

Towards Making Jatropha “Tubang Bakod” a Viable Source of Biodiesel in the Philippines

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Towards Making Jatropha “Tubang Bakod” a Viable Source of Biodiesel in the Philippines(#)

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Abstract

Jatropha becomes acceptable as alternative source of biodiesel at current prices of crude oil (P40 per liter) at high yields (36,000 kg/ha), high rates of oil extraction (34% and 38%) and by-products included as added income aside from sales of oil. At low yield level (12,000 kg/ha), it will become profitable for farmers growing it if the current diesel oil price increase to about P90 per liter of crude oil at 30% rate of oil extraction (The estimates excludes processing and marketing costs) . The inherently low Jatropha seed yield explains the low revenue but this presents R/D opportunities. Research must be done to increase further the seed yield of Jatropha plant to find ways that will maximize total farm yield and the use of by-products. The relatively long gestation period (5 years) before the crop reaches optimum fruiting and the low seed yield of Jatropha require that optimal crop mixes (multiple cropping schemes) or compatible diverse cropping involving short maturing crops and high value fruit/wood trees to increase the total farm income and as a risk minimizing farming strategy. Recognizing that the technology for Jatropha processing is yet to be established in the country, it is necessary to accelerate the knowledge build-up on processing raw oil into trans-esterified oil before it can be used as biodiesel oil and processing of by-products (press cake) into organic fertilizer or livestock feed and glycerol into high priced products. Likewise, Jatropha oil has high saponification value making it as an excellent substrate for soap making. But which product is most profitable, soap or biodiesel from Jatropha?

Despite the limitations of Jatropha, it presents enormous employment opportunities in the rural areas if comprehensive programs are designed to tap the positive aspects of the crop. In addition, the inflows of investments in the rural areas will propel economic activities and it can be the key to finding lasting peace in insurgency-dominated and poverty stricken rural areas. As industry and government leaders are gearing up for massive and large scale planting of Jatropha, it is imperative that an environmental,

economic and social impact assessments be conducted considering that a) *Jatropha* is a non-food crop and b) it has known toxin- toxalbumin curcin.

At the start, mitigating measures must be put in place. The notion that it has no pests, to begin with is quite acceptable because it is planted simply in the fence line or hedges. Some pests should be anticipated to surface once planted in large scale monoculture.

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Introduction

The Philippines being a net oil importing country is negatively affected in many ways by the current upswing in the price of fossil fuel. It is considered as a “real challenge to the country’s economic survival.” As the era of cheap oil is gone, the search for alternative source of energy is on the upbeat as well. There are a number of crops that are planned to be tapped as renewable bioenergy source. One of them is *Jatropha curcas*. At present, both the government and the private sector are interested in the culture of *Jatropha*. There are obvious reasons for this. One, *Jatropha* may mean considerable dollar savings if the bio-diesel yield of 700 – 1,500 li. oil per ha. is considered and two, it will have great employment generation/job creation impacts in the rural areas where poverty or unemployment is high since crop establishment/care (first to second year) and harvesting of fruits of *Jatropha* is labor intensive. Planted in marginal hilly areas where it is known to be growing well will mean income opportunities for farmers. It may signal the start of economic upliftment of the people in areas where it will be planted. As an agro-industrial venture, planting *Jatropha* will also require mill construction where the oil will be processed. Transporting the harvested fruits from the farm to the mill needs roads and bridges to be constructed and hauling trucks to be procured. It will have vast economic multiplier effects in the rural areas.

With all these prospects of the crop, it is no surprise why many people are asking about the real facts behind it. Will planting of *Jatropha* provide the financial benefits to the farmers who will be growing it? With these views in mind, this study was done with the following objectives: 1) to determine the yield and yield attributes of the crop under Philippine condition; and 2) to assess its financial viability, especially for small scale farmers or to those farmers who would like to grow the crop.

