Feasibility of Jatropha oil for biodiesel: Economic Analysis

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Abstract: *Jatropha curcas L.* (also called the physic nut) is found to be a potential alternative source of renewable energy since its cultivation and oil extraction contribute to sustainable development, poverty alleviation, combating of desertification and women empowerment in developing countries. The jatropha seeds after three years of cultivation have an oil yield between 1-4 tonnes and 2.5-12 tonnes per hectare when rain fed and irrigated respectively. The Operational and maintenance costs for the oil extraction are minimal, and can be estimated at approximately 10 – 15% of the capital cost per year. In Ghana, for instance, in 2010, whilst the cost of jatropha oil and kerosene were estimated to be US$0.085/liter and US$1.23/liter respectively, the cost of biodiesel from jatropha oil and petroleum diesel were also estimated at US$0.99/liter and US$1.21/liter respectively. This indication gives jatropha oil the best 'candidate' for 'green kerosene' and biodiesel in diesel engines and particularly in multi-functional platforms (MFPs) used agro-processing/industrial applications in rural areas of Ghana. This paper presents a comparative technical feasibility of jatropha oil as fuel and biodiesel in MFPs. It also presents the findings from a study carried out in Ghana with respect to the promotion of jatropha oil as a fuel in rural areas of Ghana.

Keywords*: Jatropha, Crude oil, Renewable energy, Biodiesel*

1. Introduction

Jatropha curcas L. has various socio-economic benefits which makes it more economical when cultivated on commercial scale. A hectare of jatropha plantation is reported to yield 2.5-3.5tonnes of seeds in the third year and increases sharply to 5000-12,000 tonnes per hectare from the sixth year onwards [1]. Like other vegetable oils, jatropha oil can be used directly in modified diesel engines for automobile applications in Europe, North America and some other parts of the world. It is however found from researches that the neat jatropha oil can be used to run the engines in mini-vans for rural transportation, haulage trucks, farm tractors and other agricultural machinery, but may require little modification [10]. According to Achten et al., 2008, at full output, hydrocarbon emission level using neat jatropha oil was observed to be 532ppm against 798ppm for fossil diesel, NO level was 1163ppm against 1760ppm and smoke was reduced to 2.0 Btu against 2.7 Btu [2]. In the northern part of Ghana, women engaged in shea butter production, use jatropha oil in place of diesel the MFPs comprising shea butter press, dehuller and the mill. Since it's quite cheaper to use jatropha oil in these MFPs, commercial cultivation of jatropha and subsequent extraction of the oil for such purposes are done in the rural northern Ghana to empower women in the area of job creation. To enhance and improve the viscosity of jatropha oil, this study assesses the feasibility of the oil for biodiesel instead based on the Ghanaian production conditions. In the rural areas where jatropha plantation and extraction are done, the drying of the seeds are done by spreading the fruit on the ground or a dark-coloured mesh net to dry in the sun. Solar and forced air dryers offer faster drying capabilities. According to research performed at the Kwame Nkrumah University of Science and Technology (KNUST) in Ghana, a fabricated 500 kg tent dryer suitable for small scale applications [3] was about US$2000 but may be costly for rural folks. This research work considered drying in the sun to minimize cost. From the roots to the seeds of the plant are numerous uses which solve some of the socio-economic problems of most people in the rural sectors of the world. The oil extracted from jatropha can be used as a substitute for kerosene without any further processing. This is more economical compared to kerosene from crude oil, which are used for rural electrification. Moreover, the raw oil is used by most rural folks for soap making which ease them of most economic problems. Jatropha farming is labour intensive thus providing job for many people in the rural areas. This paper assesses the potential of local production of biodiesel in remote areas of Ghana where jatropha plantation is done in commercial scales and used for other purposes other than biodiesel production. Since every economy is driven by the quantum of energy produced, utilized and destroyed in a particular section of the economy, the sustainability of energy systems needs to be analysed critically to allow room for improvements, process and material optimization.

