Summary of Outcome of R&D Projects
Ministry of New and Renewable Energy , New Delhi

1. 0 Project Title	**: Assessment of Techno - economic Feasibility of Large Scale Seaweed Cultivation Integrated with Biofertilizer and Ethanol Production**
2.0 Project sanction no. & date	**:** F.No 7/141/2009 – NT/BF Dated 30/11/2009
3.0 Project time frame	**:** Dec.2009 – Nov.2012 (3 Years)
4.0 Executing Institution	**:** CSIR Central Salt & Marine Chemical Research Institute, Bhavnagar-364 002, Gujarat.
5.0 Project Outlay	**:** Rs. 204.79 Lacs

6.0 Key Objective **:**

Development of cost effective and sustainable offshore structure for scaled up cultivation of seaweeds, *Kappaphycus alvarezii* and *Gracilaria edulis* and utilisation of seaweed biomass for biofertiliser and ethanol production.

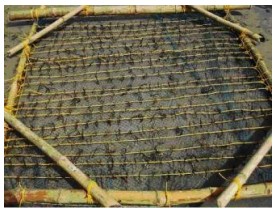
7.0 Project Outcome **:**

Offshore cultivation of two seaweeds, *Kappaphycus alvarezii* and *Gracilaria edulis* with higher yield and co-production of bio-fertiliser and ethanol from *K. alvarezii* using *S.cerevisiae* isolated marine yeast, *Candida sps.*

8.0 Significant achievements summarizing technology development and commercialization

- Cultivation in offshore region comparatively yielded higher biomass than onshore region for both seaweeds, *Kappaphycus alvarezii* and *Gracilaria edulis* which may be favoured by huge clear water column, less wave breaking forces minimal desiccation and absence of epiphytic growth and sediment deposition.

Rafts of *K. alvarezii* at offshore



Gracilaria edulis seedlings on raft

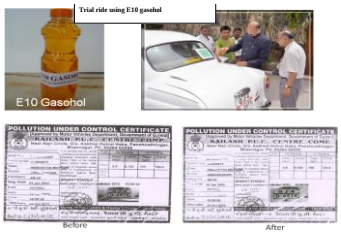
- During the project period, 7500 liters of Sap (a biofertiliser) from *Kappaphycus alvarezii and* 3500 litres of sap from *Gracilaria edulis* and 1.6 tons of residual biomass, feed stock for ethanol were produced.

Expeller (extreme left), Sap and residue (right) obtained from grinding of fresh *K. alvarezii*

Reactors for saccharification

1000L Fermentor with 100L pre-culture unit

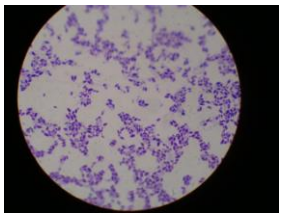
- The residual biomass of *K. alvarezii* was sachharified with 0.9N H2SO4 at 100°C with reducing sugar yield of 30.6% which was converted to ethanol with efficiency of 80% by *Sachharomyces cerevisiae*.



- A report was prepared for the utilization of a a marine yeast *for converting K.alvarezii* biomass into ethanol as a byproduct under highly saline conditions to avoid desalting step which makes

the process more efficient and economically viable.

- The marine yeast was isolated and identified as *Candida sps*.,



- Successful run of a petrol vehicle with E10 gasoline made from the seaweed-based ethanol.

9.0 S & T benefits

9.1 Patents :

- Mody KH, Ghosh PK, Barindra S,Gnanasekaran G, Shukla AD, Eswaran K, Brahmbhatt HR, Shah BG, Thampy, S, Jha B. A process for integrated production of ethanol and seaweed sap from *Kappaphycus alvarezii*. WO2011/027360A1 dated 10.03.11, EP2475776 A1, US20130005009 A1 dated Jan 3, 2013, JP2013503650 (A), CN102597251 (A)

9.2 Publications

International :

1. Yasmin Khambhaty, Kalpana Mody , Mahesh R. Gandhi, Sreekumaran Thampy, Pratyush Maiti, Harshad Brahmbhatt, Karuppanan Eswaran, Pushpito K. Ghosh, *Kappaphycus alvarezii* as a source of bioethanol, Bioresource Technology 103:180–185 (2012) (IF 4.98)

2. Yasmin Khambhaty, Devang Upadhyay, Yogesh Kriplani, Nidhi Joshi, Kalpana Mody and M.R.Gandhi, Bioethanol from macroalgal biomass: Utilization of marine yeast for production of the same. Bioenergy Research 6: 188-195 (2013). (IF 4.624)

10.0 Future direction for Research :

Short term goals (next two years):

- Collaboration with offshore engineers to develop engineered floating devices for offshore cultivation of marine macroalgae as feedstock for biofuel and bioenergy applications.

- Further optimisation and integration of cultivation and production of biofertiliser and bioethanol from sea weed algae to develop a cleaner process.

Long term goals (Next five years):

- Complete systematic study and technology development on Utilisation of present isolated and other marine yeast for converting algal sugar to ethanol may result in to a economically viable option eliminating energy step of electrodialysis.

- Detailed work on isolation and utilization of polysaccharide degrading bacteria for hydrolysis of algal biomass to achieve higher yield of monosachharide further convertion to ethanol.

- Assessment of the economic viability of ethanol production from seaweeds.

- Evaluation of the performance of bioethanol in vehicles for emission standards and engine performance.

- Assessment of other seaweeds for its use in bioethanol production.

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