CHAPTER 7

COMPARATIVE STUDY OF JATROPHA AND MICROALGAE BASED GREEN DIESEL PRODUCTION SYSTEM

7.1.Introduction

This chapter provides a detailed comparative analysis of green diesel production from Jatropha and microalgae on the basis of four parameters agronomical practices and challenges, technical suitability, environmental acceptability and economic competitiveness. While doing so, this chapter also compiles the entire thesis and its results. Framework with the details of the parameters for comparative analysis of Jatropha and Microalgae based green diesel production system is shown in Figure 7.1.

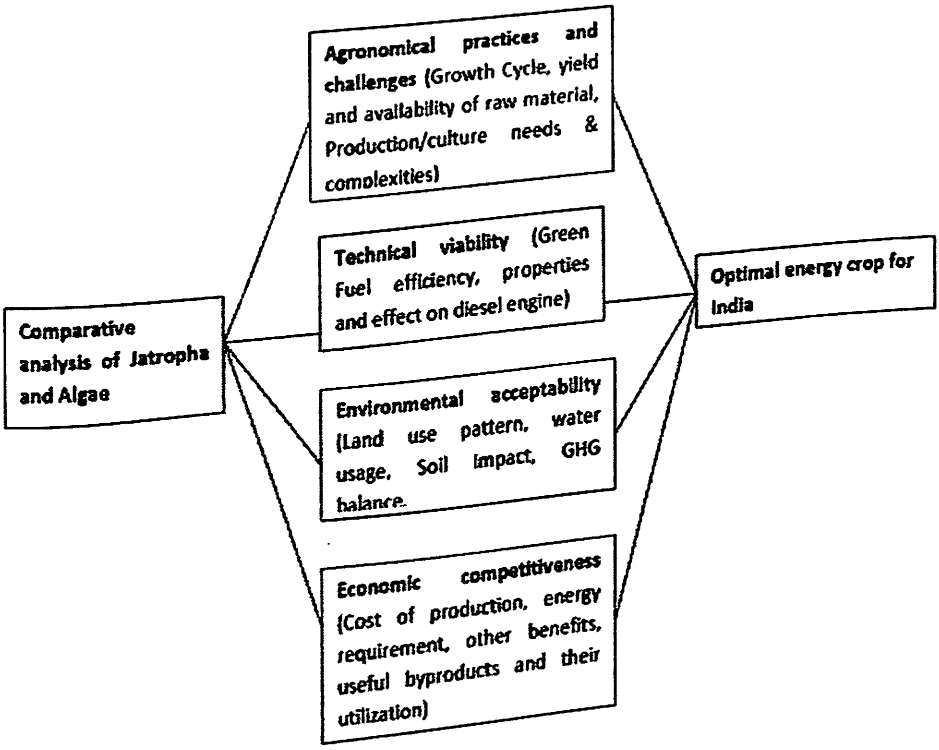

Figure7. 1: Framework showing the details of the parameters for comparative analysis of Jatropha and Microalgae based green diesel production system

The comparison is based on the best route for green diesel production from both Jatropha and algae based green diesel production system over 5 years.

7.2. Agronomical practices and challenges

Table7. 1: Comparison of Different Agronomical practices & Challenges through entire Life Cycle of Jatropha and Algae

Agronomical practices and challenges			
		Jatropha	**Microalgae**
Growth Cycle, yield and availability of raw material		Starts yielding fruits only in the second year of the growth, but starts producing full fledge fruits only 5^{th} year onward.	Short doubling period of 19 hours for *Chlorella vulgaris* [256].
Production/culture needs		Grows well in tropical and subtropical regions of the world, thus India is suitable for cultivation of this crop.	They have specific temperature need, at which their growth rate is high. India has four seasons in a year with different temperature ranges. And thus to maintain a specific temperature heat exchangers are required. Heat exchangers can be used for photobioreactors but not for open raceway ponds, which also shows the effect of the same in the form of low productivity in open raceway ponds.
Complexities	**Cultivation**	Cultivated just like a normal land crop, and thus, semi-skilled labor is required.	For maintaining a fixed flow rate and concentration levels, skilled labor is required.

	Extraction	Extraction process is very simple and can be performed easily with mechanical pressing and moreover semiskilled labor can easily operate them	For maximum extraction, solvent extraction is more suitable. But then it also involves careful and calculated addition of hazardous chemicals like chloroform and methanol. For such complex operation skilled labor is required.
	Processing	Can be processed both by transesterification and hydrogenation processes as the entire Jatropha oil is readily available for both the processes for conversion.	Only the TAG component of the lipid/oil is available for transesterification, therefore in order to process the entire lipid only hydrogenation is a possible option.
Conclusion	It is clear from the above comparison that from agronomical point of view, Jatropha can be grown and processed with far better ease than algae.		

