www.coast.osustech.edu.ng
COAST
JOURNAL OF THE SCHOOL OF SCIENCE
Volume 3, Issue 1. June, 2021 ISSN: 2714-3716
Coast, J. Sch. Sci. 3 (1): 534 - 541

REVIEW

REVIEW OF THE ENCUMBRANCES AND CHALLENGES OF MICROBIAL BIOENERGY PRODUCTION

[1*]Osiboye, O. O. and [2]Odusina, B. O.

[1] School of Science, Tai Solarin College of Education, Omu-Ijebu
[2]Department of Chemical Sciences , Tai Solarin University of Education, Ijagun, Ogun State.

Abstract

The dilemma of global climate change portends an overall temperature increase for our entire planet in association with rising levels of Green House Gases (GHGs). The global consensus emphasizes the contribution of human activities as well as natural sources to the concentration of GHGs overtime. First generation biofuel systems, such as ethanol made from corn grain, tend to emit more GHGs than cellulosic ethanol systems. In comparison to perennial biomass production, corn planting needs more fertilizer and pesticide thus resulting into greater soil disturbance leading to land use-induced carbon emissions. However, the second and third generation biofuels offer greater potentials for GHGs mitigation through the use of cellulosic feedstock sourced from production systems that has less land-use related GHGs emissions implications. The global potentials for biomass energy production are absolutely enormous, but it falls short of replacing the current energy demands. Increasing biomass production in order to increase biofuels generation would have remarkable negative effect on land use and agriculture. Besides biomass availability, biofuel production is also determined by its interaction with other energy options. More biofuels in the market is capable of reducing the global oil prices which tends to put the oil producing countries of OPEC at a gross economic disequilibrium. Advanced biofuel technology is expected to expand production capacity slowly, but high feedstock prices continue to encumber biofuel producers in Europe. The major player in OPEC appears to draw consolation from these challenges that seems to slow down the biofuel invasion of the global oil market.

Keywords: Green House Gases, biofuels, challenges, energy, cellulosic

The drive for renewable microbial bioenergy is a global agenda, but a successful outcome requires creative technologies that impact the in-depth understanding of microbial systems. The need for renewable energy options to replace fossil fuels in a sustainable manner has become a pressing issue requiring premium innovation. Strategies to identify novel enzymes and new organisms with optimum biofuel production capacities will certainly require tinkering functional cellular processes (Rubin, 2008). The motivation of the global drive to decrease green house gas (GHG) emissions and reducing the reliance on fossil fuels remains the critical thrust of deriving different scheme of supporting sustainable microbial bioenergy production. Therefore, anthropogenic activities that prioritizes participation in putting in place frame works that facilitate the outright banning of fossil derive materials such as coal, oil and gas and so on beacons for global interrogation. The potential consequences of escalating occurrences of extreme climates events occurring on the global scale, foretell the harsh outcomes which the future portends for earth's inhabitants, if fossil fuels production and consumption is not discontinued (National Energy Technology Laboratory., 2010).

Therefore, efforts to address climate change and guarantee energy provision have led to the development of a number of policy priming. For instance, the climate and energy package (2008) of the European Union requires that 20% reduction of CO_2 emission and a target of 20% share of energy supply from renewable energy by 2020 from her 27 member states. Policy instruments within the package are the European Union Fuels Quality (Directive (EUFQD, 2009) and the Renewable Energy Directive (EU RED 2009). The FQD goal is the reduction of harmful atmospheric emissions, including green house gases, and includes monitoring of life cycle GHG emissions. The RED focus is to provide renewable energies including bioenergy and biofuels with sustainability of the biofuels and the land used to grow feed stocks as its tangential component (Kyndt, 2010).

