THE ASSESSMENT OF "JATROPHA" AS RAW MATERIAL FOR BDF

Satoshi Matsuda, Bambang Rudyanto, Mutsuo Kojima, Wino Herdiana, Emiko Fujiwara

Abstract:

The "second-generation" of bio-fuel made from non-food biomass has attracted much attention especially after the Hokkaido Toyako G8 summit held in November 2008. Among various plants or biomass materials, "Jatropha" has come to the front as one of the most promising candidates for future bio-diesel production. In fact, there are many plans or projects aiming at large scale cultivating Jatropha for bio-diesel oil production in several African or Southeast-Asian countries. However, it should be pointed out that there are too many unknown factors still remaining that are important in practical use of Jatropha oil, for example, productivity as well as sustainability, long-term impact of its large-scale use on soil quality, practical costs of the oil and so on.

In this study, an assessment on the validity of Jatropha production was tried as quantitatively as possible using the data obtained from a field survey in Indonesia conducted by the authors in January and March of 2009.

Although LCI data for LCA calculations obtained was very limited, the true reality of the situation about Jatropha could substantially be demonstrated to some extent. The main point was that the oil cost was dominated mainly by labor costs, because many work operations could not be mechanized and inevitably be manual handling tasks. In many cases, the labor costs could not be covered by the income from the Jatropha oil (or seed) due to the low productivity of the biomass, whereas the prime cost of the biodiesel oil was rather high expensive compared with fossil fuel.

Keywords: *bio-fuel, Jatropha, feasibility study, field survey, labor costs.*

1. Introduction

1.1. Background

Prevention of global warming is becoming urgent issue and "biofuel" gathering worldwide attention has been put into practical use not only in US, EU, Brazil or other countries but in Japan. As for its impact on environment, however, evaluation still varies including aninfluence on global economy, for example food price crisis that might have been caused by competition with food. In the previous study [1], one of the authors pointed out that "bio-ethanol" from crops is never "carbon neutral", that means the production and use of the fuel does not lead to a net increase in atmospheric CO_2 concentration, nor useful as a countermeasure against global warming.

Since the shortage of food crops affected by the expansion of biofuel production became a critical issue, the "second-generation" of biofuel made from non-food biomass has attracted much attention all over the world. In particular, the following statement in the Hokkaido Toyako G8 summit held in November 2008 accelerated this trend: "use of biofuels with food security and accelerate development and commercialization of sustainable second-generation biofuels from non-food plant materials and inedible biomass" (in "G8 Leaders Statement on Global Food Security" [2]).

The target biomass has a wide variety of kind; cellulosic materials such as woody biomass and paddy straw, algae and some kind of oil producing plants, which are considered as sustainable and research is in progress. Among them "Jatropha" has come to the front as one of the best candidates for future biodiesel production [3], partially because the production of bio-ethanol from cellulosic materials has encountered many difficulties in practice.

Jatropha is native to Central America and has become naturalized in many tropical and subtropical areas, including India, Africa, and North America as well as Southeast Asian countries. The hardy Jatropha is resistant to drought and pests, and produces seeds containing 27-40% of oil [4] (average: 34.4% [5]). However, despite its abundance and use as an oil and reclamation plant, none of the Jatropha species have been properly domesticated and, as a result, its productivity is variable, and the long-term impact of its large-scale use on soil quality and the environment is still unknown [3].

1.2. Objective

In Indonesia, nevertheless, there is a national program of biofuels development in which 20% of diesel consumption will be supplied with biodiesel utilization mainly by Jatropha oil (equiv. 10.22 million kL) by the year 2016 to 2025. In this study, an assessment on the validity of Jatropha production was tried as quantitatively as possible using the data obtained from a field survey in Indonesia conducted by the authors in January and March of 2009.

2. Results and Discussion

2.1. Bio-Energy Productivity

The standard planting rate of Jatropha in Indonesia was 2500 to 2800 trees per hectare, producing about 4 ton of seed (as dry matter yield) per hectare per year after 4 years of planting (note: only a little seed can be harvested in the first year, 1-1.5 t-dry seed/ha/yr in the 2^{nd}

year, and 2.5-3 t-dry seed/ha/yr in the 3rd year). Generally speaking, one ton of fresh fruit consists of 300 kg of seed and 700 kg of coat, which is equivalent to 200 kg of dry seed. This means that 5 kg of fruit is required for 1 kg of dry seed, thus 20 ton of fruit per hectare per year should be harvested to obtain 4 ton of dry seed. It was not certain whether or not such a high productivity of biomass can be maintained permanently.

