Recent Advancements in Prodution Technolgies Of Biofuels From Algae - A Technical Review

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***Abstract*— Algae are fast reproducers requiring only a form of energy, water, CO_2 and a few nutrients to grow. This paper sheds light on current trends in biofuel production from algal biomass in comparison with first and secondgeneration biofuels. It reviews the various genetic transformation technologies and their applications along with environmental impacts and constraints. The most potentially significant resources of sustainable biofuels in the future of renewable energy is algae. Algal productivity can offer high biomass yields per acre of cultivation. Continuous usage of petroleum sourced fuels is now widely recognized as unsustainable because of depleting supplies and the contribution of these fuels to the accumulation of CO_2 in the environment. Researchers and innovators have long recognized the potential of algae to help provide commercial quantities of biofuels. Several companies and government agencies are funding more efforts to reduce capital and operating cost and make algae fuel production commercially viable.**

Key words: Algae, Biofuel, Biomass, Renewable Energy.

INTRODUCTION

Today, fossil fuels isheavily relied upon for energy productionwiththree-fourths ofglobalproducingcomingfrom fossil fuels [1]. This global dependence has led to the increasing carbon dioxide (CO2) concentration in the atmosphere[2].Analternativeforfossilfuelconsumptionmust beutilizedin reducingtheatmosphericCO2concentration. This can be achieved through the use of biofuels. Biofuels are one hasthecapabilityofyieldingzerotonegativecarbonemissions while acting as a substitute for fossil fuels [3]. Globally, countries such have already started on utilizing biofuels as a source of energy. Indonesia has eyed on having a 5% biofuel mix in its energy blend. Malaysia, one of the largest producerof fossil fuel in the region, has implemented biofuel policies utilizing palm oil feedstocks

