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Cultivation and Management of Biofuel Plants in Rajasthan

Dr. Yogesh Chahar

Associate professor in Chemistry, SBD Govt. College, Sardarshahar, Churu, Rajasthan, India

ABSTRACT: Rajasthan has become the first Indian state to implement the national policy on biofuels unveiled by the centre.High-power Biofuel Authority approved this implementation. Highlights of the Biofuel National Policy:

- The State Government will be putting emphasis on increasing production of oilseeds
- Further, the State Government is promoting research in the fields of alternative fuels and energy resources
- Biodiesel plant with a capacity of eight tonnes per day has already been installed in the state
- There would be further emphasis on biofuel advertisements by the state government to create awareness about the same

Women's self-help groups (SHGs) will be created by the State Rural Livelihood Development Council to encourage the use of biofuels. If would also help farmers to dispose off their surplus stock in an economic manner and would also reduce the country's dependence on oil imports. It encourages setting up of supply chain mechanism for biodiesel production from non-edible oilseeds, used cooking oil and short gestation crops.

KEYWORDS: biofuel, Rajasthan, cultivation, management, plants, government, energy, alternative

I. INTRODUCTION

Biodiesel is an alternative fuel which can be used in place of fossil fuels.It is manufactured from vegetable oils, recycled grease, algae, and animal fat. It can be used in diesel-powered cars, trucks, tractors, boats, shipping equipment, irrigation systems, mining equipment, electrical generators and all those applications where diesel is typically used. Biodiesel can be used in diesel engines with little or no modification.It is a renewable fuel.It can be produced locally.It is produced through a chemical process called transesterification, in which glycerine is separated from the fat or vegetable oil.The process of transesterification leaves behind two products -- methyl esters and glycerine -- which can be sold for the preparation of soaps and other products.It is biodegradable.[1,2]It is non-toxic.While burning, it emits 60 per cent less carbon dioxide.The energy that biodiesel produces is approximately 90 per cent of the energy produced by petroleum diesel.It is also used in non-engine applications such as to remove paint

Seeing the strong prospect of production of BioFuel on the culturable wasteland of Rajasthan through Jatropha and other such tree borne oilseeds Bio Fuel Mission has been constituted in 2005-06 under the Chairmanship of Hon'ble Chief Minister. To implementation of the objectives of the BioFuel Mission the State Government has declared the Bio Fuel Policy and has constituted the Bio Fuel Authority.[3,4] Rajasthan government now providing government enterprises and private companies to do the following work along with cultivation of Jatropha, Pongamia and other such tree born oilseeds for Bio-Diesel:

Mission of Bio Fuel Authority

- Establish a processing unit.
- Establish transesterification unit/Bio diesel refinery.
- Take up research and development work for package of practice.
- Establish a nursery for developing of good quality planting material and seeds.
- Provide employment to local people's on priority.[5,6]

Benefits of Bio Fuels

India have a high usage of traditional fuels like coals and petroleum products for which the goverment have to import it and have to pay heavy money for it, which is a blocking the growth of India. So using Bio Fuels will not only help the government but also will make less pollutions and have many other benefits like –

- It will reduce to be dependent on the imported oils.
- Reduction in diesel consumption and and greenhouse gases.
- It will creat many job opportunities since local will work in the bio fuel plants.
- With the set up of these plants more facilities will come to the area like proper roads and other facilities.[7,8]

