkhali (22^{0}13'20"N, 88^{0}56"43"E) and Saatjelia (22^{0}8'39"N, 88^{0}52'40"E) islands of the Indian Sundarbans. The samples were washed with water and prepared for spectrophotometric studies.

HIGHLIGHTS

- » A native macro-alga of coastal Sundarbans, Enteromorpha intestinalis, shows excellent growth in saltwater inundated areas that has lost farmlands owing to sea level rise.
- » The green algal flora is rich in nutrients and can be an alternative source of food feed and fodder for marginal farmers, showing a prospect in sustainable aquafarming.
- » The alga also has bio-economic potentials as an alternative source for biodiesel as it conforms to the UNE-EN-12424 (2003) standards for the same.

Figure 1. *Enteromorpha intestinalis* (left); Collection of *E. intestinalis* using culture tray (right).

They were then sun-dried for a few days, since water inhibits trans-esterification. Afterwards, dried algae were crushed and extracted in n-hexane in a Soxhlet apparatus as per UNE-EN 734-1 (2006). The transesterification process was conducted simultaneously with the extraction in order to avoid the previous step of oil extraction and purification of obtained oil (Karaosmanoglu et al., 1996; Lang et al., 2001).

The protein and carbohydrate content of freeze-dried alga was determined spectrophotometrically following Bannerjee et al. (2009). Lipids were extracted from the samples following Yan et al. (2010) and Fatty Acid Methyle Esters (FAME) and Linolenic acid content was estimated using gas chromatographic (GC) methods conforming to the UNE-EN-12424 (2003) standards, using Bruker 450-GC. GC control and data handling were done using Bruker Galaxie™ Software.

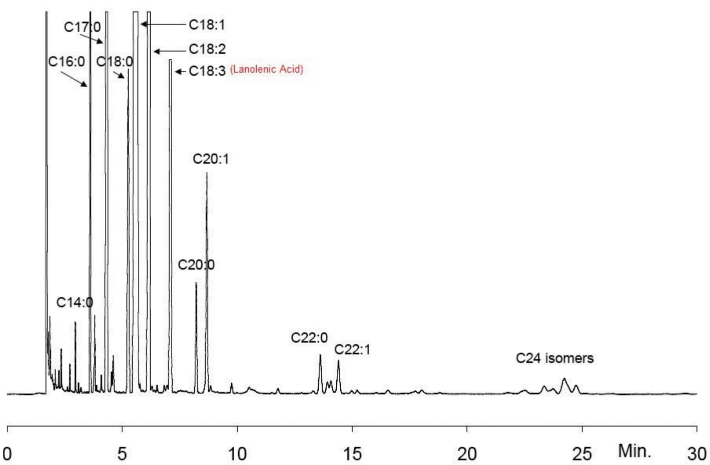

Figure 2. Findings of spectrophotometric and chromatographic analysis.

Results and Discussion

The results showed that in the post-monsoon season, when average salinity is 21.85 ppt, available oil in *E. intestinalis* was maximum ranging up to 0.37% which declined to 0.31% during monsoon, when average water salinity drops to 12.10 ppt, since vegetative growth rate decreases in this algal flora also during monsoon as found in recent studies (Maity & Dey, 2014). However, convertible biodiesel was as high as 93.27% and Linolenic acid content was 0.24%. Interestingly, the findings of spectrophotometric and chromatographic analysis (Figure 2) also showed that this particular variety of green seaweed is rich in protein, carbohydrate and omega fatty acids which are nutritionally significant. It has been found that the protein content of *E. intestinalis* is as high as 12.9-15.79%. Also, these species contains 53% carbohydrate on average, which does not show much variation across the seasons, as reported earlier (Mitra et al., 2009; Reeta et al., 2009). Thus, it is presumed that utilisation of this species as a part of the human diet after conducting toxicity tests may cater to the acute nutritional deficiency in the region. Its extensive utilisation can parallel and bring a radical change to the lives of Sundarbans inhabitants.

Conclusion

It is obvious that end users for algae are often found in the production of food supplements and biofuel. So, the green-house gas benefits from algae culture arise only as offsets when the algal use displaces the combustion of a fossil fuel or is used for the production of electricity. Earlier reports from FAO (2010) showed that it is possible to produce algal biodiesel at less cost and with a substantial greenhouse gas and energy balance advantage over fossil diesel. However, the economic viability is highly dependent upon algae with high oil yields capable of high production year-round, which has yet to be demonstrated on a commercial scale.

This paper substantiates the bio-economic potentials of aqua-farming of the algae *E. intestinalis* as a place based climate adaptive intervention in climate vulnerable deltaic Sundarbans of India, since mangrove ecosystems in Indian Sundarbans are known sources for methane, having very high global warming potential (Jha et al., 2014). While higher optimistic carbonaceous biomass fixation capacity of *Enteromorpha* can be considered as a direct indication of carbon capture by this aquatic flora in inundated waters, as evidenced earlier (Maity & Dey, 2014; Kaladharan et al., 2011), perusal of results from the present study shows its estimable potential for being used as a source of both biodiesel and food supplement.

The relevance of this study finds its significance in the fact that the settlement areas of deltaic Sundarbans has unusually high emission footprints in power and transport sectors as reported by WWF (2012), since these desolate islands are not yet connected to the country's national power grid, whereas loss of agricultural land due to rapid coastal erosion and inundation (Rahman, 2012) has accentuated the need for alternatives in food, feed and fodder. This research has impending merits to find a local needs-based solution for combatting the impacts of global change.

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PROJECT INFORMATION

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