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Life Cycle Assessment Of Neem And Karanja Biodiesel: An Overview

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Abstract: Biodiesel is one of the best substitutes to the fossil diesel fuel today in the world. Owing to big climatic diversity, there are numerous oil bearing seed plants/trees available in India. Extraction of the oil from these plants and its conversion to bio-diesel involves energy consumption at various stages starting from the plantation to the end use in the compression ignition engine. Karanja & Neem are the promising tree species suitable for providing oil for biodiesel production . This paper addresses the systematic evaluation of the energy consumed by Karanja and Neem trees at each stage during the growth cycle and conversion its seed oils to bio-diesel fuels and global warming potential. Results obtained verify that the total energy consumption during life cycles of the plants under study is lower than the energy output during combustion in IC engine. In addition The environmental impacts have been benchmarked with the life cycle impacts of fossil diesel. Moreover, the above aspects were significantly superior in Neem & Karanja biodiesel system when compared to Jatropha biodiesel system.
Keywords*:* Bio-diesel; life cycle analysis; non-edible vegetable oil; global warming potential; energy consumption.

1.Introduction

In the last few years interest & activity has grown up around the globe to find a substitute of fossil fuel. According to Indian scenario the demand of petroleum product like diesel is increasing day by day hence there is a need to find a solution. The use of edible oil to produce biodiesel in India is not feasible in view of big gap in demand and supply of such oil. Under Indian condition only non-edible oil can be used as biodiesel which are produced in appreciable quantity and can be grown in large scale on non-cropped marginal lands and waste lands. Non-edible oils like contain 30% or more oil in their seed, fruit or nut. India has more than 300 species of trees, which produce oil bearing seeds[1]. Around 75 plant species which have 30% or more oil in their seeds/kernel, have been identified and listed[2]. Traditionally the collection and selling of tree based oil seeds were generally carried out by poor people for use as fuel for lightning. Biodiesel has become more attractive because of its environmental benefits and fact that it is made up of renewable resources[3]. Although short term test using vegetable oil showed promising results, longer tests led to injector coking, more engine deposits, ring sticking and thickening of the engine lubricant[4].

Among various seed bearing trees rich in oil, Jatropha (jatropha curcas), Neem (azadirachta indica) and karanja (Pongamia pinnata) are the favorable species as they can be grown almost on all types of sands all over India.

It is evident that Jatropha plantation alone can meet only one third of the estimated biodiesel requirement and would require additional 30 million ha of waste land to meet the target of 20% biodiesel. Studies reveal that Jatropha produces estimated yields in irrigated land than rain fed[5]. A majority of the waste land available around villages are grass lands and community forests, which are meant for providing land less, small and medium scale farmers with commodities like fodder, fuel wood, timber and thatching material for homes.

Therefore combination of tree species planted in these wastelands around the villages is very important for the lively hood of the rural poor. If such lands are planted with Jatropha, it is likely to create more hardship to rural community, depriving them of their daily needs, because Jatropha leaves do not serve as fodder and it does not yield enough wood as well.

Hence it is very evident that planting Jatropha as a promising biofuel crop is not a feasible strategy both economically and ecologically. Thus, there is a need to identify alternate local plant which can add to the biodiesel feedstock without affecting the local ecology. In this context various research organizations across the world have been working for more than two decades to identify suitable vegetable oil yielding tree species to produce oil and convert the same into biodiesel[6]. Neem & Karanja are the promising tree species suitable for providing oil for biodiesel production, which conforms to international standards.

Milletia pinnata is a species of tree in the pea family, Fabaceae, native in tropical & temperate Asia including parts of India, China, Japan, Malaysia, Australia & Pacific islands[7,8]. It is often known by the synonym Pongamia pinnata and it was moved to the genus Milletia only recently. Pongamia pinnata is one of the few nitrogen fixing trees (NFTS) to produce seeds containing 30-40% oil. It is often planted as an ornamental and shade tree but now-a-days it is considered as alternative source for Bio- Diesel.

