Renewable and Sustainable Energy Reviews 73 (2017) 205–214

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Utilization of bioresources for sustainable biofuels: A Review

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ARTICLE INFO

Keywords:
Biomass
Terrestrial
Marine
Biofuels
Sustainability

ABSTRACT

The global energy demand has been increasing rapidly due to depletion of fossil fuels, continuous growth of world population and industrialized economy. India has surpassed to Japan and Russia and become the third largest oil consumer in the world. Unfortunately, India's primary energy consumption has increased due to reduced oil and gas production. The increased consumption of imported oil could lead to turbulence in economic growth. Due to increasing demand of oil fuels and consequent impact of global warming issues, development of alternate energy is a top priority in research and developments sector. The bioenergy produced from the biomass is being a sustainable alternate energy source which received high acceptance in various sectors include public, industries and government policies. from the Government, public, industries and researches for its sustainability. This review focuson bioprospecting of biomass from terrestrial and marine resources for non conventional energy production and the stepping stones of biofuel for near future. These carbohydrates can be converted into various forms of biofuels either directly or indirectly by exploiting microorganisms. However, the production process and chemical transformation is being an expensive process and therefore commercial supply of biofuel in largescale is not yet successful. Hence an economic and efficient production process is essential to commercialize biomass based biofuels. This article highlights the overview of sustainable and renewable resources for biofuel and stepping stones of biofuel commercialization.

1. Introduction

1.1. Over view of Biofuel

In current situation fossil fuel is being a primary energy and its contribution around 80% in which transport sector takes share of 58% [1]. The sources of these fossil fuels and oil reserves are depleting very fast and they are found to be major contribution for emission of harmful gases. These gases leads to negative effects like, receding of glaciers, loss of biodiversity, climate change, rise in sea level, etc. High demand for this fossil fuel is also affecting the global economic activities as there is increase in the prices of crude oil. The high-speedy modern world travels by both industrialization and motorization and it is being a main cause for the unpredictable fuel demand [2]. Many alternative energy sources have been already available include biofuels. Researchers are continuously working in the biofuel production from the sustainable biomass since it is being an efficient alternative to replace non renewable fuels [3].

The advantages of biofuels over petroleum fuels are (a) they can be easily extracted from the biomass, (b) they are sustainable due to biodegradable property, (c) its combustion based on carbon-dioxide cycle, (d) more environment friendly. The share of biofuel in automobile market will grow rapidly during the next decade because of its environmental merits. This will definitely result strong growth in agriculture sector for more production and associated by-products [4,5].

Biofuels which are produced predominantly from biomass are referred to solid, liquid and gaseous fuels. The biofuels are classified into three generations as first, second and third based on the chemical and complex nature of the biomass. The first generation fuels, biodiesel and vegetable oils has been produced from the crop plants and the second, bioethanol and biohydrogen has been produced from agricultural by-products and energy plants which requires fertile lands for growth. The marine resources, seaweeds and cyanobacteria are attractive sources for the third generation biofuels production (biogas, bioethanol and biobutanol) as they produce large biomass in a stipulated time period and it doesn't require land for growth [5,6].

Biomass has been reported as a fourth largest available energy resource of the world [7]. Biomass can also be referred as natural and inexpensive form of storage device for energy and that energy could be utilized at any time [8,9]. The current annual availability of biomass in India is estimated around 500 million metric tons, which includes

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http://dx.doi.org/10.1016/j.rser.2017.01.070
Received 15 September 2016; Received in revised form 17 November 2016; Accepted 9 January 2017
1364-0321/

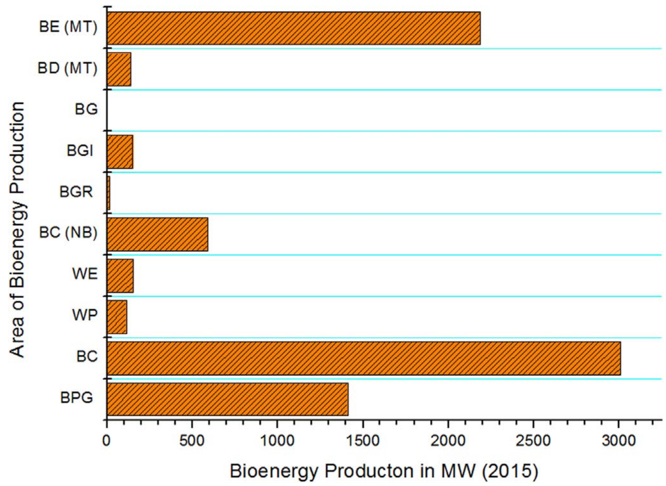

Fig. 1. Bioenergy production prospects from biomass utilization in India. Note: BE-Bioethanol, BD-Biodiesel,BD-Biodisel, BG-Biogas, BGI-Biomass gasifier industrial, BGR-Biomass gasifier rural, BC (NB)-Biomass cogeration Non bagasse, WE-Waste to energy, WP-Waste to power, BC-Biomass cogeneration, BPG-Biomass power and gasification, MW-Megawatts, MT-Million tons.
Source: India Biofuel Annual 2015 [18].