However, comparing with the overall drive to facilitate bioenergy generation is the agricultural land holdings and expansion. In so many countries upholding agricultural practices it is crucial to improve living conditions and local economy. Therefore, setting targets for biomass used for bioenergy must be premised on the availability of biomass resources and the requirements for land use. Thus, the potential of bioenergy generation is hinged on biomass production which hangs on (land) or aquatic productivity potentials. Apart from the issues surrounding land, considering the technologies for converting feedstock is very germane. Every technological consideration comes with its specifications that must be put into cognizance *vis-à-vis* the feedstock composition, uniformity, quantity and quality. The efficiency of feed stock production directly bothers on sustainability of cost-effective options.

For many developing economy, biofuel has been in use for centuries as the main provision for domestic energy supplies. However, the need to generate energy from available biomass for the provision of light, industrial needs and powering transport is still an imperative challenge.

Many of the emerging technological initiative in the generation in the developed as well as developing economies of the world depend on first generation biomass feedstock (Stricklen, 2006). These sources are largely food crops and thus technically not sustainable for biofuel production. The adverse effects of using largely food crops for biomass feedstock compels research into the use of lignocellulosic resources, otherwise known as second generation biomass feedstock. These feedstocks are mainly residues of crops, woods and crops cultivated majorly for biofuel production and are considered as sustainable alternatives since they are not competing with food (Cherubini, 2010).

In the trail of research into the use of lingnocellulosic biomass resources, is the exploration into the wide variety of photosynthetic and fermentative bacteria and algae as biocatalysts for biofuel production owing to their high lipid or carbohydrate constituents. In comparison to the first- and second-generation feedstock, these microbial cells refer to as third generation feedstock are relatively more sustainable since they are not in competition with food. They unlike the "generations" before them, do not require expanse of land, aquatic provisions, fertilizers additions or pesticides for cultivation (Stolarski, et al., 2015)

However, biofuels generated from third generation sources have critical limitations which require genetic modification or metabolic engineering in order to improve some of their characteristics features such as high energy density, low hygroscopicity, and economic performance. The processes of improving these features are categorized as the fourth-generation bio-refining.

The technological readiness levels to fully engage the third and fourth generation bio-refining are at different stages of research, development and demonstration. For instance, generating ethanol from lignocellulosic waste through hydrolysis and fermentation has the capacity for high bioenergy potential but the commercial deployment of the technology is yet to be operationalise. The conversion of cellulose to ethanol involves two steps: the breakdown of the cellulose and hemicellulose components of the biomass into sugar and then the fermentation to obtain ethanol (Wyman, 2010).

Africa in Particular in spite of its agronomical suitability lacks infrastructure and technical know-how for operating commercial scale biofuel plants. Many countries in the region are unstable and are affected by varying degrees of corruption that erodes the capacity to build sustainable infrastructures. Thus, corruption and lack of regulatory control have resulted into ineffective environmental regulations, which ultimately frustrate the possibility of large-scale sustainable biomass cultivation (Fredriksson and Svensson Cubbin and Stern, 2006). It is impossible to imagine that the optimal exploitation of agricultural resources could be sustainably attained in countries with compromised capacity for environmental governance. The Existence of widespread corruption has a deeply corrosive effect on the capacity of government for sustain development. In addition to the negative effects of corruption on development, lack of funding for research also encumbers bioenergy production because public funds have found various illicit ways of getting into private pocket.

Literature Review

Global investment in renewable energy decreased in 2012 from the previous year of $279 billion to $244 billion in response to economic and policy-related uncertainties in some traditional markets, as well as to falling technology costs, which had a positive effect on capacity installations (Cerutti *et al,* 2017). Renewable energy is becoming increasingly affordable in the developing economies with investment expanding. Ultimately biofuels will be produced at lower cost overtime but the feedstock and technology pose time and money encumbrances since the new supply chains, feedstocks and technology are yet to be proven and investment capital expenditure is still very high. Therefore, upgrading facilities and infrastructures to meet production projections will definitely be slow. Indeed, cellulosic ethanol plants are still considerably more expensive to build than corn ethanol plants, by a factor of 2-3 in higher investment costs even though cellulosic feedstock are cheaper (U.S. Annual Energy Review, 2011). Capital impediments make competition for financing other renewable energy alternatives such as wind forms stronger. Thus, the solar and wind sectors are certain to expand with a combined share of 90% investment while biofuel is projected to reach a share of just 8% in total money investment over the next 20 years.

