CHAPTER 1

Boundaries and openings of biorefineries towards sustainable biofuel production

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1.1 Introduction

Biorefineries and bioproducts play a key role in the development of bio-based economy due to depletion in natural resources such as fossil fuels and a wide range of environmental climatic changes (Clauser et al., 2016). A variety of work plans are established as initiatives to biofuel and bioenergy production by regional, national, and international levels. Other biochemical production also entails some initiative works. The significant components of bio-based economy are considered as some bio-based chemicals, derivatives of cellulose, fermentation products, and fatty acids (Axelsson et al., 2012; Isikgor and Becer, 2015). To support the circular economies, energy recovery from waste resources plays a prominent role in sustainable waste management. With the increased focus on circular economy over the last half-decade, and the emphasis on holistically resolving the fiscal, environmental, and social elements of the industrial-sector, biorefineries serve as a strategic framework for the realization of a circular bioeconomy (Ubando et al., 2020). It is also needed to diminish the problems in environment, sanitation, and public health. Water pollution, air pollution due to greenhouse gas (GHG) emission, soil contamination, leachate, and diseases due to flies and rodents are the results of landfilling without any proper safety measures. If these are properly utilized, wastes can be the source of value-added products, fuels, and energy. The utilization of biomass to produce gaseous or liquid fuels as alternative for conventional fuels is regarded as biofuel (Demirbas, 2007). Generally, agrowastes are renewable and easily available biomasses with high lignocellulosic contents. They are also utilized in the production of biofuel and bioenergy and used as biorefineries (Hassan et al., 2019). These biorefineries are further processed to biocharcoal, biocomposites, and bioplastics. In agrowastes, the lignin, cellulose, and hemicellulose are the major target components.

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The oils used to produce biofuels and biogases are generally nontoxic and biodegradable (Marchetti et al., 2007). Agrowastes are easily available and commercial one. Other than agrowastes, there are biorefineries available in diverse, which then established into biofuels and bioenergy sources. The major agrowastes like sugarcane trash involved in the production of biochemicals such as methanol, ethanol, butanol, furfural, and lactic acid with sequential energy production. There are some drawbacks for using biofuels, as they cannot be stored for long time since they are biodegradable, filter impediment due to solvent capacity, and have high freezing point. In the further sections, the overview of biorefineries, sources and their types, different pretreatment methods, production of biofuels and its challenges will be discussed.

1.1.1 Biorefinery

Today's bioeconomy is completely based on the biorefineries. It is due to the depletion of thermochemical and biochemical technologies, which includes several catalytic or noncatalytic methods (Vanholme et al., 2013). Biorefinery technology is mainly based on excess bioproducts synthesis from the biomass organic molecules. It is annexed in different industries mainly to show the divergence and to develop the rural and regional sectors. A various research and economic assessment is carried out, which includes biofuel and bioenergy production from the second-generation waste biomass (Hosseini et al., 2010; Kazi et al., 2010). Several biochemical or thermochemical technologies are also considered to make it efficient one (Alonso et al., 2010; Gassner and Maréchal, 2009). Over the last few years, value-added products like polymers and chemicals are developed from lignocellulosic biomasses (Bozell and Petersen, 2010; Sheldon, 2014). On considering the environmental, economic, and scientific aspects, it is necessary to increase the research and development in the production of biochemical with biofuels. Environmental impacts play a vital role in ecological development in biorefinery systems. Life-cycle assessment (LCA) (Khoo et al., 2016) is an important environmental impact, which is put forward by the International Organization of Standardization including endurance in evaluation of biorefineries. Considering the environmental impacts on GHG emission and energy balance (Guo et al., 2014), LCA shows greater potential in biorefinery technologies (Papong and Malakul, 2010; Renó et al., 2014). Due to the increase in biorefinery technologies, it increases the employment opportunities for small-scale farmers (Luque et al., 2010).