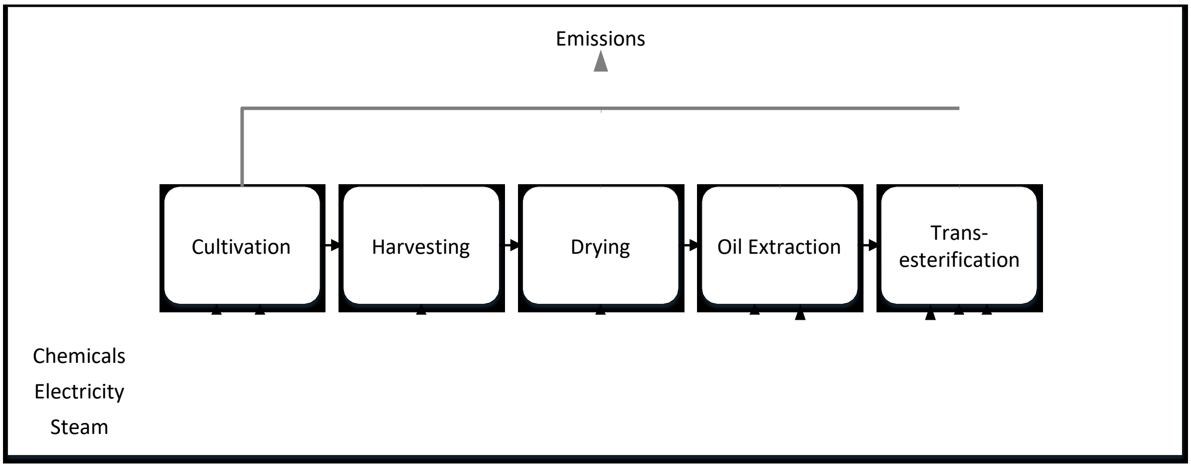

Fig. 1. System boundary of algae biodiesel production

The Philippines is not unfamiliar with biofuels as it has already been producing biodiesel from coconut oil and bioethanol from sugarcane. The utilization of these feedstocks areviable,becauseofthecountry'sagriculturalcapabilities.Its production slowed down for the past few years, because of the recent typhoons and insect infestations. The Biofuels Act of 2006 is also mandating an increase of biofuel mix in the fuel blendwithinthenext5to10years.As of2015,thecountrycan still meet the increase demand of bioethanolbut not of biodiesel [5]. Land use is also a growing concern as the Philippines is an archipelagic geography which can its utilization of land area. Lastly, the current feedstock poses a problem in the food vs fuel debate. The current feedstock contributes to the country's overall food supply, thereby, its conversion to biofuel can reduce the food supply of the country. Solutions must be found to help meet the country's biodiesel need. The shift to microalgae as feedstock can help mitigate these problems, as it possess unique characteristics that provides long term solutions. One of its unique characteristics is that it occupies less land area for oil production, approximately twenty times more than that of the coconut feedstock [6]. Microaglae are not considered as food crop, therefore, it can alleviate the pressure of the food versus fuel problem [7]. In terms of local capabilities, the Philippines has in itself the capability to already cultivate microalgae, as the aquaculture industry has already been utilizing them for aquaculture and fish feeds [8]. However, even though the country has the capability to produce microalgae, the cultivation system needs to be assessed for biofuel production. The feasibility of using the Philippine-built cultivation system for biodieselproductionmust first beassessed.

A popular tool that is used for product life cycles is the Life Cycle Assessment (LCA) methodology. It is an assessment tool utilized in determining the environmental implications on the process flow of a product. Its scope can range from its production phase to its utilization phase. The assessment is done by quantifying and interpreting the raw material consumption and emissions entailed during the life cycle process[9].Itsparticularusein assessmentofalgalbiofuelhas been studies by several literatures [10]. These studiesinclude a) comparative analysis of two thermochemical conversion techniques [11], b) assessment on the production of bio-jet fuel [12], c) investigation of different cultivation systems and fuel conversion techniques [13], d) assessment on the utilization of subcritical water extraction technique [14], and e) assessment of pond cultivation in a localized setting [15].

I. PROBLEMSTATEMENT

Although a former study was already conducted in comparing the performance of an aquaculture-oriented cultivation system in the Philippines with that of an existing system [16], there has yet been a study in comparing it with one of the prospects for biodiesel feedstocks of the Philippine government, which is jatropha. In this study, we focus on a comparative analysis between microalgae and jatropha for biodiesel production in the Philippines.

A life cycle model of algae-derived biodiesel and jatropha- derived biodiesel is defined, through data from literature on the considered processes in this study. The inventory flow for the production of the materials in the life cycle model can be accounted for through the of the Life Cycle Inventory (LCI) database. The quantified inventory flow and emissions implicated by the processes of the modeled life cycles can be accounted for and characterized by a Life Cycle Impact Assessment (LCIA) methodology.

II. METHODOLOGY

A. FunctionalUnitandSystemBoundary

A functional unit in a LCA study is a reference flow rate of which the model is scaled into. The functional unit, used for this study is the production of 1 ton of biodiesel. The system boundary of a LCA study is the scope of the processes considered. Fig. 1 shows the system boundary for algal biodiesel production, while Fig. 2 shows the system boundary for jatropha biodiesel production. The difference between the two models is that the jatropha biodiesel does not consider the use of harvesting and drying processes.

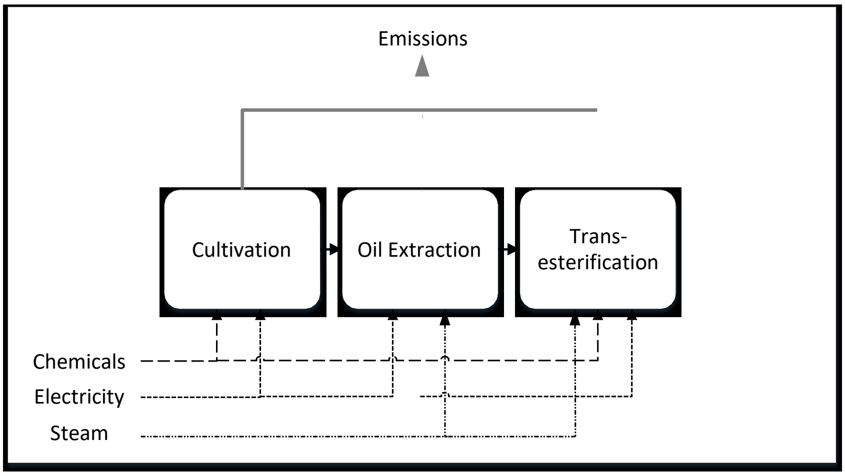

Fig. 2. System boundary of jatropha biodiesel production

B. *Cultivation*

The cultivation process is responsible for the production of the biomass feedstock. An open pond cultivation system is considered for microalgae production. The inventory flow is based from the reference [16]. This cultivation system was intended for the production of fish feeds and is an outdoor cultivation. It cultivates the microalgae *Nannochloropsissp.*. Fertilizers and nutrients are required for the algae to grow. Electricityisusedforlightsource,mixingandforaeration .The cultivation system for jatropha is obtained from the reference [17]. Table I and Table II shows the inventory flow for the algaecultivationandthejatrophacultivation,respectively.