Innovative Research in Microbial Bioenergy Production

The primary research and development

objectives of bioenergy and biofuel production tentatively encompass a tripartite frame of aims. These aims include:

1. Evolving optimum scientific engineering and technology path ways for converting lignocellulosic and municipal waste biomass as well as residues of agriculture into clean energy
2. Reducing to the barest minimum the consumption of process water and the hazardous aftermath of energy production on the environment that often led to air pollution and global warming.
3. Addressing the critical long-term issues of availability and sustainability of feedstock

The conversion of organic compounds into electric power generation has been reported in various designs and size of microbiofuel cell (MFCs). In this regard MFCs based on compost have been shown to have the capacity to generate bioelectric power by hydrolysis and oxidation processes of organic substances (Siddiqui and Pathrikar, 2013). The MFCs has been supplied with diverse feedstock such as agricultural residues ranging from waste from cutting grass, oil cake from extracted mustard grains, chicken droppings materials of carbonaceous nature (wastes like wood shavings and dry leaves from chicken pens) (Srivastava, 2019) .

Also, bioelectrochemicals cells (BEC) have gained contemporary significant interest in generating bioenergy from organic biomass and waste materials. In particular microbial fuel cells (MFCs) and microbial electrolysis cells (MECs) have been extensively exploited for bioelectricity and biohydrogen generation (Logan *et al.,* 2015; Dai et al., 2016). The unique characteristics of the microorganisms or exoelectrogens deployed in both fuel cells for bioenergy production in BEC is the exhibition of a definite molecular mechanism that aid the transfer of electrons from microbial outer- membrane to the conductive surfaces (Kracke *et al*, 2015).

Theoretically, an MFC can produce a maximum voltage of 1.2v and the optimum hydrogen production yield in MEC would be 3.4 mol H_2/mol-[1] acetate (Logan *et al*, 2015). Thus, the energy generated from MFCs and MECs are currently insufficient for industrial applications and hence not commercially feasible. The possibility of exploration of the compelling potentials of BECs will be facilitated more robust understanding of the microbial pathways that are instrumental in BECs systems innovation.

Innovative research is needed to strongly enhance biomass pretreatment and fractionation enzymatic hydrolysis, saccharification, microbial fermentation as well as product separation and purification processes. Furthermore, engineering tinkering are required to design, optimize, and scale-up the biochemical conversion system, which include both the biochemical reactor and the supporting auxiliary components. Also, the thermochemical gasification which is the main process of converting biomass into synthesis gas (syngas) such as H_2, CO, CO_2, CH_4 water vapour, and trace impurities. Arguably one of the most cost-effective and efficient energy conversion processes, thermochemical gasification is achieved by reacting the biomass feedstock at high temperature (700°C) (Li et al., 2019).

Biosyngas conversion to liquid hydrocarbon fuels produce a more dense substance compared to gasoline and other petroleum derived fuels. (Bala, 2005). However, Huber (2013) opined that biomass feedstock are fundamentally different from petroleum feedstock because of the high oxygen content of biomass leads to low thermal stability thus leading to a high degree of difficulty in controlling functionality

Huber (2013) therefore suggested that the selective removal of oxygen from biomass derived molecules is the key to efficient conversion of biomass derived molecules into fuel.