In a study, based on production of biofuel , The utilization of dedicated energy crops and agricultural residues for producing biofuels and bio-oil in a range of energy conversion technology is attracting more research interests. Pyrolysis is one of such important thermochemical method for converting lignocellulosic biomass into biofuels. This work investigates the pyrolysis of residues from a dedicated energy crop, *Jatropha* using intermediate pyrolysis. Pyrolysis of *Jatropha* biomass residues [*Jatropha* fruit shells (JFS) and *Jatropha* seed coat (JSC)] was carried out in a tubular fixed bed reactor at a temperature of 450^{o}C, using intermediate pyrolysis method. Bio-oils were obtained and subsequently characterised for their physico-chemical properties. The yields of the resulting bio-oil, biochar and gas were determined. The compositions of the bio-oils obtained were also determined by gas-chromatography mass spectrometry (GC-MS) and carbon, hydrogen, nitrogen, sulphur (CHNS) elemental analysis. The main constituents of the bio-oils obtained from JFS and JSC were acetic acid, guaiacol, 2,6-dimethoxyphenol and phenol. The empirical formula of the obtained JFS and JSC bio-oils were found to be CH1.77 O0.28 N0.04 and CH2.03 O0.47 N0.04 respectively. The bio-oil samples that were produced from JSC and JFS of Nigerian origin were found suitable for bio-oil production.[9,10] Valuable compounds found in the bio-oils indicated potential industrial applications.it was also investigated that The demand for biodiesel has soared along with government subsidies and mandates for sustainable energy. The quality and performance of biodiesel depends on the composition of the fatty acids present in the oil as it has a direct impact on the ignition quality, heat of combustion, flow at low temperature and oxidative stability. The oil extracted from *Jatropha curcas* seeds has been used by many countries as a biodiesel feedstock. To have good oxidative stability and flow properties under low temperature, biodiesel needs more monounsaturated fatty acids (oleic and palmitoleic acids), less polyunsaturated acids and less saturated acids. New insights into genes of *Jatropha* oil biosynthesis and metabolism as well as of transcriptional control are beginning to unfold biotechnological enhancement of oil content and quality by direct genetic engineering. To minimize unwanted effects at whole plant level, precise control of gene targeting will be needed. The deletion of antibiotic selection marker from the transgenic plants will also further increase the public acceptance of transgenenesis. In this review, we focus on the strategies and genes that have been successfully applied to the genetic engineering of oil fatty acids. There is also interspecific breeding, useful gene resources and new strategies for improving the properties of biodiesel and jet biofuel from *Jatropha.[11]*

The plant multiplication would however increase biofuel production. Physic nut plant (*Jatropha* curcas L.) is considered as one of potential sources for a non-edible biofuel-producing energy crop throughout the world. The conventional propagation methods for this species present many problems including poor seed viability, low germination, unstable yield and high oil content. In addition to the problems associated with establishing seedlings, *Jatropha curcas* was found to be largely recalcitrant to in vitro regeneration and unresponsive to many plant growth regulators. Recently, a rapid and effective system of somatic embryogenesis and organogenesis from leaf transverse thin cell layers (tTCLs) of *Jatropha curcas* L. was established. By inducing several thin cell layers precisely with various plant growth regulators, numerous small shoot clumps formed directly. These small shoot clumps were then transferred to a new medium for shoot elongation. Besides, tTCL promoted indirect organogenesis, through callus formation, on media containing kinetin and IBA.[12,13] Nodular callus structures started to differentiate into shoot buds when hard compact ones were transferred to fresh medium containing kinetin only. Embryogenic calli were induced and proliferated on MS medium supplemented with kinetin and 2,4-D, including vigorous somatic embryos. These embryos developed to plants with normal phenotype and rooted easily in growth regulator-free half-strength MS medium. Regenerated plantlets from organogenesis and somatic embryogenesis were acclimatized under the controlled greenhouse conditions with a high survival rate.[14,15]

II. DISCUSSION

Governments around the world see biofuels as a common solution to the multiple policy challenges posed by energy insecurity, climate change and falling farmer incomes. The Indian government has enthusiastically adopted a second-generation feedstock – the oilseed-bearing shrub, Jatropha curcas – for an ambitious national biodiesel program. Studies estimating the production capacity and potential land use implications of this program have typically assumed that the 'waste land' slated for *Jatropha* production has no economic value and that no activities of note will be displaced by plantation development. Here we examine the specific local impacts of rapid *Jatropha* plantation development on rural livelihoods and land use in Rajasthan, India. We find that in Jhadol Tehsil, *Jatropha* is planted on both government and private land, and has typically displaced grazing and forage collection.[16,17] For those at the socioeconomic margins, these unconsidered impacts counteract the very benefits that the biofuel programs aim to create. The Rajasthan case demonstrates that local land-use impacts need to be integrated into decision-making for national targets and global biofuel promotion efforts.