Brief Information about *Jatropha*

Botanical description. Locally known as tuba tuba, tubang bakod (Tagalog), galumbang (Pampanga), *Jatropha* belongs to the family Euphorbiaceae, subfamily Crotonoideae and tribe Jatropeae .There are approximately 175 species under the genus *Jatropha* and , there are least 4 important species, namely : *J. curcas*, *J. gossypifolia*, *J. podarica*, and *J. multifida*. *Jatropha* is a succulent shrub. Plants do not grow very tall (up to 20 ft. tall). They have spreading branches and stubby twigs, with milky and yellowish exudates, leaves are deciduous, alternate but apically crowded, ovate, acute to acuminate, basally cordate, 3-5 lobed in outline, 6-40 cm long and 6-35 cm broad. Mature trees bear male and

female flowers. They bear several flowers which are greenish cymes, yellowish and bell shaped. Plants from this genus natively occur in Africa and *Jatropha* spread as a valuable ridge plant to Africa and Asia through the Portuguese traders. It is widely grown in Tamil Nadu, India, growing as weeds in Brazil, Fiji, Honduras, Jamaica, Panama, Puerto Rico, El Salvador and it is commonly planted in fence lines in the Philippines, hence the name *tubang bakod*.

Agronomy. *Jatropha curcas* grows well under subtropical and tropical climates. The plant is known to tolerate a wide range of rainfall [48 cm to 238 cm (mean = 143 cm)] annually, grows in a wide range of temperature [18-28.5°C (mean = 25.2)]. It thrives in any soil type – sandy, gravelly, saline soils but well drained. It needs full sun. They are easily propagated either by seeds or stem cuttings, are fast growing, and are adapted to marginal soils with low nutrient content. Seedlings (3-4 month old) can be planted with the following distances: square planting: 2m x 2m (2,500 plants/ha) or 2m x 3m (1,666 plants/ha). Best time of planting coincides with the start of the rainy season. Care of plants is simple as it involves only ring weeding during the first year, under brushing in later years to control vines and other dominant/highly competitive weeds. Fertilizer application depends on the soil fertility and the farmers' capacity to buy. When established, it needs minimal attention or management. No insect pests are known to attack the crop and it is not palatable to ruminants (cattle or sheep, goat) making it a desirable plant for the fence lines.

Plants start to bear fruits within two years after planting but reach maximum productivity after 5 years. Fruits are harvested at yellow stage, each fruit containing 3-4 black color seeds 2 cm long and 1 cm thick. The yield per tree (fresh weight) ranges from 4-12 kg. Yields by year are as follows: 0.4 tonnes/ha during first 2-3 years, 2-3 tonnes/ha in 3-4 years, 5-6 tonnes/ha in 5 years to 50 years. Dry seed is about 15% of fresh weight of fruits. Dry seed is 32% meal, 30-38% crude oil, 30-38% seed coat.

Uses. *Jatropha curcas*, while it is non-edible, is known as an oil-yielding perennial shrub with multiple uses. Whole seeds are reported as being purgative and have insecticidal and fungicidal properties. The latex is used in healing wounds and in the treatment of various skin problems, decoction of the roots is known to cure indigestion and diarrhea, the bark as poultice for sprains and dislocations, fresh stems as toothbrushes and to strengthen gums and cure bleeding, spongy gums or gum boils. *Jatropha* has many other known medicinal uses: extracts have been shown to have anti-tumor activity, latex contains alkaloid jatrophine which shows anti cancer properties, seeds can be used as remedy for constipation, and leaves are boiled to cure malaria. *J. podarica* is used to tan leather while foliage and fruits of *J. gossypifolia*, called belly ache bush, are toxic to humans and animals. In the Philippines, *Jatropha* leaves are used to cover swelling portion of the body and the bark is known to cure dislocated bones. The seeds contain toxalbumin curcin that makes them totally toxic but roasting eliminates the toxin.

As an agro-industrial plant, various products can be derived from *Jatropha*. These include oil which can be edible after detoxification or it can be converted (trans-esterification) into biodiesel, press cake which can be processed into fertilizer or feed concentrate with protein content of 56-58% after

detoxification, glycerol as raw material for the pharmaceutical and cosmetics industry. Processing includes these steps: harvesting and depulping, seed drying, removal of the seed coat, pressing the seeds, filtration and detoxification --> edible oil, trans esterification of the oil --> fuel, and detoxification of the seed meal --> animal feed, or composting of the press case --> organic fertilizer.

Seed composition. At 6.2% moisture content, protein is 18%, fat 38%, carbohydrates 17%, fiber 15.5%, ash 5.3%. The oil content is 25-30% in seeds, 50-60% in kernel; Oil contains 21% saturated fat and 79% unsaturated fat. Oil has high saponification value (195.0). Thus, it is excellent for soap making. Jatropha press cake as organic fertilizer revealed the following analysis: N: 5.7 – 6.48 % , P₂O₅: 2.6 – 3.1, K₂O 0.9 – 1.0, CaO:0.6 – 0.7 MgO: 1.26 – 1.37.