1.2 Sources of biorefinery

Various biomasses are used to produce different kinds of biofuels. Generally, the biomasses are categorized into different types: (1) forest products, which include trees, shrubs, sawdust, bark, and wood; (2) biorenewable wastes, which include, mill wood wastes, urban wood wastes, agricultural wastes, and organic wastes; (3) energy crops,

which include grasses, starch crops, herbaceous woody, short rotation woody crops, and switch grass; (4) food crops, which include grains, oil seeds, sugarcane, sugar beets, molasses, and sorghum; (5) aquatic plants such as algae (kelps, prokaryotic, and eukaryotic algae), water hyacinth, reed, rushes, and water weeds; (6) organic wastes such as industrial organic wastes, municipal solid wastes, and sludge; (7) landfills such as inert wastes, liquid wastes, hazardous and nonhazardous wastes; (8) mosses such as polytrichales, bryophyta; (9) lichens such as foliose and fruticose lichens, crustose lichens, and other notable lichens (Speight, 2011). Another fascinating biomass is animal waste, which is also responsible for odor problem and GHG emissions. In rare cases, animal wastes also become the basis of water pollution in rural areas. This can also conquer by anaerobic digestion for energy making and carbon impounding by utilizing the animal wastes (Liu et al., 2013; Nallathambi Gunaseelan, 1997).

With the usage of different developing technologies, the conversion of wastes into significant amount of renewable fuels, chemicals, and energy is done. The two main techniques involved in biomass-to-bioenergy production process are (1) thermochemical conversion techniques (direct combustion, gasification, liquefaction, transesterification, and pyrolysis) and (2) biochemical decomposition techniques (fermentation and decomposition in anaerobic conditions). In contribution to environmental and economic impacts, biofuels are evolving as an alternate for fossil fuels. Some studies show that organic residual tributaries like food wastes, nonedible *Sterculia foetida* uses transesterification process along with nanocatalysts like Fe_2O_3 and $CuO\text{-}CeO_2$ for biodiesel production. In biofuel production, the optimization and control process are possible by having deep knowledge of thermodynamics and kinetics reactions. In addition, the understanding of simple and multiple order reactions, which has to be compared with the versatile Sestak–Berggren model, is needed in pyrolysis and biomass usage like algae. Nowadays, heat, power, fuels, and different value-added products from waste biorefineries are fascinating around the world. There are different experimental data on pyrolysis of plastic wastes for biofuel and bioenergy production. Other biorefineries like sludge from wastewater treatment, household cooking oil wastes, poultry wastes, other codigestible wastes like plant biomass and agroindustrial wastes are also utilized. There are different approaches for the optimization of wastes as biorefineries. One of the prominent food waste biorefineries is biochar which is known for its positive role in the development of anaerobic digestion system (Rehan et al., 2019). Biorefinery concepts are classified according to feedstock, technology type, technology status (first- and second-generation biorefinery), and intermediate (syngas platform, sugar platform, etc.) (van Ree et al., 2007). The International Energy Agency Bioenergy Task 42 describes biomass in a way that the biomass can be ecologically processed into a continuum of profitable products (food, feed, materials, and chemicals) and energy (fuels, water, heat). As a result, a biorefinery may be competence, a method, a farm, or noted as constellation of facilities for biomass conversion (Jong et al., 2011). The

biorefinery can also be incorporated with a petroleum-based refinery. In cases like refining using petroleum products, oil and natural gas, which are fossil-based materials, are used to generate energy and chemicals. For producing energy and chemicals, biomass is used in biorefinery (de Jong and Jungmeier, 2015; Kamm and Kamm, 2004). To intricate this term, biorefineries are categorized based on feedstock types used, intermediates that are generated (syngas or sugar), process of conversion (thermochemical, biochemical, two platform), and the prominence of technology execution (conventional and advanced). As a result, biorefineries are classified into three groups (Clark and Deswarte, 2008; Kamm and Kamm, 2004).

1.2.1 Phase I biorefinery

Phase I form of biorefinery uses a single feedstock material that has a fixed processing capacity and produces only one primary product. The vegetable oil, pulp, and paper mills are utilized for biodiesel production and corn grain for ethanol production are instances of Phase I biorefinery (Naik et al., 2010).

1.2.2 Phase II biorefinery

It is equivalent to a Phase I biorefinery and one feedstock can be utilized, but it produces a variety of products. The manufacturing of various chemicals from starch, production of variety of carbohydrate derivatives, and bioethanol derived from grain crops are examples of Phase II biorefineries.

1.2.3 Phase III biorefinery

Phase III biorefineries are specialized biorefineries that can use a wide range of feedstocks, manufacturing processes, and materials. Phase III biorefinery systems are classified into four types (Clark and Deswarte, 2008):

1. whole-crop biorefinery
2. green biorefinery
3. lignocellulosic biorefinery
4. two-platform concept biorefinery

1.3 Classification of biofuels based on biomass

Sources availability and types of production process decide the biofuel to categorize under three divisions. Natural oils, ethanol, methane, biodiesel, hydrocarbons, and butanol are some of the products obtained from the biomass. Further process and purification of these products enable the production of desired products. According to the standards put forth by European Committee, biofuels are categorized significantly for standardization, and they are branded by EN Standards (International and Network, 2004).