Sustainability of any industrial process design comprises three main parts namely social, economic and environmental aspects. The economic indicator is based on the costs of purchasing material and energy, employing labourers, and other product prices [4] [12]. This paper focuses on the economic feasibility of biodiesel production from *Jatropha curcas L.* considering the processes from jatropha farming, through oil extraction to biodiesel production. Each unit process contains different inputs and outputs of which some have more than one alternative. Each alternative carry different values in terms of costs and to make a more proper renewability analysis in terms of economy, each production unit needs to be quantified accordingly. The economic analysis is done to compare the various alternatives for getting the final product, biodiesel. This paper assesses the cost benefits of biodiesel produced from *Jatropha curcas* considering all the processes from jatropha farming to biodiesel purification, and present the results in monetary units. Data in this research were obtained from literature [5] [9] and situations in Ghana as well as some parts of the world where jatropha is grown on commercial scale. The economic analysis of any project can only be done based on the estimates from the investments required and the cash flows. The actual cash flows achieved in any year will be affected by any changes in raw material costs and other operating costs, which may also dependent on the sales volume and price of the products [6] [13].

2. Methodology

The traditional method of producing jatropha biodiesel in the northern parts of Ghana were analysed and compared to those employed in modern technologies worldwide. In this work, the criteria used to determine the economic viability of jatropha oil for biodiesel production include the total capital cost, the total production cost, profitability and sensitivity assessments. There are currently no tax credits or subsidies for renewable energy production in Ghana and so no consideration of it in this work.

2.1 Total capital investment

This is the amount of money that must be supplied or required to finance the purchasing of equipments as well as its auxiliary parts, spare parts, construction of the plant and the acquisition of items necessary for plant operation. The total capital investment comprises the fixed capital, i.e. investment needed to supply all production facilities as well as supply of construction overheads and plant components that are directly or indirectly related the biodiesel process from jatropha; and the working capital, i.e. the amount of money needed to start the project. This is normally estimated as 0.15times the Fixed Capital Investment [6]. Total capital cost may include costs of land, equipment and installations, building and construction costs.

2.1 Total production Investment

The total production investment involves the cost needed to run the project including marketing of the product. This generally consists of the variable cost, fixed costs and general expenses. Variable cost consists of direct and indirect costs. Generally, variable cost may include costs of raw materials, utilities, miscellaneous materials, shipping and packaging which are negligible in this work because the biodiesel processor is fabricated locally in Ghana. Fixed costs also include the cost of maintenance, operating labour, supervision, plant overheads, capital charges, Insurance rates and Royalties [6]. General expenses are made up of administrative costs, engineering and legal costs, office maintenance and communications, distribution and selling cost [7].

2.3 Profitability analysis

The methods used in estimating the profitability of the project are Rate of Return on Investment (ROR), pay back period, break even point, discounted Cash Flow Rate of Return (DCCFRR) and the net present/future value [5].

2.4 Sensitivity Assessment

Sensitivity analysis is a way of examining the effects of uncertainties in the forecast on the viability of a project. This is achieved by the most probable values for various factors which establish the base case for the analysis. The cash flows and criteria of performance used are calculated assuming a range of error for each of the factors in turn [6].

2.5 Process Description and Assumptions

Fig. 1 shows the system boundary for the jatropha cultivation, oil extraction and biodiesel production.

2.5.1 Jatropha curcas farming

A case study of Jatropha curcas cultivation in Gbimsi, a village located in the northern part of Ghana was used. Organic fertilizer used for the cultivation is assumed to be produced from the seed cake through composting [8], in which the energy input is considered negligible. Labour work was assumed to replace diesel fuel consumed by the machines used in cultivation, i.e. one labour hour is approximately equivalent to 0.8 liters diesel [6]. Many researchers have argued that jatropha plant can succeed without irrigation and therefore does not compete for water or displace food production from prime agricultural land [14]. However, Ariza-Montobbio et al. reports that irrigation makes a big difference to yields, and even with irrigation the yields are so much lower than those reported from experimental plots [11]. For this study, on the other hand, irrigation of the jatropha plant was considered as done in Ghana. Harvesting of fruits starts from the 2nd year of plantation, where seed yield would have increased.