Extent of production and potential as biodiesel. In the Philippines, Jatropha is not planted as extensively as in other countries because, up until now, its sole function when planted at all is just to provide a living fence, hence, the name tubang bakod. It is only recently, when news that Jatropha can be a source of biodiesel, that people took notice of the tree and started planting more and in larger areas. Large scale planting has just started in India. Best yielding selection of Jatropha is now being mass produced by a biotech firm(D1 Oils') in their plantations. The plants are projected to yield about 1,000 barrels of oil per year per square mile (730 li/ha) of cultivated area.

Bioking is to develop, together with Mr. Demba Diop (Senegal), a large scale plantation of oil seed in Senegal that will enable the company to become a major producer of biodiesel in the international scene. A first stage, 15,000 hectares extensible to 60,000 hectares is aimed at (WEB- BIOKING- BIODIEDEL EQUIPMENT) .

Methodology

Jatropha fruit yield and seed characterization

To obtain the fruit yield attribute of Jatropha, harvesting of fruits was done in Barangay Bangyas, Caluan, Laguna starting mid June to mid July 2006 .In various stages of maturity, fruits harvested were based from their color (yellow and black). The weather condition during harvesting was also noted. Mid-June was relatively sunny and dry while mid-July harvesting was relatively wet as there were more frequent rains. Fruits were characterized using the following parameters: fresh weight of black or yellow fruits, number of seeds per fruit and average seed weight.

Based from these characteristics, the following were derived:

weight of seeds

1. % seed recovery = ----- x 100

gross weight of the fruit

100

2. Kg-fruit/1-kg seeds = ----- x 100
% seed recovery

Note: See attached Jatropha Seed Information

Seeds extracted from the black colored-fruits were also tested for germination. According to literature, soaking seeds overnight before sowing improves germination and is completed in 10 days. But instead of soaking, slight cracking of the seed coat was tried to determine if it is as effective as soaking and if it would speed up germination. Seeds were slightly cracked so that water can easily penetrate through the seed coat initiating rapid germination. Seeds sown were observed everyday until all the seeds have germinated.

Cash Flow Analysis

The financial worth of raising Jatropha from the point of view of farmers was evaluated using cash flow analysis. With the use of farm budget for a hectare of Jatropha farm (Appendix 1), the stream of net returns (for a 10-year planning period) was computed and discounted at 12% per annum. The financial worth was determined based on the size of the discounted present value of net returns (PVNR) at 3 levels of yield, 3 extraction rates, and price of Jatropha oil which was indexed at various prices of diesel oil. The decision rule is : the larger the size of the positive discounted net return , the higher the acceptability or worth of the alternative; nil or zero indicates indifference; and negative PVNR indicates rejection or inacceptability of the alternative.

The formula for finding the value of the discounted present value of net returns was:

$$PVNR = \sum_{i=1}^n \frac{R_i - C_i}{(1+r)^i}$$

Note: See attached Cash Flow Analysis Formula.

where:PVNR = present value of net returns for 10 years;

R_i = gross return for years 1 to 10;

C_i = cost of producing Jatropha for years 1 to 10;

r = discounting rate, 12% per annum;

n = planning period, 10 years.

b. The Gross Returns

The gross returns in raising Jatropha were derived from the sales of oil-equivalent and by-products at alternative yield levels and prices of diesel oil per liter.

(i) The oil production was estimated using farm yields at various stages of plant growth. The yield level was based on the data obtained from harvested Jatropha fruits from trees found in Bgy.Bangyas,

Calauan, Laguna. To allow for wide latitude of analysis of the financial worth of *Jatropha*, three (3) yield levels were assumed for the study:

low - with yield of 12,000 kg. *Jatropha* fruits at year 5, the start of peak production years or 4.8 kg. fresh fruit per tree;

medium – with yield of 24,000 kg. *Jatropha* fruits at year 5 or 9.6 kg. fresh fruits per tree ; and

high – with yield of 36,000 kg. *Jatropha* fruits at year 5 or 14.4 kg. fresh fruits per hectare.

At these various yield levels, the harvest of fruits was assumed to commence at year 2 and to increase yearly until year 5 as follows:

Yield Levels Fruiting of *Jatropha*

Year 2 Year 3 Year 4 Year 5

Low 3.3% (400 kg.) 33.3% (4,000 kg.) 66.6% (8,000 kg.) 100% (12,000 kg.)