About 30 wt% of dry seed is crude oil content as mentioned above. However, this does not mean that 1200 kg(=4000×0.30) of oil can be obtained from 4 ton of dry seed because the practical oil yield using a pressing machine was around 50%, meaning that about 150 liter oil per ton of dry seed (i.e. about 600 liter oil per hectare per year) could be obtained. But this value is larger than those of other oil crops for biodiesel [6] (e.x. 480 liter from soybean, and 390 liter from sunflower). Table 1 shows several examples of overall oil yield in bio-fuel production.

Table 1. Overall oil yield in bio-fuel production.

Raw material	*Crop*(kg/ha)	*Oil*(kℓ/t)	*Overall* (kℓ/ha)
Corn [6]	8665	0.372	3.22(EtOH)
Soybean [6]	2688	0.180	0.480
Sunflower [6]	1500	0.255	0.389
Jatropha	4000	0.150	**0.600**

If 10.22 million kℓ of bio-diesel oil (the goal of bio-diesel production for the year 2016 to 2025 in Indonesia) should be obtained from Jatropha, at least 17 million hectare of planting land area is required even if no oil loss can be achieved during bio-diesel production process from Jatropha crude oil. Incidentally, this land area is corresponding to about 46% of Japanese total land area.

2.2. Energy Balance

The data required for the estimation of energy inputs and costs in Jatropha production is as follows; Labor, Machinery, Fuels (Diesel, Gasoline and LP gas), Fertilizers (Nitrogen, Phosphorus and Potassium), Lime, Seeds, Herbicides, Electricity and Transport. In addition, there are other items necessary for biodiesel oil production including cost of equipment and utilities (steam, water, electricity and so on). However, obtained data was quite limited in this time of field survey because the production of Jatropha was still testing stage there, and almost all process was operated by human power. Only obtained data was that the electric power consumption of oil pressing machine was 12-15 kWh per 300 kg of dry seed treated, equivalent to 160-200 kWh per hectare per year. Suppose that the heating value of Jatropha oil is 37620 kJ (9000 kcal) per liter and power generation efficiency of small scale electricity generator is about 15% (1 kWh = 860 kcal/0.15 = 5733 kcal), 160-200 kWh is corresponding to 17-21% of Jatropha oil content (600 liter = 5.4 *10^6 kcal, 160-200 kWh is 0.92-1.15 *10^6 kcal). In Table 2 for reference, the data of the inputs for bio-diesel oil production from Soybeans in the US [6]. Since the process of diesel oil production is almost the same regardless of the kind of raw materials, the difference between the values or items in Table 2 and those of inputs for bio-diesel production from Jatropha will be the difference in raw material only, so that the energy input in bio-diesel oil production will be 4078 (=11878-7800) kcal/kg-oil = 3752 kcal/L-oil suppose that the specific gravity of Jatropha oil is 0.92. Thus, the total energy input in bio-diesel oil from Jatropha will be 5282-5642 kcal/L, that is corresponding to 59-64% of Jatropha oil content. This means about 60% or more energy of the Jatropha oil will be consumed to obtain the bio-diesel oil.

Table 2. Inputs Per 1000kg of Bio-diesel oil from Soybeans in the U.S. [6]

Inputs	*Quantity*	*kcal×1000*
Soybeans	5556 kg	7800
Electricity	270 kWh	697
Steam	1350000 kcal	1350
Cleanup water	160000 kcal	160
Space heat	152000 kcal	152
Direct heat	440000 kcal	440
Losses	300000 kcal	300
Stainless steel	11 kg	158
Steel	21 kg	246
Cement	56 kg	106
Total		**11878**

2.3. Economical Consideration

From the results of the field survey, it was cleared that labor cost was evidently a major part of the expense of Jatropha oil production since almost all process was operated by human power as mentioned above. The data of labor costs concerning the oil production from Jatropha obtained from this time of field survey was as follows;

1) Fertilizer Application: 5 person/ha, 2 days
   10 person · day/ha
2) Planting Work: 4-5 person/ha, 10 days
   40-50 person · day/ha
3) Mowing Grass: 2 persons/ha, 5 days
   10 person · day/ha
4) Harvesting: 4-8 persons/ha, every day
   harvest: 50-70 kg-fruit/person · day