Ethanol-Ethanol (CH3CH2OH) is a renewable fuel that can be made from various plant materials, collectively known as "biomass." Ethanol is an alcohol used as a blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions.The most common blend of ethanol is E10 (10% ethanol, 90% gasoline) and is approved for use in most conventional gasoline-powered vehicles up to E15 (15% ethanol, 85% gasoline). Some vehicles, called flexible fuel vehicles, are designed to run on E85 (a gasoline-ethanol blend containing 51%–83% ethanol, depending on geography and season), an alternative fuel with much higher ethanol content than regular gasoline. Roughly 97% of gasoline in the United States contains some ethanol.Most ethanol is made from plant starches and sugars—particularly corn starch in the United States—but scientists are continuing to develop technologies that would allow for the use of cellulose and hemicellulose, the non-edible fibrous material that constitutes the bulk of plant matter.The common method for converting biomass into ethanol is called fermentation. During fermentation, microorganisms (e.g., bacteria and yeast) metabolize plant sugars and produce ethanol.[18]

Biodiesel-Biodiesel is a liquid fuel produced from renewable sources, such as new and used vegetable oils and animal fats and is a cleaner-burning replacement for petroleum-based diesel fuel. Biodiesel is nontoxic and biodegradable and is produced by combining alcohol with vegetable oil, animal fat, or recycled cooking grease.Like petroleum-derived diesel, biodiesel is used to fuel compression-ignition (diesel) engines. Biodiesel can be blended with petroleum diesel in any percentage, including B100 (pure biodiesel) and, the most common blend, B20 (a blend containing 20% biodiesel and 80% petroleum diesel).

Renewable Hydrocarbon "Drop-In" Fuels-Petroleum fuels, such as gasoline, diesel, and jet fuel, contain a complex mixture of hydrocarbons (molecules of hydrogen and carbon), which are burned to produce energy. Hydrocarbons can also be produced from biomass sources through a variety of biological and thermochemical processes. Biomass-based renewable hydrocarbon fuels are nearly identical to the petroleum-based fuels they are designed to replace—so they're compatible with today's engines, pumps, and other infrastructure.[19]

Biofuel Conversion Processes

Producing advanced biofuels (e.g., cellulosic ethanol and renewable hydrocarbon fuels) typically involves a multistep process. First, the tough rigid structure of the plant cell wall—which includes the biological molecules cellulose, hemicellulose, and lignin bound tightly together—must be broken down. This can be accomplished in one of two ways: high temperature deconstruction or low temperature deconstruction.

High-Temperature Deconstruction

High-temperature deconstruction makes use of extreme heat and pressure to break down solid biomass into liquid or gaseous intermediates. There are three primary routes used in this pathway:

- Pyrolysis
- Gasification
- Hydrothermal liquefaction.

During pyrolysis, biomass is heated rapidly at high temperatures (500°C–700°C) in an oxygen-free environment. The heat breaks down biomass into pyrolysis vapor, gas, and char. Once the char is removed, the vapors are cooled and condensed into a liquid "bio-crude" oil.Gasification follows a slightly similar process; however, biomass is exposed to a higher temperature range (>700°C) with some oxygen present to produce synthesis gas (or syngas)—a mixture that consists mostly of carbon monoxide and hydrogen.When working with wet feedstocks like algae, hydrothermal liquefaction is the preferred thermal process. This process uses water under moderate temperatures (200°C–350°C) and elevated pressures to convert biomass into liquid bio-crude oil.[20]

Low-Temperature Deconstruction

Low-temperature deconstruction typically makes use of biological catalysts called enzymes or chemicals to breakdown feedstocks into intermediates. First, biomass undergoes a pretreatment step that opens up the physical structure of plant and algae cell walls, making sugar polymers like cellulose and hemicellulose more accessible. These polymers are then broken down enzymatically or chemically into simple sugar building blocks during a process known as hydrolysis.

Upgrading

Following deconstruction, intermediates such as crude bio-oils, syngas, sugars, and other chemical building blocks must be upgraded to produce a finished product. This step can involve either biological or chemical processing.Microorganisms, such as bacteria, yeast, and cyanobacteria, can ferment sugar or gaseous intermediates into fuel blendstocks and chemicals. Alternatively, sugars and other intermediate streams, such as bio-oil and syngas, may be processed using a catalyst to remove any unwanted or reactive compounds in order to improve storage and handling properties.The finished products from upgrading may be fuels or bioproducts ready to sell into the commercial market or stabilized intermediates suitable for finishing in a petroleum refinery or chemical manufacturing plant. [21]

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III. RESULTS

Due to the diverse characteristics regarding biodiversity and elasticity of microalgae along with their higher growth rate compared with terrestrial plants, the ability to grow on non-productive land and use poor-quality water, the ability to remove pollutants from wastewater and to sequester CO_2 from flue gases, etc., microalgae have been considered as a promising future biofuel feedstock [1, 2]. There are several pathways for processing microalgae into biofuel: biodiesel production through transesterification of lipids [3], bioethanol production through fermentation of the algal biomass, biogas production through anaerobic digestion, and bio-crude production through thermochemical conversion are among the alternatives processes [4,5,6]. Simultaneous production of biodiesel and biogas from microalgae has received interest as it enables the utilization of lipid-extracted algae for further processing and biogas production so that it could help to enable a maximum utilization of the algae biomass [7, 8].