TABLEI. MICROALGAE CULTIVATION UNITPROCESS

Inputs	Values	Units
Energy Consumption	67.47	kWh
NaH2PO4	0.70	g
FeCl3.6H2O	0.21	g
CuSO4.5H2O	284.00	g
KNO3	7.02	g
Ammonium Phosphate (21-0-0)	53.20	g
Ammonium Sulphate	26.60	g
Urea	26.60	g
Output		
Wet Biomass	1.00	ton

TABLE II.
JATROPHACULTIVATIONUNITPROCESS

Inputs	Values	Units
Energy Consumption	1.69	kWh
Nitrogenous Fertilizer	19.40	kg
Phosphorous Fertilizer	5.40	kg
Potassium Fertilizer	3.60	kg
Output		
Jatropha Biomass	1.00	ton

C. *Harvesting*

A slurry of water and algae are produced from the cultivation system. This slurry must be dewatered to extract the oil from the algae. A coagulation process with assistance from an air sparger was considered for the harvesting process of the microalgae. The inventory flow of this unit process was obtained from the reference [18]. Table III shows the inventory flow of the unit process.

D. *Drying*

The harvested biomass from the harvesting process must further be dewatered through the use of a drying process. Microwave drying was in drying the harvested biomass to a dried biomass with 10% moisture content. The model was based from the reference [19] and the inventory flow of the process is shown in Table IV.

TABLEIII. HARVESTING UNITPROCESS

Input	Values	Units
Wet Biomass	2.33	ton
Electricity	1.53	kWh
Output		
Harvested Biomass	1.00	ton

TABLEIV. DRYING UNITPROCESS

Input	Values	Units
Harvested Biomass	3.03	ton
Electricity	244.44	kWh
Output		
Dried Biomass	1.00	ton

E. Oil Extraction

Oil can be extractedfrom the jatropha biomass and the dried microalgae.Thisoilextractionprocesswasconsideredto have the same inventory flow for both biomass. The inventory flow is shown in Table V. The oil content of jatropha is assumed to be 30%, based from the reference [17], while the oil content of the microalgae is assumed to be also 30%, based from the reference[20].

TABLEV. OIL EXTRACTION UNITPROCESS

Input	Values	Units
Jatropha Biomass/Dried Biomass	3.33	ton
Electricity	231.97	kWh
Steam	3.07	GJ
Output		
Oil	1.00	ton

F. Transesterification

Onceoilis extractedfromthebiomass,aprocess knownas transesterification is utilized to convert the oil into biodiesel. Similar to the oil extractionprocess, it is assumed that both biomasshave the same unit process. The inventory flow for thisprocessisshownin TableVIandwasobtainedfrom[17].

TABLEVI. TRANSESTERIFICATION UNITPROCESS

Input	Values	Units
Oil	1,018.00	kg
Methanol	96.00	kg
Steam	1.57	GJ
Electricity	40.00	kWh
Output		
Biodiesel	1.00	ton

G. Life Cycle Inventory and Life Cycle ImpactAssessment

As evident in the unit processes, the life cycle of the two types of biodiesel utilizes material that have already been processed. The processing of these materials will entail their ownemissionsandrawmaterialconsumption.Itiswhythereis a need to use an inventory database or an LCI database in quantifying the emissions and the raw materials. EcoInventis the considered LCI database, because its capacity in determiningtheprocessflowofthematerialsconsideredinthis study. In assessing the environmental impact of the emissions and raw material consumption for the production of the biodiesels, the LCA methodology is used. TheEnvironmental Development of Industrial Products (EDIP) impact assessment methodology is considered as the LCIA for this study, because of its middle point approach and its wide variety of categorization. A midpoint approach is preferred as it provides a general categorization of environmental impact. The characterization factors for EDIP is enumerated in Table VII along with theirnomenclature.