1.3.1 First-generation fuels

Agricultural crops which is rich in sucrose like starchy grain feedstocks sugarcane, root crops, sugar beet, sorghum, molasses, whey and molasses are utilized for the first-generation biofuel production (Lin and Tanaka, 2006). By using milling process, the ethanol is synthesized by extracting high sugar content from sugar crops. The ethanol production from sugar is facilitated by the fermentation process. Starch is converted into sugar particles in assistance with microorganisms by enzymatic hydrolysis (Persson et al., 1991). This includes the utilization of cellulose-hydrolyzing protein like *endo*-β-1 4-glucanases, cellobiohydrolases, and β-glucosidases. First-generation fuel has numerous preferences such as high accessibility of recognizable feed stocks, effectively adaptable generation capacities, easy generation methodologies, and fungible with petroleum inferred fills.

1.3.2 Second-generation fuels

In the second-generation fuel production, feedstocks with high polysaccharide possessing materials such as grasses, straw, and wood has been used (Chozhavendhan et al., 2019). Crop residues, agricultural wastes, and woody materials that have high lignocellulosic materials come beneath this category. This conversion requires pretreatments. Physical pretreatment methods involve ultrasound, milling, and mechanical grinding. Acid and alkali treatments are chemical pretreatment methods. Biological pretreatment involves enzymatic hydrolysis, etc. The evacuation of lignin results in the hydrolysis of biomasses (Sims et al., 2010).

1.3.3 Third-generation fuels

Algal biomasses and other microbial things are involved in the production of third-generation fuels (Nigam and Singh, 2011). Usually, the rapid development in feedstock among living organisms comes about in tremendous production of oils. By using extreme downstream operations such as combustion, liquefaction, gasification, and pyrolysis procedures, it experiences thermochemical changes to produce diesel.

1.3.4 Fourth-generation fuels

The extended third-generation procedures using microorganisms result in fourth-generation fuels. Usually, the fourth-generation fuels come under the third generation. This includes the application of genetic engineering techniques. For biodiesel production, the yield of hydrocarbons is enhanced by altering the cellular metabolism. The metabolic pathway alternations are generally due to gene transformation, which in employed to genetic engineering techniques. Fourth-generation fuels play efficient role in reducing carbon dioxide emission by storing and capturing it. It also helps

in reducing emission of poisonous gases. It has economic impact in long term and requires high investment.

1.4 Production methods of biofuel

Farming feedstock mainly comprises lignin and carbohydrates in energy crops involved in the production of value-added products because of biochemical conversion techniques. The legitimate pretreatments and hydrolysis are involved in the conversion process. It involves (1) chemical conversions—acid hydrolysis and esterification process, (2) thermochemical conversions—gasification and pyrolysis, (3) biochemical conversions—fermentation and enzymatic methods, and (4) mechanical process (Fig. 1.1). Initially, the microorganisms utilize the sugars obtained from residues (Sharma and Chadha, 2011). The major raw materials include wheat, rice, and barley, which are regarded as secondary raw materials. Other raw materials such as potatoes are fourth-largest crop after corn, rice, and wheat (Ranjan et al., 2013). These potential raw materials are used in the production of heat, biofuel, and electricity. The Steps involved in biofuel production is shown in (Fig. 1.2).

1.5 Pretreatments

The alternate in physical and chemical structures of biomass to synthesize biofuels is the result of various pretreatments. Pretreatments should be economically suitable, with low energy requirement and reduction in consumption of various chemicals, and should facilitate easy denaturation. Above all, these pretreatments are assisted in the

