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Editorial

Bioengineering of CO_2 Utilization for Establishing Circular Bioeconomy and for Mitigating Climate Change

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Carbon dioxide levels in the atmosphere are rising and this is leading to unprecedented climate changes which are causing floods, forest fires, weather changes, draughts etc. effecting global economy There are physical, chemical, biochemical, aquatic and geological techniques for the sequestration, storage and utilization of CO_2. Utilization of CO_2 through some of the physical and chemical techniques has been suggested as a circular economy. However, natural biosequestration technique seems to be a time tested technique for the permanent capture and utilization of CO_2.

The depletion of carbon sources for producing useful chemicals, materials, drugs, fuels etc. has led the world to explore the alternative carbon sources. Plenty of CO_2 is available to produce these carbonaceous commodity products. Enhancement of photosynthesis can lead to the production of huge amounts of different chemicals in plants, trees or algae the natural chemical factories [1,2]. However, there is a grave need to improve the efficiency of sluggish rubisco enzyme which is the universal enzyme produced in abundance. Its reversible action i.e., photorespiration activity is detrimental for the enhanced production of biomass. Thus more research on the genomics, proteomics and metabolomics of this bigger size enzyme would be required to engineer this enzyme for improving its photosynthetic activity. In fact, this enzyme is also present in several chemoautotrophic bacteria which are involved in commercial metallurgical operations, e.g., gold, uranium, copper and pyritic ores [3]. These chemoautotrophic bacteria can sequester CO_2, however, research work would be required for enhancing their growth. The attention of researchers is also invited towards the research on cometabolism of acidogenic microbes with acidogenic microalgal species. The genetic manipulation of rubisco enzyme may be further studied in bacteria such as *E. coli* for the faster production of host of chemicals through Calvin Benson Bessam cycle. In future the biofactories or biorefineries may be set up where these autotrophic microbes may be exploited to utilize CO_2 as the feedstock.

In fact there are six different carbon cycles for fixing carbon in microbes. There is a need to look at the possibility of combining the merits of each carbon cycle with Calvin Benson Bassam cycle by using newer tools of systems biology. Algae use carbon concentrating mechanism and desert plants use crassulacean acid metabolism to operate under limiting conditions. There is a need for deeper understanding of these systems for enhancing the photosynthetic efficiencies. Directed evolution techniques may be used to engineer the action of enzymes for boosting photosynthetic efficiencies in host organisms.

Another area which merits consideration is overexpressing the genes of C4 crops, e.g., maize or sugarcane in C3 crops, e.g., rice, wheat or even some petrocrops or medicinal plants for enhancing their yields through improved activity of these enzymes. A wide variety of commodity products, chemicals, biodegradable polymers, medicines, nutrients etc. can be produced from CO_2 using photosynthetic technique in autotrophic bacteria, plants, algae and other photosynthetic bacteria [4,5].

Further research is also required in the areas of strain screening or strain improvement, recombinant genetic manipulations and designing advanced photobioreactors.

Attention of researchers is also drawn towards further developing the microbial electrosynthetic systems using nanoelectrodes for CO_2 utilization. Enzymatic and bioelectrochemical reduction of CO_2 also leads to the production of higher chemicals. Thus the photoelectrochemical systems may be developed further for converting CO_2 to valuable chemicals. Use of nanomaterials in the electrodes seems to be attractive option. Biotechnological systems may be exploited cascadically to make these processes cost effective and sustainable.

Conversion of CO_2 of the biogas in the anaerobic digesters through microbial action needs more research efforts too. Research work on the artificial photosynthesis is also worthy of further investigation. The modern techniques of synthetic biology, systems biology such as genomics, proteomics, interactomics, quorum sensing, quorum quenching or metabolomics etc. should be explored for studying the microbial conversion of CO_2 using chemoautotrphic bacteria, algae, grasses, aquatic biomass, faster growing plants and trees etc. [5,6]. Research work in these areas deserves more attention. The use of nanobiotechnology or high pressure for improving mass and material transfer in the bioreactors would help in CO_2 bioconversion. Researchers may also pay attention on the development of microbial fuel cells including algal fuel cells for wastewater treatment even, as the research in these areas is still at the stage of infancy.

In order to enhance the photosynthesis in plants and trees the interactomics and metabolomics of plant root and soil microbes especially of nitrogen fixers should be further studied. Exploration on the use of hydrocavitation technique in the bioconversion of CO_2 to produce high value chemicals in higher yields may also be considered.

The transfer of enzymes from one photosynthetic organism into another or their recombination or re-engineering also merits consideration for the production of a wide variety of chemical feedstocks from autotrophic microorganisms including bacteria, microalgae, macroalgae, plants etc. [4-6].

The driving aim should be to improve the conversion efficiencies, sustainability and process economics for producing a wide range of chemicals and drop in fungible fuels with better charateristics [7]. Thus biotechnology would help in addressing the problem of availability of chemical feedstocks and cleaner fuels by utilizing CO_2 instead of polluting petroleum, coal or natural gas.

The concepts of setting up integrated biorefineries based on algae, autotrophic bacteria, land and aquatic plants utilizing CO_2 for the production of great value commodity products, platform chemicals and biofuels can enlighten and energise the future vision of establishing circular bioeconomy in the coming years.

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