Table 1.
Biomass generated from main agricultural crops in India.
Source: Agricultural Research Data Book 2016 (http://www.iasri.res.in) [17]

Crop	Biomass residue Million tons (2009-15)	Biomass average Million tons (2009-15)
Rice husk	303	50.5
Wheat straw	719.4	119.9
Maize cobs	39.1	6.51667
Pearl millet Straw	74.8	14.96
Sugarcane bagasse	675.3	112.55
Coconut shell	12.5	2.5
Coconut fiber	15.1	3.02
Coir pith	22.7	4.54
Groundnut shell	13.8	2.3
Cotton stalks	171.6	34.32
Jute sticks	13.2	2.642

agricultural and forest biomass and the energy potential of this biomass is estimated at around 18,000 MW [10]. In India the bioenergy production achieved from biomass was shown in Fig. 1. The researchers are finding the effective way to grasp the potential energy saved in the biomass though the mechanism of energy transfer mechanism is not appropriately exhibited yet. Tones of biomass generated from industry, forest, agricultural, marine and urban solid waste are decaying with uncontrolled mechanism and leading to environmental problems by unpredictable toxic gas emission [7,11,12]. The biomass generated from major agricultural crops of India is listed in Table 1. The effective utilization of these renewable resources would leads direct benefits as reducing GHG via utilizing the green fuels, reducing environmental pollutions, improving rural economy [13,14]. Of late, biorefineries or biomass refineries have been reported to produce the required energy (direct electricity generation in combined cycles), fuels (liquid bio-fuels), and chemicals (platform hydrocarbons extracted from biomass using an assortment of processing techniques) with less ecological foot prints [15].

Production of biofuels predominantly dependent on terrestrial plants, which have the limitation of cultivable land exploitation, marine biomass include seaweeds are new sources of biofuel feedstock produces highest percentage of biomass productivity in lesser time and therefore such bioresources can be exploited for renewable biomass based energy production. The various terrestrial and marine resources for sustainable and renewable resources for biofuel production are listed in Table 2.

The photosynthesis fuel has been initiated as another blooming field of biofuels. The plants and algae effectively utilizes the atmospheric CO_2 and stored the energy as biomass which be converted in to any form of energy in reverse. The photosynthetic microbe cyanobacteria has the ability to convert the CO_2 directly into ethylene a fuel chemical without production of biomass. The NREL research team developed genetically engineered cyanobacteria for hyper production of ethylene [16].

1.2. Global view

Globally, it has been observed that for future energy systems the estimates of biofuels are very high. If the share of biofuel in automobile market reaches to its maximum then the availability of bioresources for

Table 2:
Various terrestrial and marine resources for renewable and sustainable energy.

Terrestrial resources		Marine resources	
Energy Plants	Agricultural by-products	Macroalgae Seaweeds	Microalgae
Jatropha	Oil palm shells	*Acrosiphonia orientalis*	*Scenedesmus obliquus*
Switchgrass	Pineapple waste	*Ulva fasciata*	*Nannochloropsis oculata*
Alamo – WP	Forest (logging) residues	*Ulva lactuca*	*Dunaliella tertiolecta*
Alamo – leaves	Coir pith	*Enteromorpha compressa*	*Phaeodactylum tricornutum*
Alamo – stems	Sugarcane bagasse	*Caulerpa peltata*	*Tetraselmis suecica*
Blackwell – WP	Empty fruit palm bunches	*Valoniopsis pachynema*	*Chaetoceros calcitrans*
Cave-in-Rock – WP	Oil palm fronds	*Bryopsis pennata*	*Isochrysis galbana*
			Botryococcus brauni
Cave-in-Rock – WP (high yield)	Coconut husk	*Enteromorpha intestinalis*	*Chalmydomonas reinhardtii*
Cave-in-Rock – leaves	Soybean hulls	*Caulerpa racemosa*	*Euglena* sp.
Cave-in-Rock – stems	Corn stover	*Caulerpa sertularioides*	*Spirogyra* sp.
Kanlow – leaves	Wheat straw	*Padina tetrastromatica*	*Phormidium* sp.
Kanlow – stems	Oil palm fibers	*Dictyota adnata*	*Cyanobacteria*
Trailblazer	Oil palm trunks	*Lobophora variegata*	
Silver grass	Silk cotton	*Sargassum wightii*	
Bermuda grass	Rice husk	*Spatoglossum asperum*	
	Banana residues	*Centroceras clavulatum*	
	Paddy straw	*Gelidium pusillum*	
	Reed	*Grateloupia filicina*	
	Rapeseed	*Asparagopsis taxiformis*	
		Gracilaria corticata	

Table 3.
Chemical constituents (% DW) of agricultural by-products.
Source: [44]