Neem (Azadirachta indica) is a tree in the mahogany family Meliaceae which is abundantly grown in varied parts of India. The Neem grows on almost all types of soils including clayey, saline and alkaline conditions. Neem seed obtained from this tree are collected, de-pulped, sun dried and crushed for oil extraction. The seeds have 45% oil which has high potential for the production of biodiesel[9]. It comprises mainly of triglycerides and large amounts of triterpenoid compounds, which are responsible for the bitter taste. It is hydrophobic in nature and in order to emulsify it in water for application purposes, it has to be formulated with appropriate surfactants.

The list of tree borne oil species has been constantly increasing. Many clean developments mechanism project developers are interested in exploiting these tree species for meeting challenges of energy supply and green house gas (GHG) emission reduction. With this number increasing, a scientific approach to identify environmentally sustainable tree species is in the wanting[10,11]. A vital requirement for bio-fuels to be a sustainable alternative fuels is that, it should be produced from renewable feed stock with a lower negative environmental impact. Consequently a study is needed in order to infer whether above requirements are met.

2.Methodology

Life cycle assessment (LCA) method has been found to be a suitable for evaluating the environmental impact of biodiesel produced from vegetable oils[12]. Life cycle analyses look at the whole picture of how a fuel is made, from cradle to grave. The life cycles begin with the extraction of all raw materials to make petroleum diesel and biodiesel, and end with using the fuels in vehicles. Examining global issues, such as CO2 emissions, requires a comprehensive life cycle analysis. Understanding the benefits of biodiesel requires us to compare its life cycle emissions to those of petroleum diesel. This study examines biodiesel energy's balance, its effect on greenhouse gas emissions, and its effects on the generation of air, water, and solid waste pollutants for every operation needed to made biodiesel and diesel fuel. We made no attempt to quantify its domestic economic benefits.

To evaluate the energy consumption during the life cycle of the plants derived biodiesel as fuel for compression ignition engine, a cradle to grave analysis is carried out. For this, energy inputs at each stage of the cycle during plant nursery, plantation, growth, seed collection, oil extraction, transesterification and care & safety are calculated. Sum of all energy inputs gives us the total energy input and it is compared with the energy contained in the fuel. For calculation purposes,

one hectare of land is considered as reference area. Energy considered in interaction during life cycle is indirect energy, given to the system and not direct energy like energy contained in the soil and solar energy taken by plant.

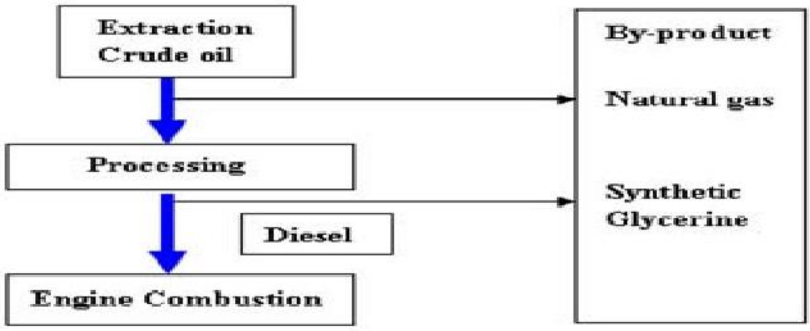

Fig.1 System boundary for Diesel

2.1 Life Cycle Inventory:-

In the present paper, LCA study of Karanja and Neem for investigating the environmental sustainability as biofuel feed stock has been presented.

Life cycle analysis shows the inputs of extra energy needs to convert the energy present in the raw material in to useable energy of the fuel. The life cycle analysis calculates the net energy ratio which is evaluated by dividing the energy output of the system in the form of fuel energy delivered to the compression ignition engine by the cumulative energy demand of the system. The study analyzes biodiesel production and identifies resource consumption and energy use for various life cycle stages and sub-processes.