Anaerobic digestion has also become a special focus in the utilization of microalgae for biofuel production particularly from the bio-refinery point of view. For a viable production of biofuel from microalgae, some challenges, such as managing a high-energy and capital-intensive harvesting/dewatering process [9], coping with the high amount of residues left after lipid extraction in the case of lipid-based biofuel production (microalgae biomass contains 30–40% lipid, and up to 70% of the residual biomass is left after the extraction process) [10], and the need for fertilizers [11], need to be overcome. Anaerobic digestion can provide a pathway to avoid some of these problems by recovering nutrients from the extracted residual biomass and producing electricity from the methane biogas [12].The production of biofuel from microalgae however has not yet been realized in large-scale production. Major research gaps, such as reducing energy input, maximizing yield, and those related to an efficient material and energy usage, are waiting to be addressed. In microalgae cultivation, the nutrient supply has a significant impact on cost, sustainability, and production sitings [13], whereas the major nutrients (nitrogen and phosphorous) need primary focus.It has been reported that the integration of microalgal biofuel production with industrial or power plants might help to increase the feasibility of the process [7, 8]. The aim of this research is to conceptually couple microalgae cultivation with an existing Ethiopian sugar factory, which has an annexed ethanol factory, so that the wastewater and the flue gas from the factories are used as nutrient and CO_2 sources for the microalgae growth. The study explores a future possible microalgal cultivation integration approach with sugar and ethanol production factories by following a case study approach which uses the wastes and by-products as inexpensive CO_2 and nutrient sources for the growth of the algae. The primary goal was to produce biodiesel and biogas using this integrated process. Bio-fertilizer is also considered as a by-product of the integrated process. The integrated process was evaluated with regard to product output, energy requirement, and energy output. Likewise, the effect of several factors, such as oil content in the microalgae and the nitrogen content in the wastes on the production of biodiesel, have been investigated. [11]

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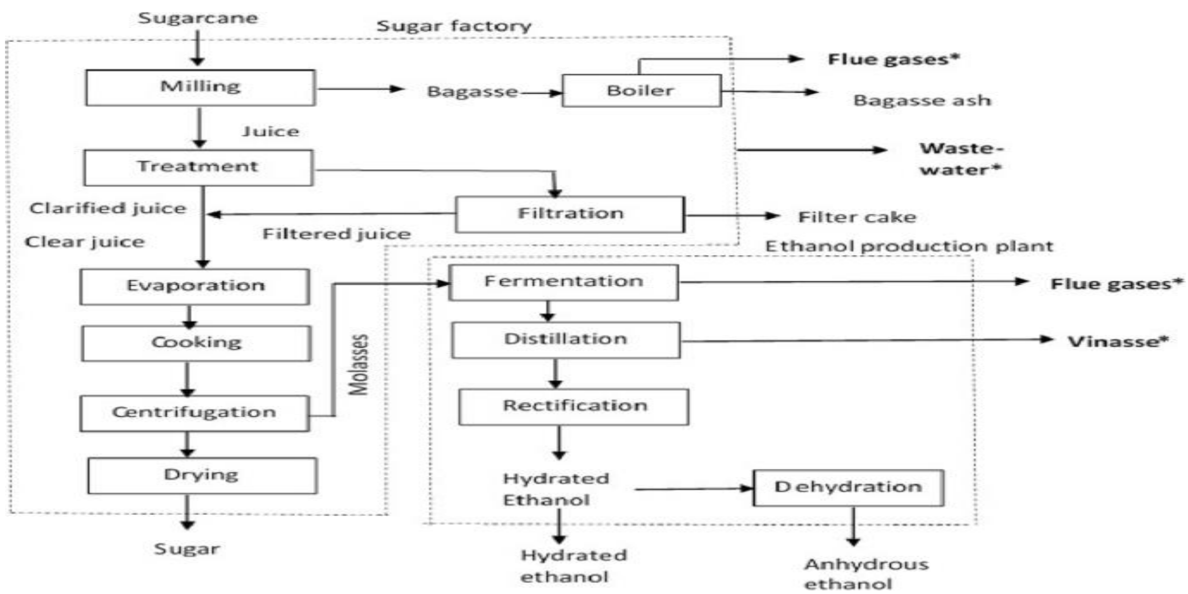

The biodiesel production should involve cell disruption, extraction, and transesterification of the oil to biodiesel.