Lignocellulosic biomass	Cellulose	Hemicellulose	Lignin	Extractives	Reference
Oil palm shells	20.8	22.7	50.7	4.8	[23]
Pineapple waste	19.4	22.4	4.7	–	[24]
Forest (logging) residues	46.3	28.3	26.5	4.4	[25,26]
Coir pith	26–30	03–07	30–40	–	[27,28]
Sugarcane bagasse	26–50	25–28	23–25	–	[29,30]
Empty fruit palm bunches	54.4	28.0	17.6	2.8	[31]
Oil palm fronds	62.3	24.2	14.8	1.8	[32]
Coconut husk	44.2	12.1	32.8	6.4	[33]
Soybean hulls	29–51	10–20	1–4	–	[34–36]
Corn stover	31–41	20–34	16–23		
Wheat straw	32–49	23–39	5–19		
Oil palm fibers	20.8	38.8	28.5	6.3	[37]
Oil palm trunks	41.2	34.4	17.1	2.8	[38]
Silk cotton	80–85	10–15	3.5–05	–	[39]
Rice husk	35.1	20.9	17.6	–	[40]
Banana residues	31.9	18.0	22.4	8.0	[41]
Paddy straw	35.0	21–25	6 –13	–	[30,42]
Reed	39.5	29.8	24	–	[43]
Rapeseed	27.6	20.2	18.3	–	

biofuel production will become a critical factor.The transition of hydrocarbon economy to carbohydrate economy can be attained with the help of biomass to produce biomethanol and bioethanol to replace oil based fuels. The biofuel scenario have produced reduction in oil imports, growth in GDP, gave an energy ratio and growth in per capita affluence. Every scenario is having advantages as reduction in carbon-dioxide emissions, generation of jobs, growth in GDP, the production process energy ratio, etc. [19,20].

1.3. Biofuel Economy

In today's world even with high oil prices, the cost of biofuels has not been compromised with conventional fuels. The economy of biofuel is boosting rapidly since 21st century. Over the past century the development of hydrocarbon economy had been shaped, the same forces are now shaping the biofuel economy and its biorefineries. As the biofuel has its own merits towards eco-friendly environment, the effective contribution of biofuel in transport sector will leads to rapid growth in near future. Biofuels are considered as relevant technology because of several reasons by both industrialized and developing countries. If the public support (transport) system get benefited with the utilization of biofuels then only the national indicative targets could be achieved. For encouraging the supply of feed stocks for production of biofuel some supports are available, the main approaches were biofuel obligation and tax reduction [5].

In recent years the energy production is being an important driving force of the agriculture development. For economic development the agriculture energy production plays an important role. The development of economy is based upon the most number of people lives in rural areas and their agriculture production. Therefore, adopting the development programmes for integrated communities is very necessary. These community programmes will enforce the development of socio-economic aspects of the country. Agricultural production of methanol from natural gas and synthesis ethanol from ethylene is very expensive at present. The simultaneous production of bioethanol parallel to the biomethanol from sugar juice is quite attractive in terms of economic aspects in the areas where hydro-electricity is available at cheaper cost. Conversion of biomass into methanol is quite expensive and less efficient than into hydrogen from the natural gas, biomass and coal. The research reports and reviews constantly warns the depletion of conventional energy like petroleum, natural gas and coal and propose the environment friendly huge biomass as a best alternative for the energy demand [5].

The objective of this review is to explore the available bio resources for biofuel production which includes:

(a) Classification and potential of terrestrial and marine bioresources
(b) Combine the challenging factors of biofuel production
(c) Current technology involved in the bioconversion of biomass
(d) Sustainability, policy analysis and commercial aspects of biofuel.

2. Bio resources (Terrestrial and Marine)

2.1. Classification and potential of Terrestrial resources

2.1.1. Jatropha

The project Jatropha has been started by 2007 and successfully completed three phases. The phase IV was initiated in the state of Tamil Nadu, India by 2012 and preceding the recent objectives. The important goal of the project is to decrease the CO_2 emission by increasing the utilization of biodiesel. It also targeted the youth from the developing countries to alert the environmental issues caused by green house gas and its negative influence on environment (http://www.projectjatropha.com). The plant Jatropha has the energy potential of around 300–400 Lt./ha/year [21].

2.1.2. Agricultural by-products

The better understanding of agricultural biomass has given a route for many secondary energy carriers like ethanol, methane and hydrogen. The production of energy from agricultural and other biomass residues through microbial action could complement these well-known renewable energy sources in serving as eco-friendly sources of alternative energy. Various forms of lignocellulosic substrates are available in nature that could be grouped into a main category as agricultural by products based on the abundance. The agricultural biomass mainly composed of lignocellulose contains 60 – 70% of holocellulose which includes cellulose and hemicellulose. The lignin content in the biomass is approx. 10–25% of the dry weight (Table 3).

The number of research reports clearly indicated the composition of biomass from various sources as cellulose, hemicellulose and lignin. However, few researchers reported other components of biomass in two categories as extractive and non-extractive (non-cell wall materials) – NCWM [22]. The effect of these molecules in bioenergy production from biomass is not well reported yet. The chemical constitutions of various forms of biomass are given in Table 4.