RESULTS

Characterization of environmental impacts are assessed using the EDIP impact assessment methodology. The characterized impacts for the production of algae biodiesel are then compared with the production of jatropha biodiesel.

Jatropha biodiesel has scored lower impact as compared to the algal biodiesel, as evident in Fig. 3. Among the impact categories, electricity consumption has played a major role in the contribution of the environmental impact score. Algal biodiesel had a significant larger electricity demand than the jatrophabiodiesel,becauseoftheaddedprocessesneededinits life cycle, which are the drying and the harvesting process. Electricity consumption entails additional emissions and raw material utilization, production of algae biodiesel has therefore scored a larger impact score. In the aquatic eutrophication (N), ecotoxicity water chronic and in the ecotoxicity soil chronic, however, algae biodiesel has scored lower impact scores. This is attributed to the fertilizer consumption on the cultivation processofbothfeedstocks.

The contribution of each process to the overall impact characterization of algal biodiesel is shown in Fig. 4. The different cultivation process has is the highest contributor among the impact scores. This is different, however, in the ozone depletion impact category, where transesterification is

CONCLUSIONS

This study assessed and compared the biodiesel production from two types of feedstocks. The study analyzed the performance of utilizing an aquaculture-oriented cultivation system for biodiesel production. The study was able to generate a comparative scoring using EDIP for LCIA and EcoInvent for its LCI database. Results show that the algal cultivation system is the major contributor to the categorical impact scoring, attributed to its high electricity consumption. Its fertilizer consumption of, however, poses better results as compared to the eutrophication impact category. Improvements on the energy efficiency of the cultivation can, therefore, result to a better scoring of the algal biodiesel.

This study shall aid decision makers for algal biodiesel production in the Philippines. The electricity and the material flow of the biodiesel considered is obtained from EcoInvent. Future studies may need to consider the factor of locality of material flow for attaining a more robust result. Future studies may also want to consider providing a single scoring of the environmental impact using well defined normalization values and weighting, because of the inherent subjectivity in LCA studies. The work done in the reference [21] may be used for the weighting of LCIA in the Philippines. Lastly, land usage is an important aspect as the country has an archipelagic geography. Future studies may wish to consider land usage of the biodiesels as an added impact category.

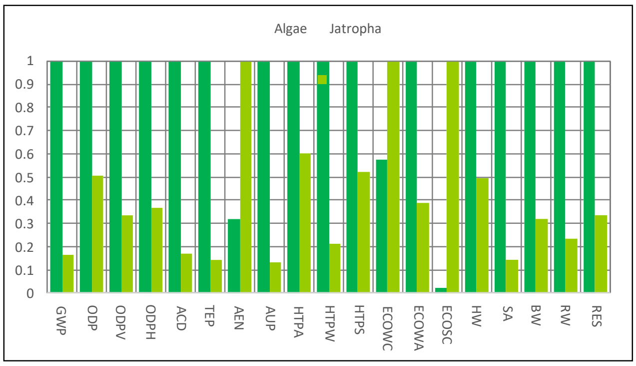

Fig. 3. EDIP characterization between algal and jatropha biodiesel

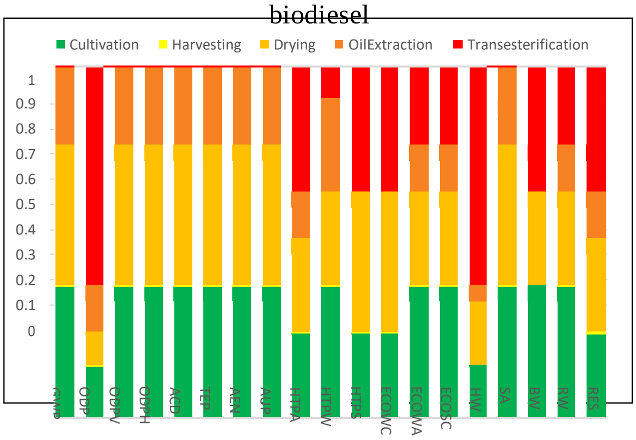

Fig. 4. Process contributions of algal biodiesel in EDIP characterization

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