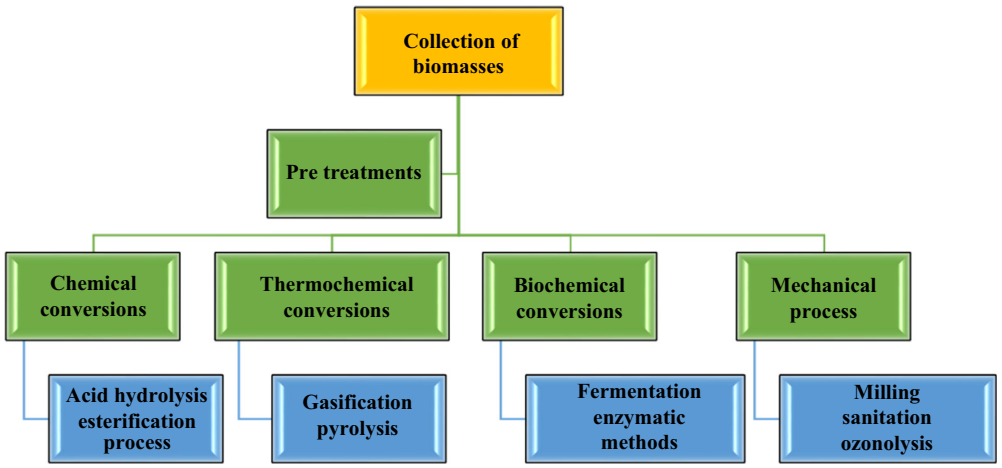


Figure 1.1 Major treatments involved in the biofuel production.

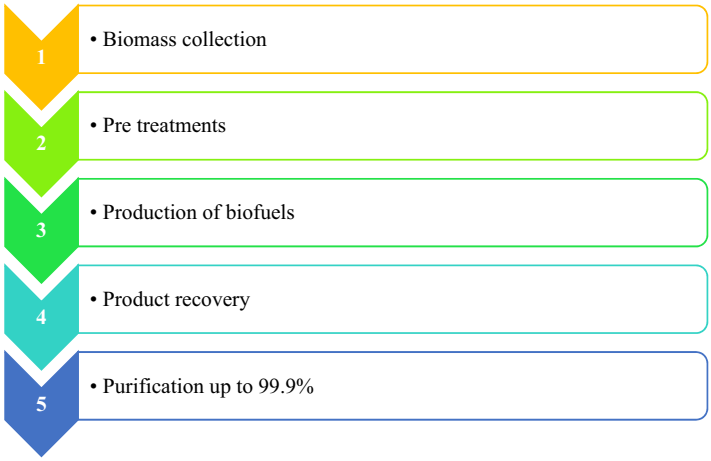


Figure 1.2 Steps involved in the biofuel production.

environmental development. Several pretreatments that used to produce biofuel are chemical, thermochemical, biological, and mechanical (Nauman Aftab et al., 2019).

1.5.1 Mechanical methods

Generally, the physical properties of biomass are altered by mechanical pretreatments. By using various physical methods, the degree of polymerization and crystallinity of lignocellulosic biomass can be decreased (Kumari and Singh, 2018). The application of these physical methods enables the increase in the surface area and pore size. The different mechanical pretreatments involve milling, sanitation and ozonolysis, freezing, etc. By using, milling mechanical pretreatment, the ethanol production is efficient since it reduces the production of hydroxyl methyl furfural and furfural, which acts as inhibitors in the production (Ramos, 2003). The usage of freezing is limited for its high operating cost. Freezing is not suitable for liquid products. Sonication involves usage of high frequency vibration that enables production process. There are different mechanical pretreatments for the biofuel production.

1.5.2 Thermochemical methods

Thermochemical pretreatments such as microwave irradiation, pyrolysis, gasification, and pulse electric field involve utilization of heat and chemicals for the biofuel production. The suppression of methanogenic activity of microbes is due to microwave irradiation pretreatments and also it is assisted with chemical pretreatments (Singhal and Singh, 2015). The lignocellulosic biomass is treated with high temperature up to 300°C is generally regarded as pyrolysis. It is one of the endothermic processes, which requires less energy for the conversion of biomass into gaseous products

such as biogas, hydrogen, and char (Farzad et al., 2017). The main mechanism which takes place in the pyrolysis is decomposition at high temperature. According to the biomass, microwave irradiation pretreatment is better than conventional techniques (Li et al., 2012). Other thermochemical methods involve ammonia fiber expansion, steam explosion, carbon dioxide explosion, liquid hot water method, and wet oxidation method.