Table 4.
Chemical constituents of various forms of plant biomass.
Source: [22,45]

Wood components	Hardwood (%)	Softwood (%)	Herbaceous plants (%)
Cellulose	40–50	41–53	24–50
Hemicellulose	25–35	25–30	12–38
Lignin	20–25	25–35	06–29
Pectin	01–02	01–02	Trace
Starch	Trace	Trace	Trace

Table 5.
Chemical constituents of energy plants.

Energy plant biomass	Cellulose	Hemicellulose (% Dry Weight)	Lignin	Reference
Switchgrass				[50]
Alamo – WP	33.48	26.10	17.35	
Alamo – leaves	28.24	23.67	15.46	
Alamo – stems	36.04	27.34	17.26	
Blackwell – WP	33.65	26.29	17.77	
Cave-in-Rock – WP	32.85	26.32	18.36	
Cave-in-Rock – WP (high yield)	32.11	26.96	17.47	
Cave-in-Rock – leaves	29.71	24.40	15.97	
Cave-in-Rock – stems	35.86	26.83	17.62	
Kanlow – leaves	31.66	25.04	17.29	
Kanlow – stems	37.01	26.31	18.11	
Trailblazer	32.06	26.24	18.14	
Silver grass	37.4	27	21.5	[30]
Bermudagrass	47.8	13.3	19.4	[43]

Note : WP-Whole Plant.

2.1.3. Energy plants

The energy plants are the dedicated crops cultivated routinely. The choice of crops could be such that numerous harvests could be obtained from a single planting as in the case of grasses. However, utilization of different biomass resources depends largely on their local availability and the product required [46–49]. The prime source of polymers of the reported energy plants are given in Table 5.

2.2. Classification and potential of Marine resources

Algae can be broadly classified into two groups, microalgae which represent blue-green algae, dinoflagellates, bacillariophyta (diatoms) and second one is macroalgae (seaweeds) which comprise green, brown and red algae. Marine algae are the most primitive group of vegetation which came to exist in the pre-Cambrian era. They contribute 90% of the species of marine plant and are crucial primary producers in oceanic food web [51].

2.2.1. Macroalgae (Seaweed biomass)

Seaweeds from marine environment are currently used as a valuable biomass for renewable energy production as its cellulose content is found to be significant with less lignin content. The low level of lignin content is the positive sign of the biomass could be preceded further for biofuel production and became the third generation production process with significant merits. The algal biomass has been tried for methane production by anaerobic digestion process. The recent research focuses on the effective utilization of algal biomass for liquid biofuel production such as ethanol and butanol via sugar production by enzyme hydrolysis and fermentation by respective microbes. The reported advantages of seaweeds for biofuel research are 1) the growth rate of seaweeds and biomass production was significantly higher than the angiosperms; 2)the land requirement for the cultivation is comparably low than the terrestrial plant; 3) no requirement of fresh water, pesticides and fertilizers for growth. We can harvest 50 tons of biomass per acre land on “Seaweed forest”. There is no conflict on food *Vs* fuel [52]. It doesn't require deforestation and land clearance for the cultivation. Since, the cultivation media is water the temperature maintenance is not much difficult the culture area can easily be movable. Though, some natural disasters like droughts, floods and fires can destroy seaweed farming [52].

The abundance and diversity of algae have made them prime material for the human use. The marine environment is the huge reservoir for the sustainable biomass in which the macro algae have been used in many application for food, feed to medicine and fertilizers [53]. The earliest reference about the uses of algae dates back to BC 3000 in China [54]. Macroalgae has been used in the traditional food and medication of Asian cultures very specific in Japan, Korea, China, Vietnam, Indonesia and Taiwan [55,56]. Approximately 250 macroalgal species have been investigated as valuable products in commercial point of view in which 150 species are found to be used as consumable food for human [57,58]. It is estimated that around 8.6 million metric tonnes/year of algal biomass are utilized as food and feed supplements for human and animals, fertilizers in the agriculture sector, nutritional supplements and medicine in the pharma field and phycocolloids [59,60]. The people of developed countries has initiated their life with more on natural products like seaweeds for its indescribable nutritional qualities which has direct proportion to the health aspects [61]. Though, the main purpose of the seaweeds cultivation in the westernized countries is extraction of agar, alginates and carrageenans [56,62]. The red and brown algal species used as sea vegetables are mainly red and brown algae [63,64]. The marine macro algae have been used as traditional and folk medicine for prolonged period in many countries specially Asia and Caribbean country. The acknowledgment ‘Pen TsaeKan Mu’ was recorded 2000 years before in the Chinese literature for using the seaweeds as traditional and folk medicines [65]. Japanese and Chinese cultures have been using seaweeds since 300 BCE for treating parasitic infections as well as other medical problems [66]. It has been used as ointments and dressings solution in the medical field in specific on gynaecology [67].

2.2.2. Microalgae

Microalgae which represent blue-green algae, dinoflagellates, bacillariophyta (diatoms) and can have 8–31% of (dry weight) lipid content. The several research reports apparently revealed the efficacy of microalgae as a best and potential source for oil extraction than the traditional biofuel crops. The microalgae has the potential net energy output of above 9000 Lt./ha/year [21].