Medium 1.7% (400 kg.) 16.7% (4,000 kg.) 33.3% (8,000 kg.) 100% (24,000 kg.)

High 1.1% (400 kg.) 11.1% (4,000 kg.) 22.2% (8,000 kg.) 100% (36,000 kg.)

Note: Figures in % mean rates of fruiting of trees or harvesting of fruits;
Figures in kg means absolute harvest of fruits.

The precise utilities of by-products of processing *Jatropha* to oil is not yet fully established. The literature, however, points out that cakes produced in processing fruits can be a source of materials for organic fertilizer, among others. To capture the worth of by-products, a 50% added premium to the sales of oil was generously assumed to increase the value of gross revenue from oil and by-products.

(ii) Rate of Oil Extraction. Limited information is also known on the rate of extraction of oil from fresh fruits or seeds of *Jatropha*. This is due to the absence of reports on operating plants that process fresh fruits or seeds to oil. The scanty literature, however, points to an extraction rate of 30% to 38% oil from seeds at 6.5% moisture content. Using this information as a benchmark, alternative levels of oil extraction rates were used in the analysis, namely: 30%, 34%, and 38%. The alternative levels of extraction rate were expected to capture the most efficient process of extracting oil.

The conversion of fresh fruits to seeds was given at 7.41 kg. fresh fruit to one (1) kg. seed based on preliminary studies at University of the Philippines at Los Banos.

(iii) The Price of *Jatropha* Oil. Information on the price of *Jatropha* oil in the world market is also limited. There is no information yet on trading of *Jatropha* oil in the world market according to the literature. To proceed with the analysis, the price of *Jatropha* oil was indexed at the price of diesel oil, a logical move since *Jatropha* oil will be used as a substitute to diesel oil. In this study, several alternative prices of diesel oil per liter were used, namely: P40, P50, P60, P70, P80, P90 ... up to P200. The basic price used was P40 per liter, the pump price of diesel oil in August 2006.

c. The Cost Streams

The study assumed that a farm of *Jatropha* is to be established given the best technologies available on farm establishment; crop culture, care and farm management; and processing and marketing of products. The farm budget which outlines the cost stream from years 1 to 10 of cropping *Jatropha* is shown in Appendix 1.

In this analysis, no processing cost was imputed due to the assumption that the raw seeds will be sold and valued at oil-equivalent using the price of diesel oil. It will be noticed that this assumption would tend to push upward the share of farmer in the sale value of *Jatropha* oil due to the implicit assumption that the cost of processing will be shouldered by the processor as in the case of coconut oil milling where nuts are bought as they are delivered to the mill. It may be worthwhile to mention, too, at this juncture that information on cost of processing *Jatropha* seeds is also limited as there is no known processing plant operating in the country yet.

Results

Jatropha fruit yield characteristics

Under Calauan, Laguna, Philippine conditions, tubang bakod (the local name of *Jatropha curcas* L) bears harvestable fruit from April to July. Hence, the harvesting practice for *Jatropha* fruit is priming (harvesting the fruit as they mature). Matured fruits are yellowish and turn blackish as they dry. As presented in Table 1, four samples represented the conditions when fruits were harvested. Samples 1 and 4 were harvested at the same time and on a sunny day, hence fruits were relatively dry. Samples 2 and 3 were harvested on a rainy week, therefore they are relatively wet. These are the weather conditions during the harvesting period of *Jatropha* fruits.

Black- and yellow-colored fruits differ in moisture condition, with the yellow-colored having higher moisture, thus, they are heavier than the black-colored fruits. Yellow fresh fruits at 12.34 g per fruit are 3 times heavier than black fruits at 4.52 g per fruit. Extracted seeds from yellow fresh fruits at 1.27 g per seed are also heavier than seeds extracted from black fruits which weigh 0.844 g per seed. Moisture content as indicated by the color of the fruit is important as it determines the percent seed recovery (% SR).