1.5.3 Chemical pretreatment

The chemical pretreatment uses acids and alkaline compounds for treating biomasses. The pretreatment using acids includes monomer formation from the polysaccharides. The solubilization of polysaccharides to monomers using acids enables biofuel production. Either the acids with high concentration, low temperature is used or low concentration acids aiding high temperature is used (Sen et al., 2016). Usually, organic or inorganic acids such as HCl, H_2SO_4, formic acid, acetic acid, nitrous acid (Bai et al., 2016), and phosphoric acid are used to hydrolyze the biomass. In some cases, bases are also used. Alkali pretreatment involves sodium hydroxide, calcium, potassium and ammonium usage for treating biomasses (Han et al., 2019). Alkali pretreatment usually requires low temperature and low-pressure conditions. Among all these agents, NaOH is mostly used for treating biomasses, and calcium hydroxide is cost-effective.

1.5.4 Biological pretreatment

Generally, biological pretreatment has no harmful impact on environment, and it is and eco-friendly approach in pretreatments. Enzymatic pretreatments and microbial pretreatments are mostly used biological approaches (Liu et al., 2016). Cellulases and hemicelluloses enzymes hydrolyze lignocellulosic biomasses. The major drawback in using enzymatic pretreatments is the cost of enzymes is high and it reduces biogas production. The white rot fungi enhance the lignin biodegradation. White rot fungi and brown rot fungi are mostly used for biofuel production (Sindhu et al., 2016). Microbial consortium is one the effective methods to pretreat the biomasses.

During the pretreatment of lignocellulosic feedstock, enzyme inhibitors limit the treatment process during saccharification and fermentation step. Enzyme inhibitors in fermentation will be of two types as process derived and feedstock inherited (Verardi et al., 2020).

Among the different feedstocks, lignocellulosic biomass has some limitations during the process of conversion by enzymatic treatment since it contains glycosidic bonds, and it becomes the problem during hydrolysis. Therefore suitable pretreatment methods need to be considered for each feedstock (De Buck et al., 2020).

1.6 Production of different biofuels

1.6.1 Bioelectricity generation

The conversion of organic compounds to electric power generation has been documented in various strategies and sizes of microbial fuel cells (MFCs), which has lately gained more interest and emphasis in this field. In this regard, a compost-based MFC has been published, demonstrating its capability for generating bioelectric power through hydrolysis and oxidation processes for organic substrates (Kumar et al., 2020). Various organic waste materials obtained from grass cutting, form of leaf parts, inner layer of rice grain (components of bran), extracted mustard grains for oil cake production, and chicken droppings are materials of carbon compounds in nature that are supplied to MFCs (Srivastava, 2019). The electricity potential of this MFC (around 350 mV) is recorded during the fermentation under anaerobic conditions by affecting different types of membrane structures, mixing capability of fly ash components, and various nature of electrode device architecture. By combining fly ash, the maximum voltage can be increased. Bamboo charcoal (as an anode material or electrode) and carbon materials synthesized fiber (as a cathode electrode) are discovered to be a good design for optimizing power generation (Moqsud et al., 2013).

1.7 Production of ethanol and electricity

Ethanol production involves instantaneous saccharification and co-fermentation and its process model involves steam explosion pretreatment with sulfur dioxide as catalysts (Ali Mandegari et al., 2017; Brugnago et al., 2011). According to the National Renewable Energy Laboratory, the literature studies show that to minimize cost of enzyme supply, biorefinery simulation model should possess premises of cellulase production unit (Karimi and Chisti, 2015). The separation of anhydrous ethanol, water, and combustible solids from fermentation broth takes place in purification and recovery section. After molecular sieve dehydration column, the purification of ethanol up to 92.55% takes place by distillation column. It is undergone distillation to increase the grade of ethanol up to 99.5% (Batista et al., 2012; Farzad et al., 2007). For internal recycling, the stillage water is purified by an evaporation unit. This evaporation unit is also used to produce the sirup soluble along with solid residues, which is supplied to the boilers (Zichová et al., 2017). Wastewater treatment (WWT) and water cycle are components of water treatment unit, which supplied to Combined Heat and Power (CHP) unit. Biogas production takes place by anaerobic digestion in WWT, and it is sent to CHP unit. There is a continuous recycling of treated water internally.