2.2.3. Cyanobacteria

Cyanobacteria arethe group of diverse autotrophic microorganisms, it occupy a part in the habitant of marine and fresh water phytoplankton and being a key contributor of atmospheric carbon by photosynthesis. The growth of the microbe is much faster than the plant and identical to macro algae it doesn't require land, hence that could be used as a resource for bio-oil extraction by pyrolysis. The cyanobacteria are most fitted organisms for genetical modification and the engineered one has the ability to produce either carbohydrate resource or direct biofuel from the CO_2. The research is on pipeline to achieve the biofuel production for environmental and economical need for near future [16,68].

3. Technology for conversion of Bio resources (Terrestrial and marine) to bio fuels

The extraction of energy from seaweed/agricultural biomass can be categorized into two based on the initial drying step (Fig. 2). The biodiesel extraction methods using dry biomass could be performed by direct combustion, pyrolysis, gasification and finally trans-esterification to biodiesel. The energy production process from wet biomass could be performed by hydrothermal treatments, enzyme hydrolysis,

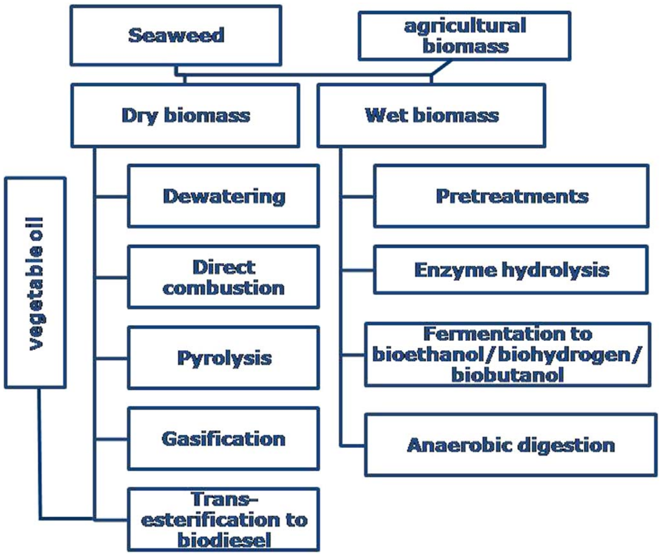

Fig. 2. Process of energy extraction from bioresources.

fermentation to bioethanol/biohydrogen/biobutanol and anaerobic digestion [69].

3.1. Pretreatment

Physical, physiochemical, chemical and biological processes have been used for pretreatment of lignocellulosic materials [70]. Since lignocellulosic materials are very complicated, their pretreatment is not simple either. The best method and conditions of pretreatment depend greatly on the type of lignocelluloses.

3.2. Enzyme conversion technology

The cell wall of plant biomass contains cellulose molecules deeply fixed in an amorphous surrounding molecules designated as lignin and hemicellulose. These polymers are attached strongly to each other molecules with non-covalent force and by covalent cross links, made a complex material called lignocellulose and it is being a major part of the plant cell approx. 90% of the dry weight.

The enzymatic hydrolysis has been promoted as a potential process for the conversion of biomass [42]. Three major cellulose degrading enzymes have been collectively known as cellulase. The major function of the cellula se include hydrolys is polymer cellulose to monomer glucose [71,72]. The complete degradation of cellulose molecule would be achieved by the action of all three enzymes. The first enzyme involved in the degradation of cellulose is endoglucanase (EG) (1, 4-ß-D-glucan-4-glucano-hydrolases; EC3.2.1.74) which acts on glycosidic bonds appeared interior of the cellulose molecule in random manner. The reducing or non-reducing ends of cellulose are then further degraded by exoglucanase (EC 3.2.1.91 and EC 3.2.1.74) and resulted with either cellobiose or glucose. The complete hydrolysis process has not been occurred without the enzyme ß-glucosidase (BGL) (EC 3.2.1.21) it acts on cellodextrins and cellobiose resulted in the prior enzymes actions and convert into glucose [50,73]. However, a break-through in the investigation of cellulose digestion processes for different biomass will have an enormous impact on the world fuel supply and economy [74].

Enzymatic degradation of hemicellulose in the biomass focuses more on xylan, which is the major hemicellulose in wood from angiosperms. The xylan molecule has a complex structure and contains xylose, L-arabinose, and D-glucoronic acid, among others. The xylan molecule also requires group of enzymes for complete degradation. The major enzymes involved in the hydrolysis of xylan are endo β - 1, 4 xylanase (EC 3.2.1.8), β – xylosidase (EC. 3.2.1.37) and the accessory enzymes are α- L-arabinosidase (EC. 3.2.1.55) and α - glucoronidase (EC. 3.2.1.131) [75]. The xylan molecule degraded first with action of the enzyme endo-xylanase which acts randomized manner on the main chains and results in unbranched xylooligosaccharides, including xylotriose and xylobiose. The β- xylosidase acts on xylooligosacharides and results with xylose. The arabinose and 4 - O - methyl glucuronic acid substituents are removed from the back bone of the xylan molecule by the action of respective α - L - arabinosidase and α - glucoronidase [76].