2.1.2 Jatropha oil extraction

Solvent (hexane) extraction, mechanical screw press and manual ram press are the most used methods but this work employed the mechanical screw press. The oil cake generated after oil extraction can be used as organic fertilizer for jatropha cultivation. For mechanical screw press extraction 77% oil content is obtained after extraction [6]. The screw press is locally fabricated.

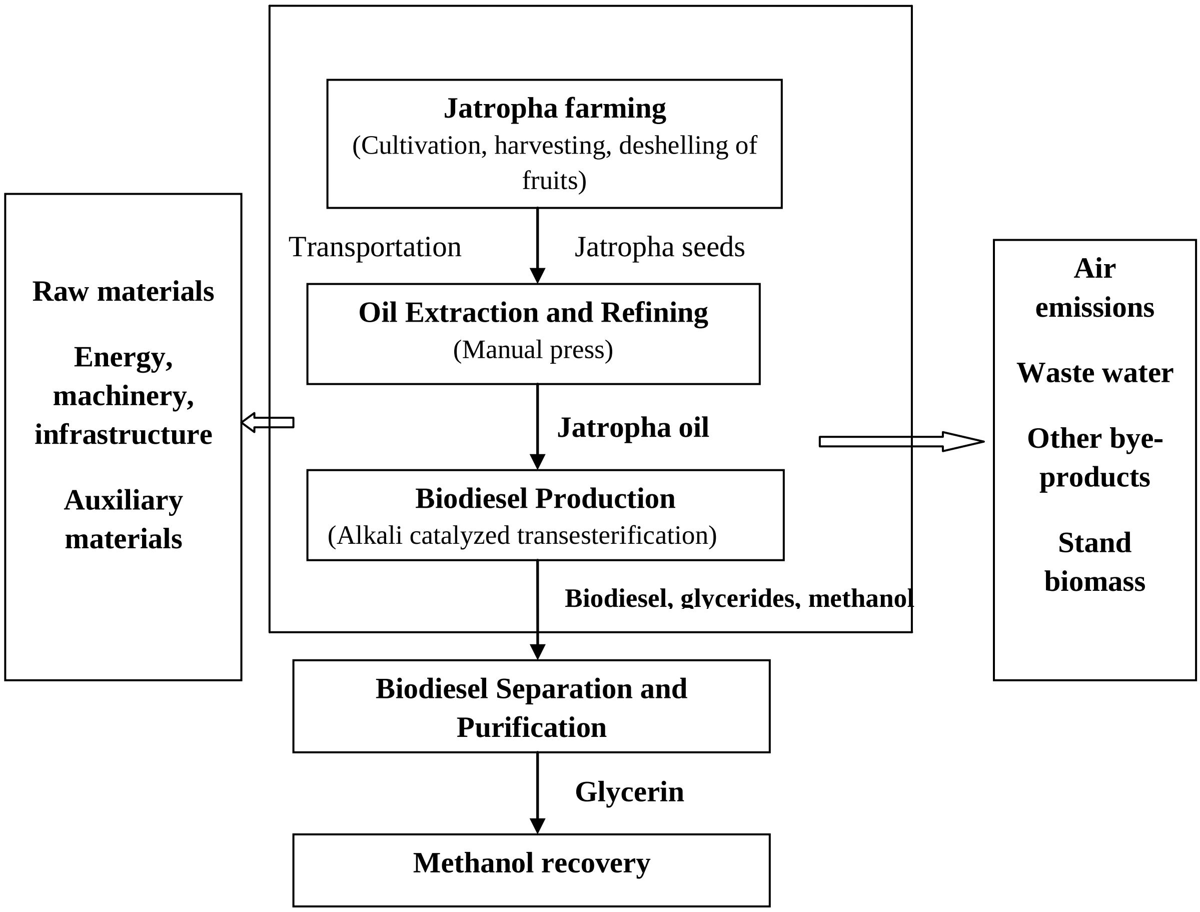

Fig. 1 Process flow diagram of biodiesel production from jatropha curcas L.