Fossil fuel as reference system:-

For a suitable life cycle comparison, the fossil fuel reference system must provide the same products and functions as the biodiesel system evaluated. Hence, all products and by-products of the biodiesel system should be substituted in the reference system. The substitutions reflect the local situation. Glycerine was considered the only by-product because the other by-products are ploughed back to the field as soil enrichment and are not system outputs. In the reference system the glycerine is substituted by synthetically produced glycerine of similar quality and

biogas produced from seed cake is substituted for Natural gas[13].

Global warming potential (GWP):-

The data w.r.t. different phases of LCA were collected form field studies at Biofuel Park and associated CO2 emissions were collected from literature and multiplied with collected data, which has been referenced. CO2 emissions for methanol and electricity production have been directly adopted. It can be observed from table that usage of wood as fuel adds to highest CO2 emission from Karanja & Neem system and cultivation phase in particular. Biogas (Methane) leakage also results in higher emission compared to combustion of biogas in an engine coupled to dynamo (Genset) for electricity and heat generation.

3. System Boundaries And Assumptions

The study analyzes biodiesel production and identifies resource consumption and energy use for the following life cycle stages and sub-processes,

(i) karanja and neem cultivation; (ii) karanja and neem oil extraction; (iii) Biodiesel production via the oil transesterification.

Assumptions[24-26]

(i) Karanja and neem cultivation starts from nursery.

(ii) Planting densities are 550 trees/ha for karanja and 350 trees/ha for neem.

(iii) Average quality soil and rainfall at the plantation site

(iv) Neem & karanja get full maturity in 10 years of plantation when full seed yield is expected.

(v) Seed pod yield for karanja and neem is 60 and 35 kg/tree respectively.

(vi) Seed yield for karanja and neem is 14 and 15 kg/tree respectively.

(vii) Seed yield per hectare for karanja and neem is 7.7 and 5.25 tones respectively.

(viii) Percentage oil yield and oil extraction efficiency for karanja and neem oils are 25% & 94%; and 28% & 94% respectively.

(ix) Seed oil yield per hectare for karanja and neem is 1.8095 and 1.3818 tones respectively.

(x) No pesticides, insecticides, or herbicides are applied to the crops.

(xi) It is assumed that the amount of NPK fertilizers needed equals the amount of the seed cake which is used to offset fertilizer use on the plantation.

(xii) The energy used in creating/manufacturing of the materials and machinery used to assist the Life cycle of the plant oil is not considered in this analysis.

(xiii) An alternative use of the seed cake i.e. combustion to produce useable heat or power, is not considered.

Net energy ratio is evaluated by dividing the energy output of the system in the form of fuel energy delivered to the compression ignition engine by the cumulative energy demand of the system.

Table 1 Greenhouse Gas Emissions- CO_2

Particulars	Quantity Year^{-1} ha^{-1}	Unit	CO_2**	Unit	g CO_2 eq ha^{-1}	g CO_2 eq FU^{-1}	References**
Cultivation Phase							
Poly-bags production & discharge	1.65	kg	5.50	kg	9075.00		14
Organic Fertilizer application 1 t (N_2O Emission)	6.00	kg	0.01	kg	60.00		15 16
Fuel Wood	3000	kg	0.44	kg	1320000		17
Diesel Use	140	km	0.33	Kg km^{-1}	46620		18
Sub Total					1375755	305.72	
Oil Extraction Phase							
Electricity production and use: - oil press + Filter press					74800		19
Biogas leakage	786.24	L	0.71g	L	12839.30		19
Biogas Combustion in an Engine	339.55	kWh	0.77	kg kWh	55.92		20
Sub Total					87695.22	19.49	
Biodiesel Production							
Methanol production					2992.00		19
Electricity production and use: - transesterification unit					74800.00		19
Biodiesel Combustion in Engine (B100)	119.95	kg	20.90	g kg	2507.00		21
Sub Total					80299.00	17.84	
Total					1543749.22	343.06	