1.8 Production of ethanol, lactic acid, and electricity

The steps involved in the production of lactic acid from biomass are pretreatment, enzymatic hydrolysis, fermentation, separation, and purification (Karimi et al., 2015; Taherzadeh and Karimi, 2008). The ethanol is synthesized from cellulosic compounds. Then, the hemicellulose fractions are the major cause in stimulation of lactic acid production. It all takes place in single pretreatment unit. Then, aforementioned bioprocesses are used in categorizing the sugar streams. The neutralization of lactic acid is due to the $Mg(OH)_2$ addition during fermentation process (Asghar et al., 2020). It is due to high inhibitory effects to the fermenting strains; it results in Mg-lactate production. Then, Mg $(OH)_2$ crystals and an R3N−lactate complex are produced as a result of reaction between Mg-lactate and organic amines trimethylamine (R3N) which are miscible in water. Lactic acid is obtained by thermal decomposition of R3N−lactate complex. In exchange reactor, it is recycled back (Sivasankaran et al., 2014). The Mg $(OH)_2$ crystals are separated from the complex using filtration techniques and fed back to fermentation process. The process involving lactic acid esterification and ester hydrolysis purifies lactic acid from fermentation broth. The crude lactic acid is purified up to 99.5wt.% by esterification and hydrolysis (Kumar et al., 2006; Su et al., 2013).

1.9 Furfural, ethanol and electricity production

The bioethanol and furfural are synthesized from cellulose and hemicellulose components, respectively (de Jong and Jungmeier, 2015). The process and conversion techniques involved in this production are similar to the ethanol and lactic acid production. The pretreatment method involves addition of hydrochloric acid as catalysts. After pretreatment methods, furfural is extracted by using tetrahydrofuran (THF) addition. Often two-phase reaction prevents the side reactions (Cai et al., 2016; García et al., 2011). Downstream decanter facilitates the organic solid fraction separation from aqueous phase. The recovery of product is materialized by distillation. The first and second furfural distillation column facilitates the THF separation and recycling. The third distillation column facilitates the formic and acetic acid separation from the rest of the slurries. The furfural is recovered with 99.8 wt.% purity in fourth distillation column. Further distillation gives acetic acid and formic acid as by-products (Xing et al., 2011).

1.10 Coproduction of butanol and electricity

Generally microbial strains like *Clostridia* are used to produce butanol from hexose and pentose sugar molecules under anaerobic conditions (Dürre, 2008). The strain of bacterium facilitates acetone−butanol−ethanol (ABE) fermentation (Karimi et al., 2015; Karimi and Pandey, 2014). Here, simple explosion pretreatments are followed in the

synthesis of ethanol, whereas dilute acid pretreatments are also applied (Qureshi et al., 2010). The saccharification and fermentation along with gas stripping are needed for pretreatment of lignocellulose by hydrolysis and fermentation. It reduces the rate of feed and product inhibition. The fermentation gases like CO_2 and H_2 are demonstrated by medium of gas striping and mixing in fermenters (Qureshi et al., 2014). After purification, the condensation of gases at 0°C through cryogenic cycles enables ABE product recovery (Ezeji et al., 2005). The purification of butanol up to 99.5 wt.% is due to distillation and ethanol; acetones are obtained as the by-products (Cai et al., 2016).

1.11 Production of methanol and electricity

The syngas production from the lignocellulosic substances like sugarcane is assisted by allothermal gasification (Petersen et al., 2015). The mechanism involves dual fluidized bed gasifier, in which the medium between the combustion and gasification chambers acts as heat transfer medium. The heat is required for endothermic gasification reaction (Farzad et al., 2007; Pfeifer et al., 2004). The stimulation for very low tar syngas production is due to gasification. The cooling and conditioning of syngas occurs after the gasification process followed by separation from bed (Diederichs et al., 2016). Then in a Rectisol unit, the removal of CO_2 and H_2S from syngas takes place (Kumar, 2014; Sun and Smith, 2013). After the cleaning and conditioning process, it is highly compressed up to 98 bar, while in a liquid phase. In the fixed-bed synthesis reactor, the compressed gas is converted to methanol (Hamelinck et al., 2005). The steam generation by cooling the effluent is utilized to maintain isothermal conditions for preheating the reactor feed up to temperature of 250°C. The double fluid heat exchanger enables the heating of the reactor feed. The separation of unconverted syngas and other inert gases like CO_2, CH_4 and recovery of methanol is possible by cooling the vapor phase product in single-phase reactor (Phillips et al., 2011). To recover the compression energy of gas, the complex mixtures of gas streams are heated in a turbo expander generator.