2.1.3 Jatropha biodiesel production

1 tonne of biodiesel output (apprx. 1136l) was chosen for the material balance. Alkali-catalyzed transesterification is used. All results were estimated under conditions in Ghana, and some data obtained from literature [9].
Three scenarios (Cases 1-3) were considered for jatropha oil cost at various economic conditions of Ghana, to obtain and estimated cost of the biodiesel as well as profit.
Case 1 shows present economic conditions of Ghana but estimated high cost of jatropha oil
Case 2 shows present economic conditions of Ghana but reduced cost of jatropha oil
Case 3 shows slightly reduced present economic state of Ghana yet reduced jatropha oil cost.
These three cases were chosen based on present and future cost of living in Ghana.

3. Results and Discussion

Assuming holidays and days for maintenance, the plant will work for 230 days/year

Table 1. Estimation of Fixed Capital Investment (FCI)

Item	Quantity	Estimated cost, US dollar
Land	0.67ha	496.7
Irrigation Pump	1 Hp	168
Mechanical Screw Press	1.5 tonne capacity	1000
Biodiesel Reactor	1.5 tonne capacity	11,944.41
Other land area for work	0.405ha	299
TOTAL		**13908.11**

Total Capital Investment (TCI) = FCI + Working Capital (WC) = **16362.48USD**
WC = 0.15TC

Table 2. Estimation of Total Production Cost (TPC)- Variable costs

Item	Quantity	Estimated cost, US dollar
Organic fertilizer	30kg	0
Pesticides	0	0
Cultivation Total Cost		**0**
Irrigation water	147680 l	147.68
Jatropha seeds	3.5 tonne	1750
Diesel	10.91 l	12.2
Extraction Total Cost		**1909.88**
Process water	3408 l	3.408
Methanol	227.5 l	49.98
Electricity	120kWh	14.4
Catalyst	0.082 tonne	82
Biodiesel production Total		**149.79**
TOTAL		**2059.67**

Table 3. Estimation of Total Production Cost (Fixed cost and General Expenses)

Item	Factor	Estimated cost, US dollar
Maintenance cost	0.05FCI	695.41
Operation labour	-	705.14
Administration	0.02TPC	41.19
Miscellaneous	0.1Maintenance	13.9
TOTAL		**1455.64**

Source: (Sinnot et al, 1985)

3.1 Profitability analysis

Based on the following assumptions and the estimates made in Tables 1 to 3, Table 4 was developed with the help of software for modeling the cost of an industrial plant.
Production capacity is 1136 litre for 8hour shift
The number of 8 hour shifts per day is 1
Yield of biodiesel is assumed to be 0.93

Table 4. Profitability Assessment Results of a Biodiesel Production Plant from Jatropha oil

Item	Unit	Estimated cost, US dollar excluding VAT		
		Case 1	**Case 2**	**Case 3**
Jatropha oil	per litre	2.5	0.18	0.18
Methanol	per litre	0.22	0.22	0.25
Labour cost	per week	76	76	350
Rent	per month	50	50	50
Insurance	per year	2500	2500	2500
Interest rate	percent	12	12	12
Biodiesel plant	per tonne	13849	13849	13849
Catalyst	per litre	0.006	0.006	0.006
Duty on biodiesel	per litre	0	0	0
VAT rate	percent	14	14	14
Water	per litre	0.001	0.001	0.002
Electricity	per kWh	0.120	0.120	0.120
Overheads costs	per year	4,762	4,762	4,762
Overheads costs	per litre biodiesel	0.018	0.018	0.018
Labour costs	per litre biodiesel	0.013	0.011	0.062
Water cost	per litre biodiesel	0.002	0.002	0.015
Electricity cost	per litre biodiesel	0.015	0.015	0.004
Estimated Biodiesel cost	per litre	2.779	0.383	0.339
PROFIT		**-89.42**	**803.03**	**409.91**

