Photosynthetic factories for manufacturing biofuel ethanol

The declining petroleum reserves have forced steady escalations in the price of petrol. A litre of petrol in Bangalore now costs some 34 times more than its cost in 1970. The steep hike in the price of petrol is a global phenomenon forcing all science-minded countries to find alternative sources of energy. Anxious to wean itself away from dependency on foreign oil, the United States in 2005 passed the US Energy Policy Act which mandates replacing 30% of the amount with biofuel by 2012. United States has been on a major excursion to find the ultimate and most efficient sources for renewable fuel. Ethanol, butanol, biodiesel and dimethylfuran derived from plant biomass are being talked about[1–3]. In the US state of Texas, which we usually associate with numerous oil-wells, R. Malcolm Brown Jr and David R. Nobles Jr – plant biologists at the University of Texas at Austin have been researching on the photosynthetic blue-green algae (cyanobacteria) as a renewable energy source. They have devised methods for cultivation of blue-green algae in large tubs placed in degraded lands. This offers exciting prospects for a country such as India where farming land is limited although sunlight is unlimited. The energy derived from the sun's irradiation of the Earth each day suggests that photosynthesis is one of Nature's most ancient and efficient methods for capturing the energy of the sun to utilize atmospheric CO_2 for creating the major chemical building blocks of plants and of all the other organisms that directly or indirectly feed on autotrophic plants. Glucose is the primary and premium player for cellular metabolism. From glucose, the living cells make nucleic acids, proteins, and a myriad of other organic compounds essential for cellular function. From glucose one can also produce fuel alcohol by the ancient technology of making alcohol in wine by fermentation by the yeast, or other types of fuel using certain species of bacteria[3].

Although the microbial-based processes of manufacturing fuel ethanol from plants, i.e. sucrose in sugarcane or starch in corn are in place, critics have argued that sugarcane and corn are feed for the men and his domesticated animals not for burning in cars[1]. Some have suggested alternative cellulosic sources – the Elephant grass *Miscanthius giganteus* or the wood of poplar *Populus trichocarpa* as feedstock for renewable energy. In the expectation that new varieties will be created that will grow more quickly in a small space and with a higher proportion of cellulose to lignin the genomes of these plants have been sequenced. However, these plants may not be the most efficient future sources of biofuel since they require good agricultural land and applications of fertilizers. Preferable would be the blue-green algae or the cyanobacteria which fix atmospheric nitrogen thereby eliminating the need for unfriendly petroleum-based nitrate fertilizers required for traditional crops. Additionally, these may be grown in saline water drawn from a nearby sea. This would reduce the use of shrinking and increasingly valuable fresh water supplies. Several countries have vast regions of desert, semi-desert or degraded non-arable lands where large-sized plastic tubs can be set-up and filled with water taken from the nearby sea or briny water in waste wells. This can be seeded with the most self-sufficient of all plants, namely, the photosynthetic nitrogen-fixing blue-green algae or cyanobacteria.

Apparently the Texas scientists have found a strain of blue-green algae which can under special conditions be induced to excrete its intracellularly produced sucrose into the water. After a filtration step, the spent cultivation medium containing sucrose may be seeded with a salt-tolerant strain of fermenting yeast to produce ethanol. Ethanol may then be separated from aqueous medium by distillation. The importance of this discovery is that the blue-green algae are not killed in the process of producing the sugar which is induced to be secreted. After the secretion process, the cells can be used over for the next cycle of sugar production. The sugar is produced in response to osmotic stress. Using sugar directly to produce ethanol by yeasts or fourth generation biofuel from genetically modified yeasts and bacteria will offer a new feedstock source for scale up of biofuel production. Brown's laboratory has developed mutants which can functionally express and extrude cellulose in a gel-like state into the growth medium[4]. This has the potential to produce a new cellulose crop, thereby freeing lands that can be used for certain crops such as cotton and also keep the forests virgin and ecology sound. It has the potential of continuing improvement of yield of biofuel through genetic engineering of strains. Looking at the photographs (Figure 1) kindly provided by Dr Brown, a thought that comes to mind is that the thermophilic strains might be better suited for conditions that prevail in India. Hopefully this can be economi-