3.3. Microbes in conversion of biomass

The conversion enzymes production for biomass was tried by researchers for many decades. Number of wild type bacteria, actinomycetes and filamentous fungi has been reported to produce extra cellular hydrolytic enzymes when grown on specific substrates like cellulose/hemicellulose substrates [77,78]. Consequently, the advanced biotechnological research focuses on genetically engineered bacteria for hyper production of the enzymes [79,80]. New organisms search for hydrolytic enzyme production has also been continued in the biofuel research. Though, the extracellular enzyme system of the *Trichoderma* sp. was well studied and commercial level enzyme production has been investigated on the same organism [81,82]. The investigation on cellulase production from other microbes could also offer the route for its usage in the hydrolysis of polysaccharide [83,84]. In last decades, number of research work has been initiated and continued on effective utilization of agro-industrial biomass available in various sectors like apple pomace, coconut oil cake, cassava waste water, grape pomace, ground nut shell waste, rice straw, wheat straw, what bran, sugarcane bagasse, banana pseudo stem, coir pith, bamboo etc. to produce cellulase and xylanase by fungi like *Aspergillus awamori, A. niger, A. fumigatus, A. heteromorphus, A. nidulans, A. oryzae, A. terreus*, *Melanocarpus* sp. MTCC 3922 *Penicillium* sp., *Rhizophus stolonifer, Scytalidium thermophilum, Trichoderma* sp., etc. [85–94]. The enzyme production has been continued with both solid state (SSF) and submerged (SmF) fermentation and many reports investigated SSF would be the best as it cost effective and natural state of fermentation. The researchers described the advantages of SSF on enzyme production over the SmF. Even though for laboratory level, SmF is being a preferred method of optimisation [95–100].

Fermentation also referred to a biological process in which sugars such as glucose, fructose, and sucrose are converted into cellular energy and thereby produce ethanol, butanol and hydrogen. A variety of microorganisms includes bacteria, yeast, or fungi, ferment carbohydrates to energy products. Bacteria have drawn special attention of researchers because of their speed of fermentation. In general, when compared to yeast, bacteria require less fermentation time. All microorganisms have limitations: either in the inability to process both pentoses and hexoses, the low yields of end product [101].

3.4. Production of biofuels

The production of biofuels is classified into three categories: first, second and third generation.

3.4.1. First generation

The first generation production process includes production of biodiesel and ethanol by conventional method. For production of biodiesel the transesterification process is adopted to extract oil from oleaginous plants and conversion of vegetable oil into fuel which can be used by the engines directly. The direct vegetable oils could be used just as a fuel in the modified engines. The transesterification uses enzymatic catalyzers or acids, alkaline and ethanol or methanol and produces glycerin and fatty acids as a residue [19,102].

3.4.2. Second generation

The second generation biofuel production processes are relied on cellulose hydrolysis followed by sugar fermentation. The biological matters can be very useful for production of syngas (synthesis gas) by gasification process. This syngas can be converted into liquid biofuels with the help of several catalytic processes. Methane and natural gas can be produced from anaerobic digestion process. The process includes digestion of agriculture waste or crops [102].

3.4.3. Third generation

The current production process of biofuels from algae is classified as third generation process. Algae can produce oil which can be further refined to diesel and some contents of gasoline easily. Genome and metabolic engineering approaches could direct carbon metabolic pathway towards ethanol as end product. The algal biomass production method can be achieved in both photo bioreactors and open raceway ponds. The disadvantage of the third generation process is the biofuel produced from this process are less stable than the other processes [52].

4. Challenges in the Biofuel production

4.1. Economical pretreatment

An effective and economical pretreatment should meet the following requirements: (a) production of reactive cellulosic fiber for enzymatic attack, (b) avoiding destruction of hemicelluloses and cellulose, (c) avoiding the formation of possible inhibitors for hydrolytic enzymes and fermenting microorganisms, (d) minimizing the energy demand, (e) reducing the cost of size reduction for feedstocks, (f) reducing the cost of material for construction of pretreatment reactors, (g) producing less residues, (h) consumption of little or no chemical and using a cheap chemical. Several methods have been proposed for pretreatment of lignocellulosic materials. These methods are classified into “Physical pretreatment”, “Physico-chemical pretreatment”, “Chemical pretreatment”, and “Biological pretreatment” [103,104].

4.2. Cost of enzymes

Development of efficient hydrolytic enzyme production is required to reduce the cost of biofuel production. Since the high cost of commercial enzymes, the fuel production at large scale is being uneconomical for commercialization for the fuel demand [105].

4.3. Fermentation efficacy

It has been reported that genetic engineering and new screening technologies will bring bacteria and yeast that are capable of fermenting both glucose and xylose [106]. Mid-to long-term technology development will improve the fermentation efficiency of the organism (yielding more ethanol in less time), as well as its resistance, requiring less detoxification of the hydrolysate [107,108].