Source: Cash flow calculations from data collected for this work **[6] [15]**

Case 1 which also shows the conditions for maximum profits (almost at breakeven) resulted in a loss after the cash flow analysis. The loss per day is minimal recorded as -89.42 US Dollar. In this case, we assumed higher cost for jatropha oil at the present Ghana's economic status, and a higher biodiesel cost was estimated after cash flow calculations. For the second case where the cost of jatropha oil was similar compared to cost on the international market, maintaining minimal conditions, profit was observed at 803.03 US dollar per day. For case 3, profit was observed on extreme conditions i.e. the prices of jatropha oil maintained as that of the international market whilst biodiesel cost was kept low, yet there was a marginal profit of 409.91 US dollar per day. No scenario was created for harsh economic conditions because the three cases showed profitable and feasible results.

These results therefore show that the project which produces 1tonne of biodiesel per day is viable economically (except in case 1 where there was a loss) and if the plant's capacity is increased profit per day will also increase even when biodiesel price is kept as low as US$0.339. Jatropha plantation for biodiesel is worth a project considering the economic analysis with conditions and assumptions made in this report. In the northern part of Ghana where jatropha is grown on large scale, the oil after extraction is used mainly on multifunctional platforms where the oil is used purposes for fueling engines of machines which otherwise may be used manually. For instance in the northern part of Ghana, the oil is used to power the mechanical screw press instead of using diesel which is environmentally unfriendly when burnt.

Multifunctional platforms have been introduced in Ghana for such purposes to empower women especially. From the analysis, the cost of jatropha oil is much cheaper at

0.18USD/litre compared to that of biodiesel at 0.3-2.7USD/litre. It therefore presents a much more economical sense currently to use biodiesel oil from jatropha in diesel engines instead of using for producing biodiesel. However, it is still viable to go into biodiesel production using jatropha oil as detailed in the results of this work. Table 5 shows the comparison of prices between petroleum diesel, jatropha oil, gasoline and biodiesel from jatropha oil in Ghana from the year 2000 to 2010.

Table 5. Comparative prices of jatropha oil, kerosene and biodiesel in Ghana

Product	**Estimated cost, US dollar/litre**		
	2005	**2008**	**2010**
Jatropha oil	0.154	0.191	0.085
Kerosene ex-refinery	0.92	0.85	0.87
Kerosene ex-pump	0.83	0.77	1.23
Jatropha Biodiesel	1.54	1.02	0.99
Diesel ex-refinery	0.56	0.90	1.12
Diesel ex-pump	0.78	1.01	1.21

Source: Energy Commission, Ghana and TradingEconomics.com [16]

4. Conclusion and Recommendation

Biodiesel produced from jatropha oil is assessed to be feasible economically when the seeds are cultivated on large scale. In Ghana where jatropha plantation is done on commercial basis for multifunctional platforms in rural areas, jatropha oil is more economical to use compared to jatropha biodiesel. It is however viable to produce jatropha oil and further processing it when the oil is in large quantities. As reported by other studies in India, Mali etc, jatropha oil produced on commercial basis is less costly hence biodiesel production from this oil is feasible especially in MFPs which can keep the engines for a long time. Therefore, if 1tonne of biodiesel can be produced from jatropha at quite a minimal cost, then on commercial basis, when this quantity is normalized to a desired capacity, marginal profit will be reported after payback time of not more than three years. For better efficiency of diesel engines, biodiesel from jatropha is however preferred to raw jatropha oil especially in MFPs.

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