Cell disruption

In the cell disruption unit, the algal biomass needs to be treated using an appropriate technology to increase the recovery of intracellular products during wet extraction. For the present work, high-pressure homogenization was considered. This method was selected because it is a well-established technology both on laboratory and industrial scale and has thus developed to one of the most commonly used methods [16]. The biomass with 25 wt.% from the harvesting processes should be treated for cell disruption and lysis using pressure homogenization before forwarding it to extraction [18]. Energy consumption for pressure homogenization was assumed to be 0.20 kWh/kg of dry biomass and 90% efficiency, corresponding to a 25 wt.% input [21]. It is thought that the undisrupted algae in the homogenizer flow through the extraction (with no lipid recovery) to the digester with the residues.

Lipid extraction

Lipid extraction from algae is mostly performed either from wet algal paste or dry algal cake, with or without cell disruption [12]. In the present study, lipid extraction from wet algal paste using the solvent extraction technique with pretreatment or cell disruption is carried out. It is supposed that lipid extraction should be performed using ethanol. Ethanol should be used because of its polar nature enabling it to penetrate the polar cell membrane of the lipids so that more cell material could be made free and be extracted [17]. Moreover, ethanol has low toxicity and is available in the factory (ethanol is produced from cane molasses in Metahara factory). In some other extraction studies, a ratio of solvent to dry biomass of 5:1 (w/w) was used, and the same ratio was assumed for the present study [19]. A lipid recovery of up to 97% was reported in the literature [18]. However, for the present study, an 80% lipid recovery is considered as a base value. The lipid-rich solvent and the algae residue slurry are assumed to be separated through disk stack centrifugation [18]. The algal residues should then be forwarded to the AD for the biogas production, while the algae oil–solvent solution should be forwarded to a stripping column where the ethanol would be separated from the oil and recycled, leaving a 99.50% pure lipid stream [7, 18]. The electricity requirement for the extraction step is assumed to be 0.28 kWh/kg per dry biomass [21] while a thermal energy of 1.30 kWh/kg per dry biomass was accounted [21]. Solvent loss in circulation and lipid loss in the stripper are thought to be 5.20 g ethanol/kg of oil and 5 wt.%, respectively [7].

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Transesterification

The extracted lipids would be transported and converted to biodiesel by transesterification using methanol in the presence of sodium hydroxide as a catalyst (1 wt.%) [21]. The methanol-to-fatty acid mass ratio in the reactor was assumed to be 1:10 [21]. An 80% (wt.%) conversion rate of oil to biodiesel was assumed in the reactor as a base value [14]. There are some other studies which show that the free fatty acid content in the microalgae is very low, approximately 0.05% [12]. When taking this into account, a pretreatment step would not be necessary in the present study. The glycerol formed during transesterification was thought to be separated in a decanter with a purity of 85% glycerol and 15% methanol (wt.%) [7] and would then be forwarded to the AD. It was assumed that 0.1 kg glycerol would be formed per kilogram of biodiesel [5]. The unreacted methanol was assumed to be recovered via distillation and recycled back to the reactor. The final purity of the fatty acid methyl ester (FAME) was regarded as 96.50% (wt.%). The contents of water, glycerol, and methanol in the FAME were expected to be 0.50, 0.24, and 0.20 wt.%, respectively [7]. Electrical and thermal energy requirements for the transesterification were expected to be 3.80×10^{-4} and 0.68 kWh/kg of converted oil, respectively [21]. The density and energy content of the biodiesel were accounted to be 900 kg/m^3 and 42 MJ/kg, respectively [21].