Table 2 Green House Gas Emission-SO_2

Particulars	g SO_2- eq ha^{-1}	g SO_2- eq FU^{-1}	Reference
Cultivation			
N volatilization (NH_3)	0.94		22
Poly bag Production & Discharge- SO_2	117.81		14, 15
Poly bag Production & Discharge- NOx	207.90		14, 15
Diesel use- NOx	91.14		18
Sub total	417.79	0.08	
Oil Extraction			
Electricity production and use- Oil press + Filter Press	66.68		16
Biogas Combustion in an Engine	15238.08		20
Sub total	15304.76	2.81	
Biodiesel Production			
Electricity production and use- transesterification unit	711.24		20
Biodiesel Combustion	0.15		23
Sub total	711.39	0.13	
Grand total	16433.94	3.02	

System Inputs

The energy consumption/inputs starting from plant nursery to the transesterification process i.e. bio-diesel production is divided in 7 categories as detailed below:

1. Plant Nursery: It covers energy inputs in soil preparation, soil bag fillings, watering the soil bags, machinery and man power used, care and safety up to one month. Four type of energy inputs are involved, energy in machinery for ploughing, irrigation, manures and manpower for all the activities of plant nursery[27].

2. Plantation: Factors like land type, land preparation, irrigation, care & safety etc are analyzed for energy use in plantation and caring up to the age of one year of the plant. Four type of Energy inputs as required in plant nursery are involved here also, energy in machinery for Ploughing, irrigation, manures and manpower for all the activities of plant nursery.

3. Growth: Care and safety one year onwards is considered up to 3 years of age of the plant. So man power is the input for the 2 years of growth[27].

4. Seed Collection: Pod collection, pod drying, de-poding (de-husking), seed drying are carried out manually and hence no machinery inputs are considered.

5. Transportation of Seeds: Energy input in transportation of seeds from the field to the biodiesel unit through IC engine tractor trolley is analyzed.

6. Oil Extraction: Oil expeller of capacity (1 Ton of seed/hour) is selected for energy calculation.

7. Transesterification : A transesterification unit of capacity (100,000 tons/annum) is considered for analysis. Energy contained in alcohol used for transesterification process is not considered here as

equivalent amount (slightly less than the mass of alcohol) of glycerin is produced as byproduct during the chemical process.

Total of energy inputs in all the sub-processes gives the total energy which is energy input (E Input) to the system. This energy input is indirect energy. Other energies like solar energy, energy contained in soil are not considered.

System Outputs

Methyl esters of the oils (biodiesels) contain the energy, which is given by

E = CVBD*T*1,000

where, CVBD = calorific value of biodiesel (MJ/kg); T- quantity of biodiesel (ton).

Considering brake thermal efficiency of a C.I. Engine as 20%, brake output energy will give the following amount,

Eoutput = 0.20*E

Net Energy Ratio

Net energy ratio can be calculated as,

Net Energy Ratio, R= $Energy_{output}$ / $Energy_{input}$

4. Conclusions

A life cycle energy ratio of biodiesels shows that all the two fuels are renewable. All the biodiesel have higher output than inputs in terms of energy. Neem and karanja biodiesels have equivalent energy ratio for hard and good soil conditions. Under normal conditions of soil and crop yield, karanja and neem biodiesel life cycle have energy ratios, R1=1.6425 and R2 = 1.6479 respectively. The highest variation in net energy ratio is among jatropha[28] and karanja biodiesel (1.4237 - 1.8846) for high yield. Karanja biodiesel has highest energy ratio if agricultural conditions like soils are better resulting in to high yield of the karanja biodiesel. As the wood of the trees can be used in furniture and manufacturing of buildings, from green house gas emissions point of view karanja and neem trees present advantage of carbon sequestration. The energy ratios may be improved with using latest technology in agriculture.

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