Since 20 ton of fruit per hectare per year should be harvested, 333 person · day/ha · yr is needed if average harvest of 60 kg-fruit/person · day can be assumed (20000/60). Then, the sum total labor should be 393-403 person · day per hectare per year. Here, 350 person · day/ha · yr person · day is supposed because all work operations is not always required every year. The labor cost of male worker was 30 thousand Rupiah (Rp: 1 US dollar = 10100 Rp, 1 Japanese Yen = 106 Rp, in 2009) per day. Thus, the labor cost should be 10.5 million Rp per hectare per year. On the other hand, the income from Jatropha should be only 4 million Rp per hectare per year because the price of dry seed was about 1000 Rp/kg and the seed yield was 4000 kg/ha · year. In fact, other expenditure of about 1.25 million Rp per hectare per year for purchasing nursery trees and maintenance of the field would be required. This means that Jatropha production is not commercially viable operation for farmers by itself.

From the standpoint of fuel cost, however, Jatropha oil is not cheep: the price of dry seed was about1000 Rp/kg, and 0.15 kg of crude Jatropha oil can be obtained, meaning that the raw material cost of the oil will be higher than about 6667 (=1000/0.15) Rp/kg = 0.66 U.S. dollar/kg. This value is rather expensive as raw material of diesel fuel since whole production cost consists of both raw material and the facilities. This economical analysis implies that the Jatropha crude oil should be utilized as a heavy oil alternative by direct combustion.

3. Conclusion

According to the results of the survey data and calculations, it was revealed that Jatropha will not be a hopeful candidate for future biodiesel production although the concern about the environmental impacts was not researched or discussed in this study. The main points are as follows;

1) The biomass productivity of Jatropha is rather large (About 20 ton of fruit per hectare per year can be harvested) compared with other oil crops for biodiesel such as soybean and sunflower. But huge land area would be required if the plan of Jatropha oil in Indonesia should be achieved because only 0.6 kL of oil can be obtained per hectare per year in practice.
2) Although the analysis of energy balance could not be achieved completely due to the lack of field data, it was revealed that more than 60% of Jatropha oil content would be consumed for the production of bio-diesel oil.
3) Economical analysis showed that the oil cost was dominated mainly by labor costs because many work operations could not be mechanized and inevitably be manual handling tasks. In many cases, the labor costs could not be covered by the income from the Jatropha oil (or seed) due to the low productivity of the biomass, whereas the prime cost of the bio-diesel oil was rather expensive compared with fossil fuel.

ACKNOWLEDGMENTS

This work has been financially supported by The Mitsui & Co., Ltd. Environmental Fund.

AUTHORS

Satoshi Matsuda* - Department of Materials Science and Chemical Engineering, Shizuoka University, 3-5-1 Johoku, Naka-ku, Hamamatsu, 432-8561 Japan.
E-mail: tcsmats@ipc.shizuoka.ac.jp.
Bambang Rudyanto - Faculty of Economics and Business, Wako University, 2160 Kanaimachi, Machida-shi, Tokyo, 195-8585 Japan.
Mutsuo Kojima - Department of Biological and Environmental Science, Faculty of Agriculture, Shizuoka University, 836 Ohya, Suruga-ku, Shizuoka, 422-8529 Japan.
Wino Herdiana - Along Japan Center, JI. Raya Padjajaran no.21, Warung Jambu, BOGOR 16153 Indonesia.
Emiko Fujiwara - Japan Tropical Forest Action Network, 1-23-16 Shinzyuku, Shinzyuku-ku,Tokyo,160-0022 Japan.
* Corresponding author

References

[1] Matsuda S., "Validity of Bio-Ethanol as a Countermeasure against Global Warming", *J. Environ. Information Sci.*, vol. 37, issue 5, 2009, pp. 1-6.
[2] *http://www.mofa.go.jp/policy/economy/summit/2008/doc/doc080709_04_en.html*
[3] Fairless D., "Biofuel: The little shrub that could - maybe", *Nature* , no. **449**, 2007, pp. 652-655.
[4] Achten W.M.J., *et.al.*, "Jatropha biodiesel fueling sustainability?", *Biofuels, Bioproducts and Biorefining*, vol. 1, issue 4, 2007, pp. 283-291.
[5] Achten W.M.J., "Jatropha bio-diesel production and use", *Biomass and Bioenergy*, vol. 32, issue 12, 2008, pp. 1063-1084.
[6] Pimentel D., Patzek T. W., "Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower", *Natural Resources research*, vol. 44, issue 1, 2005, pp. 65-76.