Anaerobic digestion/biogas production

In the biogas production model, it is assumed that the inflows to the AD are derived from five process steps. These include the vinasse, a by-product in ethanol production; the primary sludge from the wastewater primary treatment stage; the algae residues (lipid-extracted algae (LEA and the undisrupted algae) from the oil extraction step; the filtered algae in the harvesting section; and crude glycerol, a by-product from the transesterification step in the biodiesel production.The vinasse from the ethanol production factory was one of the components with a high mass flow rate . Considering the molasses-based distillery effluent, vinasse, as the main component in the anaerobic digestion, the following four reactor configurations were implemented on a commercial scale: a continuous stirred-tank reactor (CSTR), an upflow anaerobic sludge blanket (UASB) reactor, a fixed film/media digester (or anaerobic filter, AF), and a thermophilic digester [13]. The most successful configurations today are the UASB and CSTR reactors [14]. The UASB reactors are used for the treatment of a wide range of industrial wastewaters (from low-to-high-strength wastewater) including vinasse [15]. UASB reactors are being encouraged because of their several advantages including plain design, uncomplicated construction and maintenance, low construction and operating costs, low sludge production, robustness in terms of chemical oxygen demand (COD) removal efficiency and wide applicability, less CO_2 emissions due to less energy requirement, as well as quick biomass recovery [17].

In the present study, in Rajasthan the vinasse is characterized by a high total solid and high COD content. Glycerol, high-strength wastewater (with a high concentration of CODs), lipids, and some fatty acids would be added along with the vinasse which are characterized by a high solid content. In a UASB reactor, the hydraulic retention and solids retention time are not the same, and an uncoupling of the substrate from the hydraulic system is observed. Hence, operating substrates with a high total solid content in the UASB possibly damages the granular structure. As all those compounds are complex molecules, they also might adversely affect the performance of the UASB reactor [13]. Furthermore, the phenolic compounds in the vinasse might contribute to the color of the vinasse and make biodegradability to be difficult in the UASB [2]. On the other hand, complex organic materials with high solid content can better be degraded by means of CSTR reactors. Using municipal organic waste, which is characterized by a high total solid content (171 kg/m^3) and a high COD (235 kg COD/m^3) as a substrate, allows a degradation of 68% COD to be achieved as was reported for a CSTR [7]. González et al. [5] recommended that co-digestion of vinasse with press mud using a CSTR reactor would be an excellent option for the treatment of streams of the alcohol sugar industry. Thus, a CSTR reactor was supposed to be used for the present study. In such a CSTR, a 65% COD removal and 0.29 m^3/kg COD removed is expected for the vinasse.[11]

Inputs to the AD

In the AD, the production of biogas was modeled based upon the volatile solids (VS), total solids (TS), methane yield per gram of volatile solids (g-VS), chemical oxygen demand (COD), and percent methane (CH_4) content in the biogas. The total amount of CH_4 produced in the AD was estimated using the CH_4 yield for each component transferred to the AD.One of the inputs, which would directly go to the AD, was the algal residue (LEA and undisrupted algae in the disruption unit) from the extraction step. The solid concentration of algal biomass from the centrifugation step would be 25% as explained before. As the lipid content of the algae was considered to be 30%, and from 24% of it would be extracted in the extraction unit, the solid concentration entering in the digester could be calculated using the mass flows of carbon, hydrogen, oxygen, nitrogen, and phosphorous from the oil extraction [7]. By assuming that TN and TP would not be affected in the extraction step but the carbon, the mass of the LEA was estimated by subtracting the total carbon extracted from the total algal biomass. It was assumed that the pretreatment step for the biomass, pressure homogenization, would help to increase the CH_4 yield by 20% in the AD [7]. The whole biomass and the LEA were characterized to contain 0.73 g-VS/g TS and 0.63 g-VS/g TS, respectively [7]. Likewise, a biogas yield of 0.43 L CH_4/g-VS for the pretreated algae was supposed.The primary sludge that contains grease, a carbon-containing component, which is removed during the primary wastewater treatment, was the second input their modeling considered that such grease consists of oleic acid with the empirical formula $C_{18}H_{34}O_2$ and a density of 0.90 g/mL, and also a fatty acid found in sources of animals as well as vegetables. In this study, this assumption was applied. The amount of the grease could be estimated using a component concentration and the wastewater flow. It was assumed that the primary sludge contains 5.5% solid concentration (wt.%) [7, 8, 18], with a sludge flow rate of 32 m^3/day. For the given flow rate, an average density for water and grease (of 0.99 g/mL) was assumed. In this case, the amount of solid (grease) was obtained to be as high as 1750 kg/day, which corresponds to the amount of total solids, TS. Of the total solids, typically about 98.50% are volatile (VS content of oleic acid) [15] and would be broken down in the AD [8]. The methane yield for oleic acid was assumed to be 0.32 L CH_4/g-VS [53].The third input was the crude glycerol which was assumed to consist of 85% glycerol and 15% methanol [7]. The VS content in glycerol amounted to 0.85 g-VS/g glycerol [14] and 99% of methanol was also assumed to be volatile [15]. A methane yield of 0.43 L CH_4/g-VS and 0.53 L CH_4/g-VS were estimated for glycerol and methanol, respectively [7, 55]. In anaerobic co-digestion of mixtures, it is recommended that the amount of glycerol should not exceed 1% (v/v) [16], and thus, this criteria was satisfied in the present study.