7.3.Technical viability

Table7. 2: Comparison to find out the Technical Viability of Jatropha and Algae as an Energy Crop for Green diesel Production

	Technical viability	
	Jatropha	**Algae**
Green Fuel efficiency, properties and effect on diesel engine	Since hydrogenation process, does not differentiate between the nature of neat oil (TAG and polar lipids) and presence of FFA, so more or less the green diesel obtained from Jatropha oil and algae oil have similar properties and engine effect. And as mentioned in Table 3.3 of Chapter 3, green diesel produced from hydrogenation has similar properties as fossil diesel.	

Conclusion	Therefore, technically green diesel obtained from both the energy crops is almost equally good and feasible.

7.4.Environmental acceptability

Table7. 3: Comparison of Jatropha and Algae along their Life Cylce for Green diesel production, to find out their Environmental Acceptability as an Energy Crop

	Environmental acceptability	
	Jatropha	**Microalgae**
Land use pattern	Jatropha can even thrive on barren land.	Pond construction can take place on barren land.
Water usage	• Total 825000 liter of water over 5 years for cultivation with production of 6860.9 kg of green diesel (via hydrogenation and pyrolysis process), i.e. approximately 20.25 liter of water/kg of green diesel produced. • Moreover, it is a drought and frost resistant plant, so even if for some reason it doesn't get water for some time or face frost, can survive.	• In case of open raceway pond, a lot of water is lost through evaporation. • With reference to the open pond dimensions considered in this study, approximately 112500 m^3 of water was lost via evaporation over 5 years. • Moreover, apart from the above water usage 547000 m^3 of water was used to maintain the required concentration rate for production of 142926.2 kg of green diesel. • Even if we are able to re-circulate half of the water required to maintain the culture the total water usage will be 2701 liter of

		water/kg of green diesel produced. • Not only this, extra energy would be required to re-circulate the 50% water used in culture maintenance.
Soil impact	*J. curcas* has potential of establishing itself on FA when provided with basic plant nutrients and can also accumulate heavy metals many folds from FA without attenuating plant growth [257].	
GHG balance	4.5 kg of CO2 emission for every kg of green diesel produced.	18.33 kg of CO2 emission for every kg of green diesel produced.
Conclusion	Having looked at the water uses, GHG balance and soil impact, Jatropha seems to be a more environmentally acceptable energy crop for green diesel production than microalgae.	

7.5.Economic competitiveness

Table7. 4: Comparison of Jatropha & Algae, find out their economic competitiveness for Green diesel production

Economic competitiveness		
	Jatropha	**Microalgae**
Cost of production	For the current study , cost per kg of green diesel production was estimated to be ₹ 62.43	For the current study, cost per kg of green diesel production was estimated to be ₹140.

Energy requirement	Positive energy balance with NER of about 2.54 and would grow up in the further years.	• Negative energy balance with very less NER of about 0.25. • The chemicals like methanol and chloroform required for solvent extraction method are hazardous to health and environment. Thus, after extraction process they cannot directly be disposed in the environment. Extra energy is required to recover them via fractional distillation process.
Other benefits &Useful byproducts & their utilization	Control erosion, for land reclamation, and as a live fence to keep away farm animals as its leaves and stems are toxic to animals.	They can consume a lot of CO_2 from power plants and thus contribute in fighting with global warming.
Conclusion	When looked at the NEB, NER and cost of production, Jatropha has far better potential as an energy crop for green diesel production than microalgae and economically more competitive than microalgae.	

Finally the study concludes that in the present scenario and technological availabilities, Jatropha is more optimal energy crop for green diesel production when compared with algae. Algae still has a long way to go.

7.6.Way forward for Jatropha as an energy crop

Despite that Jatropha has a great deal of potential as a green diesel feedstock, it is also important to recognize the hurdles that must be overcome before it can become a viable energy crop in most parts of the world. Experiences from the failure of initial Jatropha projects broke many myths associated with the various agronomical practices of Jatropha, which is explained in detail in first part of Chapter 5. Lack of awareness and understanding of Jatropha plant needs and agronomical practices and scarce data on growth performance and yield of Jatropha plantation, were a few major reasons for failure of initial Jatropha projects. The huge investments in Jatropha plantations were not based on profound scientific knowledge of its ecology. The major claims rested on a narrow scientific base, and the hyped interest led to the risk of unsustainable practices.

The success of Jatropha production will depend on its viability as a commercial crop. There is need for the development of a package of practices/strategies for optimization of commercial cultivation of Jatropha [27], a few of which are given in Figure 7.2.

A study on land availability and biomass production potential in India, supports that biomass productivity can be increased by using genetically superior planting materials [189] . Thus, research on *Jatropha curcas* germplam improvement is also important because genetically modified and improved Jatropha seed quality will further complement the benefits of improved agronomical practices by increasing the oil yield per seed.

From experiences with Jatropha projects, it is now clear that it performs much better with adequate access to soil nutrients and water [48]. Adding some fertilizer or manure is needed to maintain good long-term seed yields, because Jatropha is not a nitrogen-fixing crop, and substantial Nitrogen is removed with the harvesting of the seeds [48]. It is largely promoted as a crop grown on marginal and wastelands. Seed yields of Jatropha reported in literature are in the range from 0.2 tons to 12 tons per hectare depending on production conditions [27] . The use of water and fertilizer might affect the sustainability of the projects by causing negative environmental impacts, thus extensive focus should be on the research and development of utilizing waste water and bio-fertilizers for cultivation of Jatropha. Adoption of soil and water conservation practices should be adopted.