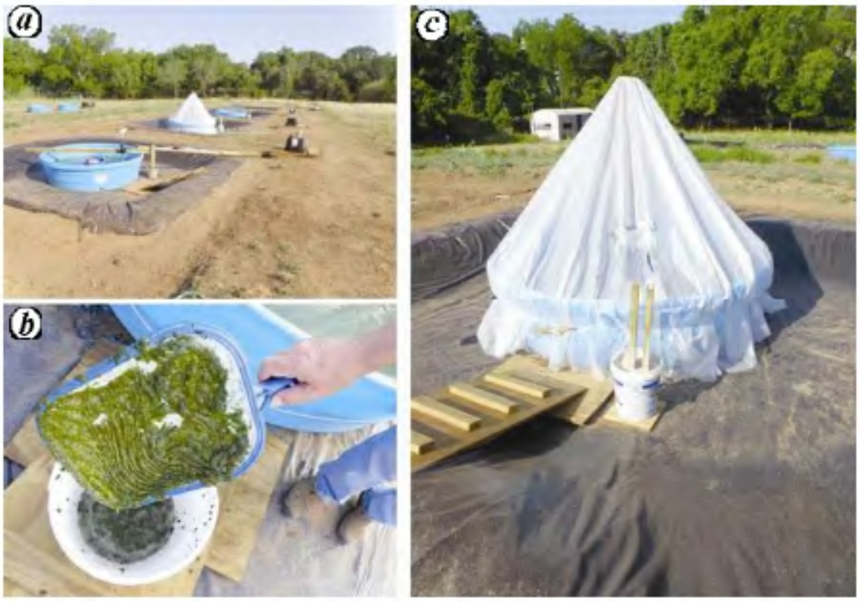

Figure 1. ***a***, A view of the experimental station; ***b***, Blue-green alga; ***c***, A readied covered vat in which alga is growing.

cally feasible. For use in fuel production in industrial-scale thousands of square kilometers of land for exposure of algae to the sun will be necessary. This will require bringing together the breadth of scientific and engineering expertise on par with the United States' 'Manhattan Project' which led to the development of the first atomic bomb. Happy news is the starting of a multibillion dollar Energy Biosciences Institute (EBI) by a consortium led by the University of California-Berkeley and the British Petroleum. The EBI initiative indicates that USA is bent upon translating basic researches into practical solutions for obtaining energy independence from foreign oil.

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India lacks open access awareness programmes

The benefits of open access are now widely known; one can read and download scientific papers without paying subscription charges. Not only readers, publishers are also benefitted by adopting an open access policy (http://www.earlham.edu/~peters/fos/overview.htm). With increasing costs of electronic access to scholarly journals and shrinking library budgets, the need for open access has increased. A recent success story of open access is how sharing of data improved the quality of research on Alzheimer's disease, leading to its early diagnosis. The credit for this goes to the initiative taken by a team of researchers to put the data into public domain such that anyone could access them. After this successful venture into data sharing, a similar project is now planned for research on Parkinson's disease ((http://www.nytimes.com/2010/08/13/health/research/13alzheimer.html?_r=4&th&emc=th)). In January 2010, GlaxoSmithKline proposed to make the database on structure and pharmacological data for potential malaria drugs publicly available (http://www.nature.com/nature/journals/v463/n7280/pdf/46301b.pdf).

The open access week (http://www.openaccessweek.org/) is being held worldwide from 18 to 24 October 2010. The main objective of the open access week is to acquaint the researchers of the benefits of open access policy and persuade them to adopt it. Though the importance of open access is being lauded with activities planned for the year throughout the world, India does not seem to be taking a lead in this direction. This is supported well by the fact that in a long list of open access events (http://oad.simmons.edu/oadwiki/2010) being held in 2010, only three events are planned in India. The irony of the situation is that many articles about open access are published in toll-access journals!

Being a developing country and a country where science is growing, a necessity for India to participate in motivating open access exists. Though India ranked fifth in the world in producing open access journals in 2006, the best Indian works are published in international toll-access journals, making the science non-accessible to Indian researchers[1]. As of 22 September 2010, there were 5,418 open access journals worldwide (http://www.doaj.org/) and about 15% of them are published in the developing world. India accounts for hardly 200 of them (S. Arunachalam, pers. commun.). What is needed is a revolution in India that goes to an international level, which cannot be achieved until progress has been made within the country. The open access week was such an opportunity that India could have utilized.

A small number of open access advocates in India have visited and revisited the issue of open access[2–5] and these have been followed up by responses[6,7]. In 2004, Arunachalam organized a workshop on 'Open access and institutional repositories'. In November 2006, he was part of a workshop on 'Electronic publishing and open access: Developing country perspectives', organized by the Indian Academy of Sciences, Bangalore and the M. S. Swaminathan Research Foundation, Chennai and hosted by the Indian Institute of Science, Bangalore[8]. A draft policy, the National Open Access Policy for Developing Countries, was the outcome of this meeting, but four years down the line none of the developing countries (including India) has adopted it. Open J-gate, the world's largest open access e-journals[9] portal, was launched at New Delhi in 2006. A. R. D. Prasad (Indian Statistical Institute, Bangalore) has organized workshops in the use of DSpace and setting up repositories. Muthu Madhan (International Crops Research Institute for the Semi-Arid Tropics) is helping institutions to set up their own repositories and D. K. Sahu (Medknow Publications, Mumbai) runs about a hundred journals, most of them open access. Apart from these initiatives taken by a miniscule number of people, not much is being done.

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