The last inflow to the digester would be the vinasse from the ethanol production factory All the vinasse would go to the AD to be anaerobically digested together with the other inflows. The residue from the digester can be used for irrigation of either sugarcane or for the cultivation of microalgae in the pond. In this study, the supernatant was assumed to be recycled to the pond so that it would provide the microalgae with nutrients in addition to the wastewater from the sugar factory while the solid by-product would be used as a bio-fertilizer for the sugar cultivation. The COD, TN, and TP reduction factors in the digester . The process energy per volume of CH_4 produced or nutrient recovered depends on the digestion time and digester size. Digesters for wastewater treatment (WWT) applications are typically designed for a 20–50-day solid retention time [13]. In the present study, for the AD system, a power consumption of 0.22 kWh thermal/kg TS and 0.09 kWh electrical/kg TS with a solid retention time of 40 days was presumed [21]. This assumption included the additional electric power, used by a disc stack centrifuge, for concentrating solids from the digestate. Then, the digestate was supposed to be dried and used as a fertilizer. The solids concentration in the digester would be obtained from the total mass flow of solids transferred. It was supposed that a biogas with a methane content of 84% and a balance CO_2 would be produced from the AD [15].

IV. CONCLUSIONS

Biogas upgrading and nutrient recovery

In Rajasthan, Biogas is commonly used to generate electricity and/or heat. Biogas can also be used as transportation fuel after purifying it into biomethane. The sugary factory produces bioethanol to be used as transportation fuel by blending it with petro-diesel. Along with this bioethanol, in the present study, it is intended to deliver the biogas and the biodiesel, which would be produced in the coupled process, to the energy grid of the country and subsequently to be used as transportation fuel. The content of CH_4 in the gas needs to be greater than 95% (96% was assumed in the present study) for the gas to be used as transportation fuel [7]. Thus, the gas needs to be upgraded using an appropriate technology. Four types of technologies are commonly employed for the removal of CO_2, H_2S, and other impurities: membrane separation, adsorption, cryogenic distillation, and absorption. Absorption processes are suitable for large-scale processing units. Water scrubbing is common for biogas production. In this study, water scrubbing was used. The principle of a water scrubber is that CO_2 is highly soluble in water, whereas CH_4 is not. The gas is fed at the bottom of the scrubber tower, while the water enters the tower from the top so that the CO_2 is dissolved in the water and the gas rich in CH_4 comes out from the top. In the reverse absorption (the stripper tower), the CO_2 desorbs from the CO_2-rich water. The CO_2 desorbs from the water as the solvent travels down the tower. It was assumed that 0.50% of the CH_4 would be lost during the upgrading process [7]. The CO_2 gas from desorption step can be used as a carbon source in the pond, depending on mass balance. It was presumed that the energy demand of the water scrubber has to be 0.17 kWh/m^3 biogas and the temperature in the scrubber process 20 °C [7]. Considering that the energy density of CH_4 is 39.90 MJ/m^3 (11.20 kWh/m^3), the energy content of the biogas could be determined [19].

In Rajasthan ,it was thought that the concentration of TN and TP after digestion could be reduced by 16% and 21%, respectively [21]. Of the inflows to the AD, only the vinasse and the algae residue were assumed to contain nitrogen and phosphorus and thus used to supply the pond. The output from the AD would be split into two fractions, namely the supernatant and the solid digestate, and it would then enter the pond to provide the microalgae with nitrogen and phosphorus, while the digester solid would be used as a bio-fertilizer after treatment. It was expected that 25% of the TN would reside in the sludge and 75% would reside in the supernatant, while the TP would be split 50/50 between the solid and liquid phases [20]. It was also assumed that there would be 5% and 20% loss for TN and TP, respectively, as was also presumed before for the wastewater.

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