It takes about 3 to 4 years, to realize the full yield of Jatropha. In the meanwhile, Jatropha can be intercropped with aloevera, a medicinal and cosmetic plant [258], which can successfully be cultivated on non-arable land [259]. It has also been successfully intercropped with chili pepper [260], sarpagandha, aswagandha, and adrak [261], which are common wasteland medicinal plants and herbs.

To achieve the full potential of Jatropha biodiesel system, research and development should also focus on the technical improvements. Initiatives should be taken to promote engines specifically designed for biodiesel use, addressing all possible technical issues.

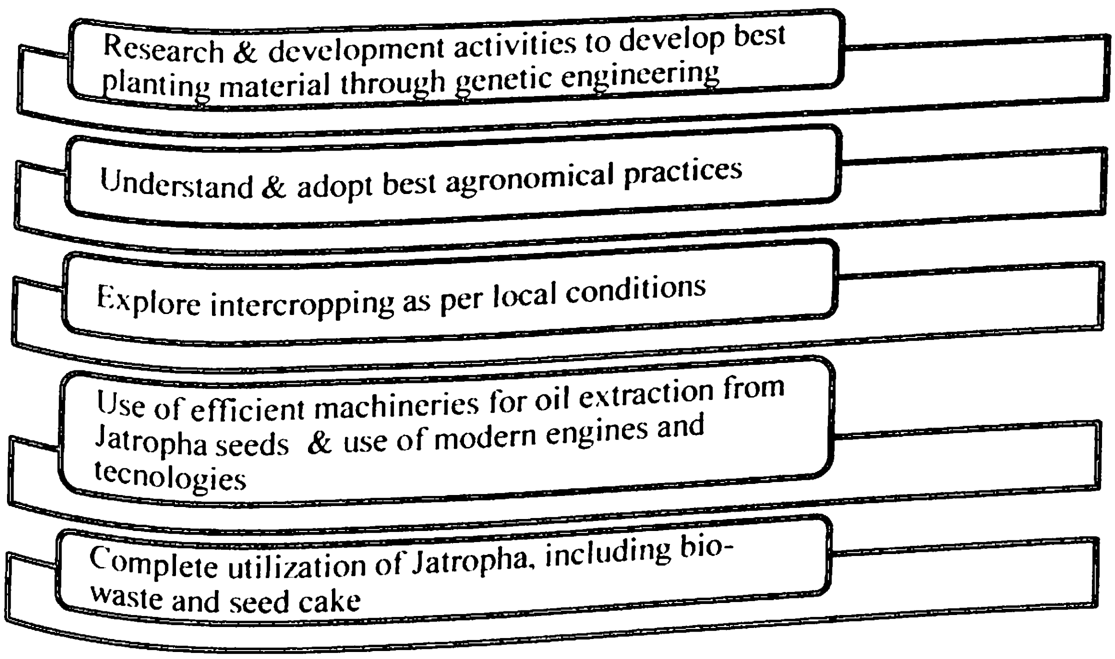

Figure7. 2: Package of Practices/Strategies for Optimization of Commercial Cultivation of Jatropha as an Energy Crop

Moreover, all the parts of Jatropha seed, i.e. oil, seed cake, husk should be fully utilized either to produce more energy or other useful products like organic fertilizer. Details of the practices listed in Figure 7.2 are given in first part of Chapter 5.

7.7. Concluding Remarks

According to the current study, when the values NEB and NER, over five years, for high input Jatropha green diesel production system were compared to the previous studies, it was found that these values were more than the NEB and NER values of the previous studies. Moreover, these values were expected to increase further with the passage of time. Furthermore, when the energy inputs and outputs of green diesel production from Jatropha seed cake were added, it increased NER by almost 1.4 times.

For algae it was found that, even on including the entire value chain and with the adoption of best available agronomical practices and recent technological advancements, the values for NEB and NER did not come out to be positive.

Finally, when the two energy crops were compared on the basis of four broad parameters i.e. agronomical practices, technical viability, economic competitiveness and environmental acceptability, the study concluded that in the present scenario and technological availabilities, Jatropha is more optimal energy crop for green diesel production. Algae still has a long way to go.

In spite of high values of NEB and NER, the success of Jatropha as an energy crop will depend only on its viability as a commercial crop. There is need for the development and adoption of a package of practices/strategies for optimization of commercial cultivation of Jatropha and realize its full potential as an energy crop.

Moreover, though the oil production of algae is far more than that of Jatropha and algae has a huge potential as an alternative source of renewable energy, yet research and development in the area of green diesel production from microalgae has to go a long way to come out with technologies, which can further reduce the huge energy requirements during green diesel production from microalgae.