1.12 Purification process

After the production of a product, recovery and purity are important processes. The untreated products possess impurities such as free fatty acids, catalysts, waxes, soaps, and glycerides. These impurities result in decreasing the efficiency of product recovery. The vacuum distillation, membrane filtration, ion materials, and some separation techniques can be used for the purification of products. In biofuel purification, the impurities, odor, and other organic salts are removed due to ion exchange between crude biofuel and ion materials (Ardi et al., 2015; Rathore et al., 2019). This method involves usage of water to remove salts and at the same time, it does experience any vaporization. After this process, the purity of the distilled product is nearly 95%–99%.

In industrial purification, vacuum distillation is one of the important techniques assisted for purification (Berrios and Skelton, 2008). Magnesol experiment is one of the purification methods involved in biofuel production. In this method, the final product is purified by using different concentrations of Magnesol and requires vacuum filtration using Buchner funnel. The standard washing time takes approximately 30 min. On the other hand, water ejector removes water, and small particles are removed using centrifugation, finally the purified product is obtained. Other methods involve wet and dry washing. In washing experiments, three wash waters are used. The wash waters are deionized, town's water, and acidified water (5% phosphoric acid). It involves washing at 60°C or at ambient temperature for nearly 30 min. Finally, gravity settling for 30 min results in the separation of products. Membrane separation involves concentration changes, hydrostatic pressure appliance and driving force gives the attired purification performance up to 99%. Different membranes are used in these techniques based on the product nature. One of the major drawbacks in membrane purification technique is sturdiness of membrane and fouling (Chozhavendhan et al., 2020a,b). Different kinds of purification techniques are handled for different kinds of products.

1.13 Biogas—biomethane production

Under anaerobic conditions, carbon dioxide and methane can be synthesized from the conversion of all types of polymeric materials by the resourceful biotechnological technique called methane fermentation. The microbes involved in conversion mainly include acidogens, fermentative microbes, acetogens involved in acetate synthesis, hydrogen producing microbes, and mainly methanogens involved in methane production (Devi et al., 2019). These microbes break the biochemical bonds of polymers and produce methane and carbon dioxide. These microbes have the potential to grow in the environment and aid to reduce the pollution. Different kinds of microbes are utilized for methane production. The anaerobes from rumen of animals and sewage digesters are analyzed before involving in methane production (Bharathiraja et al., 2018). The analysis involves studying the life span, capability, source, potential in product production, etc. The sequential metabolic interaction among the anaerobes enables the methane production. First step in methane production is conversion of polymeric materials to monomers like amino acids and glucose by using hydrolytic enzyme, which is carried out by a group of anaerobes (Chozhavendhan et al., 2020a,b). Later, these monomers are converted to hydrogen, acetic acid, and fatty acids usually with high volatility. In second-stage group, acetogenic bacteria are involved in the conversion of butyric acids, propionic acid that comes under the high volatile fatty acids to acetic acid, carbon dioxide and hydrogen. In the final step methane and carbon dioxide are obtained from hydrogen, acetic acid, and carbon dioxide assisted by a series of metabolic actions of methanogens (Axelsson et al., 2012).

1.14 Applications

Usually the methanol, ethanol, propanol, and butanol are regarded as primary alcohols. The substrates with high carbon molecules have high potential in ethanol and butanol production. It is regarded as renewable and biodegradable fuel material. Mainly these biofuels are major choice of fuel consumption (El Khaled et al., 2016). The biorefineries like industrial wastes, urban wastes, high starchy compounds, lignocellulosic materials, and fermentable feedstocks are used in biofuel and bioenergy production. It also helps in maintain the sustainable food chain. The efficient biofuel production helps in dependence on other countries for fuel and energy. This provides different applications like fuel uses, energy uses, as alcohols are higher debilitating gas distribution, and it has higher-octane value along with compression ration than fossil fuels. In heat and power generation field, it is assisted to alter the petroleum fuels (Sivasankaran et al., 2015). It is also used in industrial products such as paints and tincture. Generally, these are found as antifreezing agents. The polar solvents like ethanol and methanol have optimized dielectric constant; hence, it is regarded as frequency dependent (Pace et al., 1968). Due to this biorefinery utilization and biofuel production, there is a impact on rural employment and less complexity in technical field with socioeconomic and environmental impacts.