4.4. Sustainable feedstock

4.4.1. Terrestrial resource

A number of terrestrial and marine resources collectively termed as “biomass” are biggest energy stores and received most of the researchers attention since it has its unique merits. Biomass is being a prime and largest sustainable source of energy in the world. The coal, petroleum and natural gas are largest available form of energy but not sustainable source though it providing 14% of the world's primary energy [109]. The estimated annual primary production of terrestrial biomass was 220 billion oven dry tonnes (odt) [110]. The global production of plant biomass, with 90% of lignocelluloses, amounts to about 200×10^9 tonnes per year. The primary biomass ≈$8–20\times10^9$ tonnes can be potentially used for energy production which is four fold higher than annual energy consumption of the world [111]. They are often locally available, and with the developments in research and the process of conversion becomes achievable to convert the biomass into secondary forms of energy carriers. However, the biomass resource requires examination for valuable utilization and the analysis mainly based on its spatial and temporal availability, cost of transportation and storage of these organic materials in large quantities [47]. This sustainable biomass is a proven basis for the invention of greener technology for sustainable energy production. The developed sustainable green energy technologies from solar and wind are being placed under "renewable energy" which will be a beginning of modern energy techonolgies [47,112] and can contribute to sustainable development. The most promising sustainable and abundant biomass is lignocellulose acts as a major source of fermentative biofuel production [113].

Reported unique merits of biomass energy are 1) performing a key role in reducing the emission of greenhouse gas via utilizing biofuels as the way reducing the usage of fossil fuel, 2) first largest source of sustainable biomass in the world leads sustainable biofuel technology 3) the biomass generated by the energy plants would create new employment opportunity for rural marginal farmers significantly social sustainability 4) seems to be the only alternative energy for near future and bioprocessing give a way to disposal problem [47].

4.4.2. Marine resources

India (08.04–37.06 N and 68.07–97.25 E) located as a tropical country in the South Asia and categorised one of the mega-diverse country. The twelve reported high diversity countries are Mexico, Colombia, Ecuador, Peru, Brazil, Zaire, Madagascar, China, India, Malaysia, Indonesia and Australia. These countries have greater than 70% of the world biodiversity [114]. The reports clearly indicate that India has well defined biodiversity in all the three levels regarding species, habitat and genetic diversity [115]. It has a stretch of about 7500 km coastline with highly unique marine biota. Lateritic cliff, rocky promontories, offshore stalks, long beaches, estuaries, lagoons, spits and bars are the characteristics of Indian coast. India is being a first among the countries located in the border of the Indian Ocean for number of recorded specific and intraspecific seaweed taxa than Australia and South Africa [116,117]. Approximately, 844 species of marine algae belong to 217 genera were reported earlier in the Indian coast mainly located in both inter-tidal and deep water area [118]. However, recently the reported number of genera and species of marine algae has been increased as 271 and 1153 and it belongs to four groups of algae namely *Chlorophyceae, Phaeophyceae, Rhodophyceae*and *Cyanophyceae*have [119]. India is being a very good habitant for seaweeds to grow abundantly especially along the Tamil Nadu and Andaman and Nicobar islands (Fig. 3). The seaweeds beds seem to be very rich in the areas around Gujarat, Mumbai, Ratnagiri, Goa, Karwar, Kollam, Varkala, Vizhinjam in Kerala and Chilka in Orissa [118,120]. However, studies on chemical, biochemical, and genetic resources of Indian marine algae are not yet intensified.

4.5. Sustainable production

The nuclear and fossil fuels are depleting very fast and the resources are very less and distributed to specific location but the renewable resources are distributed evenly all over the globe. The renewable resources energy flow is very much higher than the energy used globally nowadays. The sustainability of the current energy systems is a big question mark because of economic, equity and environmental issues. To protect the land, communities and biodiversity various sustainability initiatives as well as number of schemes is being implemented for biofuels. These initiatives have been engaged by NGOs, Government bodies and private organizations. There is an immediate need to combine general and private investment to enforce the commercialization of biofuels. The countries like Brazil and

Fig. 3. Seaweed bioresources of Indian coast being unexploited for biofuel production (Photo courtesy: Joseph Selvin, Pondicherry University).

Netherland have taken initiatives for sustainable development of biofuels from crops and made agreement of cooperation for biofuels production. In US the Government funds are provided to accelerate the research and development of biofuels market. In the world's energy production China leads the third place next to Brazil and US. The Government of China is primarily focusing on production of ethanol on industrial scale. India has "National Biofuel Policy" to meet the 20% demand for diesel by replacing it with biodiesel. They have also proposed to replace 10–20% of gasoline with bioethanol [19,121].