Another thermochemical conversion is fast pyrolysis which is the process of rapid thermal decomposition of organic compounds in the absence of oxygen from 400-500°C to produce liquid oils, char and little gas quantity. Liquid bio-oil from pyrolysis has the capacity to contribute significantly to higher percentage of liquid biofuel availability and other valuable chemicals. However, plant scale up, cost reduction, oil quality and stability, environmental health and safety issues are challenges that stand in the way of exploring the maximum potentials of thermochemical conversion.

Lack of government policies to create demand for bioenergy

The political prominence of the long-term effects of climate change expectedly necessitated the increased focus on the policy reform and legislation centered on bioenergy issues. With massive important political, economic and environmental issues that trails energy security concern, many countries are compelled to actively seek alternatives to fossil fuels both in short and long term. (Chester, 2010). In encouraging the production and use of bioenergy alternatives to fossil fuels, both developed and developing countries alike are seeking to mitigate the effects of climate change. However, much of the regulatory emphasis dwells on the production and use of first-generation biofuels as a more eco-friendly alternative to fossil fuels. The overt emphasis on the first-generation biofuels sets up unsustainable competition for food production, which invariably slows down active legislation in favour of bioenergy production. Furthermore, the potentials of second and third generation biofuel production, which does not challenge food security is yet to be explored globally. Policies put in place worldwide have had a major impact on the speed and extent of biomass renewable energy development, despite design and implementation problems.

Overall, country specific policy mechanisms are evolving as countries gain experiences. The bottom line is that microbial bioenergy promoting policies should expand opportunities for rural development, but this must be done in the context of broader sustainable development criteria and not at the expense of food security or negative environmental impacts.

Cost and Affordability

Biomass could be cultivated on virtually all available land, but the reality is that yields may not be high enough to cover production cost even if favorable policy is in place. Feedstocks cost significantly affect the resultant production cost. It is estimated that about, one-third of biofuel production cost is associated with biomass cost.

In 2012, the total amount of feedstock available was roughly 341 million tons. About 70% of this were sourced from agriculture residues and the remaining 30% from forest residues (Temilsira and Ahrestha, 2011)

In the nearest future, dedicated energy crops are projected to be the major feedstock for bioenergy conversion. Potential high yielding biomass feedstock available for conversion are Agave bagasee in Mexico and Australia, Napier grass found in abundant quantity in Japan, Date palm in Middle East countries and Africa and oil palm empty fruit bunch found in reasonable quantity in Indonesia and Malaysia. (Hashimoto, 2011) In a bid to boost the availability of energy crops, farmers will have to be convinced to cultivate bioenergy feed stocks with the guarantees of buy back to remove the risk of failing to sell the cultivated products particularly in the event of an unlikely glut.

Also, relevant industrial waste supplies provide a pool of choice feedstock for biofuels and biochemicals. These choice feedstocks include wheat dust, rice dust, cotton grain waste, vineyard prunings, Orchard trimmings and fruit waste.

Global perception of oil producing nations

An increasing number of policies, programmes and projects have been put in place to support the use of biofuels by both developed and developing countries for over a decade. (United Nations. 2000.) Energy security have in recent time become central issue in the award of incentives such as mandatory blending targets and tax advantage as well as in funding research for advancing biofuel technologies. (Pradhan and Mbohwa, 2014). These measures were encouraged by the high prices of fossil fuels and the threat of burdening the environment with GHG emissions.

However, the global development in bioenegy sector notwithstanding, serious controversies has bedeviled its progress particularly the first-generation liquid biofuels derived from the edible parts of food crops. Proponents of bioenergy emphasized the potential of bioenergy to mitigate climate change, increase energy security and enhance rural development. On the other hand, there are formidable concerns that bioenergy projects portend negative environmental and socio-economic distortions such as adverse impacts on food security. (Houghton, 2008). These concerns gain more social mileage since societal perceptions are significant factors for consideration in developing future energy system of the second, third and fourth generations. It is an acknowledged fact that bioenergy stands across the borders of several policy sectors (Panoutsou, 2008) as it is more complex in its forms than the other renewable energies. Therefore, the developers of biomass projects need to take into account the perceptions of all the influencers of the development of the global bioenergy project.