In addition to this, the residual wastes (press mud) with high micronutrients like albuminoids, colloids, and inorganic salts are utilized for plant growth. This press mud is generally found in the clarification process of sugar industries. These solvents are assisted to remove stains, dyes like malachite green by using adsorbents like fly ash bagasse (Tahir et al., 2016). In construction industries, bagasse ash has high potential as partial cement materials (Tekle, 2011). Usually, vinasse and filter mud produced from alcohol industries used as fustigation substituents as liquid and solid amendments as plant growth supporter. It also reduces the environmental damages. Mainly environmental damages are due to heavy metals, mineral fertilizers, and some dye deposit on lands (Prado et al., 2013). Some of the solvents are used in paper industries for various purposes. Biomethanation is possible by spent wash, which is a liquid waste from fermentation and distillation process. It is due to the reduction of acidic content in spent wash to make it useful. Agricultural sector also utilizes the postmethanated spent wash as an alternate source of manure and fertilizers (Dotaniya et al., 2016). Methrotrexate, an antimetabolite, used to treat rheumatoid arthritis, which acts as drug carrier in pharmacological sector. Usually, the source of this drug carrier is cane lignin (Vinardell and Mitjans, 2017). Dried filter cakes were used as a folder for cattles along with the tops and stalks of sugarcane (Solomon, 2011). Usually, the carnauba wax production requires high costs, and it is made from the press mud and peels of plants mainly sugarcane (Inarkar and Lele, 2012). In addition to this, the value-added chemicals like D-003, octasanol and policosanol (Rehan et al., 2019), and some cosmetics (Clauser et al., 2016) also produced from the waste residues of biofuels.

1.15 Limitations of biorefineries

Current constraints in environmental evaluations of biorefinery structures (e.g, analytical choices and openness) result in low comparability and uncertainty across studies (van Ree et al., 2007). Apart from these methodological shortcomings, the biggest drawback of biorefinery evaluation is the need to put together core stakeholders to benefit from multidisciplinary expertise (de Jong and Jungmeier, 2015). However, commercialization of every biorefinery form is still very small. Many investors are unable to invest due to a lack of detailed method information and the associated return on investment volatility. The creation and application of process models to forecast the (economic) performance of the considered biorefinery process will help investors and policymakers to decide whether to spend further in biorefinery plants or not (De Buck et al., 2020).

1.16 Future perspectives of biorefineries

The motivations for switching to the production of bio-based products include the conservation of resources and environment protection; therefore the implementation of biorefineries must not jeopardize the environment. The following issues are of the most concern: land-use change and its effect on GHG emissions and food security. Direct land-use transition happens as feedstock for biorefinery purposes (e.g, soybean for biodiesel) and displaces a previous land-use (e.g, forest), potentially altering the carbon stock of that land. Indirect land-use transition happens as pressure on agriculture caused by the removal of a previous occupation—such as biomass feedstock processing—causes land-use changes in other areas. The substitution of existing land-use for the production of biofuels and other bio-based items will result in direct land-use changes elsewhere. When more farming fields and ecological ecosystems are used for increasing energy crops, land-use transition results in a decrease in food supply and a decrease in biodiversity. These foreseen consequences must be considered to ensure ecological and social sustainability as global bioenergy production, especially biorefiners, expands.

1.17 Conclusion

Nowadays, the increasing threat is spoilage of human health and environmental pollution. Environmental pollution can be reduced by using wastes as sustainable energy sources. The conversion of waste residues into various values added products is one of the increasing strategies for environmental recreation. Here, various types of biorefineries and its potential in waste treatments are discussed. Challenges in waste recreation and for production of biofuel from the wastes are also highlighted deliberately.

The biorefineries are diverged indifferently like food wastes, agro wastes, plastic wastes, and industrial wastes and are converted into energy, biofuels, biogas, chemicals, solvents, and some other value-added products. The main thing is that there should be a crucial development in innovative technology that improvise the methods for biofuel and energy production. It is essential to find smart ways of production to develop the socioeconomic and environmental welfares. Various biomasses are utilized to produce different kinds of biofuels. The major things to be considered while carrying out the process are that production should require minimum expenses, methodology carried should be efficient and easier than other conventional methods, and it should be pollutant-free, because the process carried in the production of biofuel requires catalysts like enzymes and chemicals in a huge amount. However, it is the major challenge facing by the production industries. Using the fundamental knowledge of biosciences is needed to improve the biomass yield. The plants with potential characteristics like bioenergy plants are enhanced to produce biogas and biofuels. Novel methodology and techniques are carried out to produce different fuels and energy from various biorefineries. These kinds of approaches facilitate the employment for rural area farmers and workers; it also provides the sustainable environment.

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