5. Sustainability, policy and commercial aspects of biofuels

5.1. Sustainable energy

Biofuels have been emerged as important source for sustainable fuel and are considered for progress in finding new energetic resources, improving air quality and limiting greenhouse gas emissions. For economic and environmental sustainability of biofuels carbon neutral and renewable biofuels are necessary. As people always need fuel for heating, living, transportation purpose etc the desire for production of fuel has been increased tremendously. The global production of oil and gas has been reached to its saturation point though alternative source for the sustainable production of oil and gas being in the pipeline. Hence, as an alternative option to fossil fuels, the biofuel is considered as a leading and sustainable energy source in future which have ability to reduce vehicle emissions, increase supply of sustainable energy and provide income for farmers as sustainable bioresources [20,121].

5.2. Biofuel policy and analysis

Energy is an essential input for economic development of the country. In India, the national policy on biofuels has framed in December 2009 with the intent of implementing the usage of bioenergy as a motor fuel with the blending ratio of 20% by 2017 which is derived from the biomass and other related renewable sources. The detailed report of policy developed by Indian Government was given in the ministry of new and renewable energy (MNRE) web [122]. For the people of rural areas in developing countries can get new opportunities in oil imports from the biofuels perspective. Hence, the energy policies of economically developed countries include the integration of market of private sector and regulatory frameworks for keeping competitiveness. The competitiveness involves liberalization of transportation, energy production, distribution, oil and gas market and electricity. On the whole, the central policy for biofuels is focused for protection of environment, higher efficiency in corporate sector and job creation [5,20]. In India the biofuel policy and regulation on the utilization of bioresources for biofuel production process is proposed by MNRE, New Delhi, India. However, the implementation of biofuel policy requires Research and Development efforts to attain an economic biofuel production. Therefore, large scale utilization of bioresources for biofuel production would be a new venture in India.

5.3. Commercial aspects of biofuel

The commercialization of biofuel projects would increase the employment either direct or indirect way. Those projects give ways to employ all category peoples include skilled to unskilled local persons for various departments. The biomass based biofuel programmes can also increase the local economy unlike solar and wind energy programme. The MNRE has initiated many programmes for rural people by family type biogas plants. The demonstration of integrated technology package on Biogas –Fertilizer plants (BGFP) for generating and application technology under RDD & D (Research, Design, Development and Demonstration) Policy. The Government has been supporting many programmes like renewable energy for rural application, National biogas and manure management programme (NBMMP), the MNRE raised financial subsidy through Central Financial Assistance (CFA). The Government has initiated some programme for urban, industrial and commercial application they are i) Energy Recovery from urban, industry and agricultural wastes ii) Bioenergy and cogeneration in industry. This programme aimed to evaluate the energy from municipal solid waste, vegetable and market waste, slaughter house wastes, agricultural residue and industrial wastes. The energy produced from the cogeneration by sugar mill industry is estimated at around 7000 MW [123].

6. Discussion and future scope

It has been seen by many people that biofuel is a cleaner way for the transport sector to meet all the energy needs. During combustion in the engine we achieve environmental benefits such as less carbon dioxide emissions correspond to the amount that was secluded from atmosphere. This results in formation of closed carbon cycle. In spite of the benefits which characterize the use of biofuels it is necessary to keep in mind that the production and end use of biofuels have serious impact on environment such as destruction of forest, increase in soil degradation, reduction in food production, use of large amount of water. There is more loss of natural habitat due to pressure on natural resources and increasing population. Scarcity of water is already a limiting factor in production of food in several regions. Biofuel crop such as sugarcane requires more water and are produced under monoculture which leads to water pollution and increased scarcity of water. There is too much pressure on water resources due to water requirement for production of biofuels which is already stressed and will be seen in many places [3,124].

In developing nations like India, implementation of alternative fuel options is a prime concern to meet up the future oil demands. As seaweeds are most diverse in Indian coasts, they can be exploited for this purpose. Seaweed cultivation in India is not a new process as they are cultivated from the past as a source of food, food derivatives, vitamins, proteins, raw material for many agar-agar and algin based industries. For the production of biofuels, they have to be cultivated in large-scale, and processes for extraction are to be studied in detail to attain nations' economical needs.

7. Conclusions

The future of global biofuel production will depend on number of interrelated factors and their profitability. The use of biofuels is being promoted by many Governments all over the world. In developing nations like India, implementation of alternative fuel options is a prime concern to meet up the future oil demands. It is obvious that each country will have to utilize the available biomass and cultivate oil producing crops which are suitable for their climate. For the production of biofuels, seaweeds have to be cultivated in large-scale, and processes for extraction are to be studied in detail to attain nations' economical energy needs.

There is a much potential for biofuel market which has been accepted globally and the use of biofuels as alternate to fossil fuels still requires technological development to reduce the cost of production and emission of greenhouse gas and to increase the feasibility. Promotion of biofuel as alternate fossil fuel requires global acceptance and development of efficient biofuel driven engines. Therefore, for strengthening the global economy, mitigating climate change and enhancing environmental quality sustainable biofuel production will play a positive role. And hence both industry and environment are benefited from their early identifications and refinement in the field of alternative fuels.

Acknowledgements

JS is thankful to University Grants Commission, New Delhi for research grant and GSK thankful to DST, New Delhi for funding support.

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