Indeed, positive social perception as well as social acceptance of bioenergy is an essential prerequisite to the political legitimacy of the bioenergy project, and by extension the willingness of policy-makers to introduce or maintain supportive policy scheme for bioenergy production.

Fear of OPEC

Oil is the leading source of commercial energy in the modern world, accounting for around 40 percent of today's world energy mix. (Ramchandra and Boucar, 2011) It is a unique commodity with a combination of attributes which exceeds that of any energy source – sufficiency, versatility, accessibility and in many areas low cost.

There is every indication that oil will maintain this leading role well into the 21st century. (Pavit and Patel, 1998) despite the fact that oil has come under pressure on environmental grounds particularly in the content of climate change.

Two-third of the worlds commercial energy is expected to come from petroleum oil and gas up till 2020. (Lange *et al.*, 2018) OPEC endowment with both hydrocarbon is not in doubt. With almost 80 percent for the worlds proven oil reserve and nearly 50 percent of its natural gas, it would seem logical that consumers will seek to get most of their oil from OPEC's member countries.

However, the fear of the security of supply and over dependence on specific regions for crude oil exist. The reason for this fear stems from the fact that the world's oil reserves are concentrated mainly in developing countries, while most biofuel industries are located in industrialized nations.

The supply of biofuels to the fuel markets causes the amount of fossil fuel (gasoline an diesel) consumed in the oil importing countries to decline, the amount consumed in the OPEC countries to increase and the global fuel consumption to increase. World fuel prices declines owing to the supply of biofuel although OPEC countries were able to mitigate the impact of the competition by deploying their market power.

OPEC however envisaged that even in the most optimistic of scenarios, biofuel will provide only a small proportion of the world's demand for fuel in the next decade. (Kelli and Josh, 2020) Nevertheless, OPEC is not unaware that a marginal increase in biofuel supply to the energy market could have a powerful impact on world's oil price. It seems that OPEC strategy of reducing the supply of oil in order to lessen the fuel price reduction attributed to the supply of biofuels appears to be working in the interim.

Conclusion and Recommendation

The potential of microbial energy production is enormous and challenging considering the various blocs of economic interest.

Therefore, the common desire to pursue clean energy options must be proceeded by deliberate global policies for promoting the cultivation of biomass feed stuffs as an alternative energy source. Thus, the need to focus on energy efficient technology in the use of cellulosic feedstock sourced from production systems that has less land use related green house gas (GHG) emissions implications should be prioritize by the different blocs of economic interest on a global scale.

References

Bala, B.K. (2005). Studies on biodiesels from transformation of vegetable oils for diesel engines. Energy Edu Sci Technol 15:1–45

Cerutti, E., Claessens, S. and Laeven, L. (2017), The use and effectiveness of macroprudential policies: New evidence, Journal of Financial Stability volume 28, pages 203–224.

Cherubini, F. (2010). The biorefinery concept: Using biomass instead of oil for producing energy and chemicals Energy Convers Manag, 51 (2010), pp. 1412-1421, 10.1016/j.enconman.2010.01.015

Chester, L., (2010). Conceptualizing Energy Security and Making Explicit its Polysemic Nature. Energy Policy, 38 (2): 887 – 895.

Dai, H., Yang H., Liu X., Jian X., Liang Z. (2016). Electrochemical evaluation of nano-Mg(OH)2/graphene as a catalyst for hydrogen evolution in microbial electrolysis cell. Fuel 174, 251–256. 10.1016/j.fuel.2016.02.013

Fredriksso, P.G. and Svensson J. (2003). Political instability, corruption and policy formation: the case of environmental policy. Journal of Public Economics, 87, 1383–1405.

Hashimoto, A (2011). "Sustainable Bioenergy Systems for Hawaii." Presented at the World Congress of Bioenergy, April 25-30, 2011. Dalian, China.

Houghton, R.A. (2008). Carbon Flux to the Atmosphere from Land-Use Changes: 1850-2005. In: Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., USA.

Huber, G. W. (2007). "Breaking the chemical and engineering barriers to lignocellulosic biofuels: a research roadmap for making lignocellulosic biofuels a practical reality," in *NSF, DOE and American Chemical Society Workshop*, Washington, DC.

Krasity K. M and Holland J (2020). "Nigeria

LNG expansion FID: Finally the right time," IHS Markit *LNG Insight*.

Kracke, F., Vassilev I. and Krömer J. O. (2015). Microbial electron transport and energy conservation–the foundation for optimizing bioelectrochemical systems. Front. Microbiol. 6:575. 10.3389/fmicb.2015.00575

Kyndt, J (2010). Current Procedures and Innovations." Algae Based Biodiesel. Algae for Biofuels.

Lange, G.-M., Wodon, Q. and Carey, K. (2018), The Changing Wealth of Nations 2018: Building a Sustainable Future, World Bank, Washington D.C.

Li, S.; Zheng, H.; Zheng, Y.; Tian, J.; Jing, T.; Chang, J.-S.; Ho, S.-H. (2019). Recent advances in hydrogen productionby thermo-catalytic conversion of biomass.Int. J. Hydrogen Energy, 44, 14266–14278.

Logan, B. E., Wallack M. J., Kim K. Y., He W., Feng Y., Saikaly P. E. (2015) Assessment of microbial fuel cell configurations and power densities. Environ. Scie. Technol. Lett. 2, 206–214. 10.1021/acs.estlett.5b00180

National Energy Technology Laboratory (NETL) (2010). Cost and performance baseline for fossil energy plants, Volume 1: November. DOE/NETL-2010/1397. United States Department of Energy.

Panoutsou, C. (2008). Bioenergy in Greece: Policies, diffusion framework and stakeholder interactions. Energy Policy, 36(10), 3674-3685

Pavitt, K. and P. Patel (1998), ''Global Corporations and National Systems of Innovation:Who Dominates Whom?'' in J. Howells and J. Mitchie (eds.), National Systems ofInnovation or the Globalisation of Technology, Cambridge University Press, Cambridge.

Pradhan. A. and Mboliwa. C. (2014). Development of biofuels in South Africa. Challenges and opportunities renewable and sustainable energy reviews (3) 1089-1100.

Ramchandra P and Boucar D (2011): *Green Energy and Technology*. Springer, London Dordrecht Heidelberg New York.

Rubin, E. M. (2008) Genomics of cellulosic biofuels. Nature. 454(7206):841–5.

Siddiqui, U. Z. and Pathrikar, A. K. (2013) The future of energy biobattery. *IJERT* **2**, 99–111 .

Stolarski, M.J.; Krzyzaniak, M.; Luczyski, M.; Zaluski, D.; Szczukowski, S.; Tworkowski, J.; Golaszewski, J. (2015). Lignocellulosic biomass from short rotation woody crops as a feedstock for second-generation bioethanol production. Ind. Crop Prod. (2015), 75, 66–75.

Stricklen, M (2006). Plant genetic engineering to improve biomass characteristics for biofuels. Current Opinion in Biotechnology, 17(3): 315–319

Timilsina, G. R. and Shrestha A. (2011). "How much hope should we have for biofuels?" Energy, vol. 36, no. 4, pp. 2055–2069, 2011. View at Publisher · View at Google Scholar · View at Scopus

U.S. Annual Energy Review (2011)"Biofuels Issues and Trends. www.eia.gov/a.

United Nations. (2000). Sustainable bioenergy: a framework for decision makers".

Wyman, C.E. (2010). "Cellulosic Ethanol: A Unique Sustainable Liquid Transportation Fuel." *Biomass & Biofuels* 33:381–2.