If the exocarp (the technical term for the fruit cover) has more moisture as in the yellow fruits, then % SR would be lower. Yellow-colored fruits have only 10.35 % SR while black-colored fruits have 20.97% SR. Fruit color or its moisture condition is also related to the number of seeds per unit weight. Using 1.0 kg as reference weight, the number of seeds per 1.0 kg seed lot was estimated:

1.0 kg (yellow-colored fruits) = 797 seeds

1.0 kg (black-colored fruits) = 1,227 seeds

The seed number as influenced by moisture content status is important as it determines the equivalent quantity of fruits to obtain 1.0 kg seeds. Based on estimates, the following data were obtained:

1.0 kg seed = 9.71 kg fresh yellow

1.0 kg seed = 5.11 kg black fruits

Average of all seeds: 1 kg seed = 7.41 kg of fresh fruit

These fruit yield characteristics are important data for the following reasons: a) Field conditions at harvesting time is related to the moisture condition of the fruit and seed. The fruit moisture in turn determines the number of seeds per kilogram, the % seed extraction and the weight (in kg) of fresh fruits that yields a kilogram of seed , b) The fruit yield data, especially the conversion from kg fruit to kg seed is important in buying *Jatropha* fruit at the farm level and c) Data/technical coefficients are needed in establishing *Jatropha* farms for production and constructing mills for processing seeds into various products (crop and mill planning)

Seed germination

Seeds of *Jatropha* become mature and can be harvested when the exocarp changes from green to yellow. The capsule is usually divided into 3 cells with one seed per cell. Mature seeds have a hard and thick seed coat that delays germination if pre-germination treatment is not done. The slight cracking method as pre-germination treatment resulted in radicle emergence after three days, with 75% of the seeds fully germinated after 5 days and after 8 days a total of 92% of the seeds germinated. Ordinary seed soaking had up to 70% germination only. Slightly cracking the seeds, although entailing additional labor, increased percent seed germination. This can be translated in terms of reduced amount of seeds required to plant a hectare. This is very important in view of the presently high prices of seeds ranging from P100-500/kg.

Indicative prices of *Jatropha* fruits/seeds

An important question farmers will raise if they are encouraged to plant *Jatropha* is related to the price of the products. To answer this question, two possibilities were considered, namely : (1) the price of seed and (2) the price of raw fruit.

Price of *Jatropha* fruits and seeds. The price of 1.0 kg seeds (at 30% extraction from the raw weight of the seed) as indexed to various prices of diesel oil (from Php 40.0 to Php 200.00/li) are shown in Table 2. .At Php 40.0/li price of diesel oil, the gross price of 1.0 kg *Jatropha* seeds is Php 12.00. As the price of diesel oil increases, the price of seed also increases. These prices of *Jatropha* seeds reflect the gross prices of oil since the cost of processing could not be ascertained at the moment.

A 50% increase in the price of *Jatropha* seeds was considered when the value of the byproducts (press cake converted into animal feed or organic fertilizers, glycerol) were included (Table 2). At Php 40/li price of diesel oil, the price of *Jatropha* seeds increased to Php 18/kg. The prices obviously increase as the index price of diesel oil also increases.

Financial Prospects of *Jatropha* as a Renewable Source of Bioenergy

Results of cash flow analysis are shown in Table 3. The financial worth of Jatropha as alternative source of biofuel is described by the values of discounted PVs of net returns estimated in 3 yield levels , namely: low,medium, high as discussed below :

Low yield level. The financial acceptability of Jatropha as alternative source of biofuel is not manifested at low yield level scenario at all levels of extraction rates and prices of crude oil from the current pump price (P40) up to P200 per liter crude oil when oil only is the source of revenue.

Acceptability is improved when the value of by-products was imputed as additional income. This was manifested starting at a) P90 per liter of crude oil at 30% rate of oil extraction; b) P80 per liter of crude oil at 34% rate of oil extraction; and c) P70 per liter of crude oil at 38% extraction rate.

Medium yield level. At this level of yield, using oil as the only source revenue of farmer, the acceptability of the Jatropha as alternative source of biofuel is manifested starting at price level of crude oil at a) P90 per liter at 30% rate of oil extraction; b) P80 per liter at 34% rate of oil extraction.

Again, the imputation of the value of by-products as additional income improved the acceptability of Jatropha although still at high price level of crude oil starting at a) P60 per liter at 30% rate of oil extraction; b) P50 per liter at 34% and 38% rates of oil extraction.

High yield level. At high yield level scenario, the acceptability of Jatropha was largely improved. At oil only as the source of income, acceptability started at a) P70 per liter of oil at 30% of oil extraction, and b) P60 per liter of oil at 34% and 38% extraction rates.

The above analysis indicates that Jatropha becomes acceptable as alternative source of biofuel at current prices of crude oil (P40 per liter) at high rates of oil extraction, 34% and 38% with by-products included as added income aside from sales of oil.

Discussions

Jatropha as a source of renewable oil is one of nature's gift to humanity. As a source of oil, it has cycling time of just 1 year compared with fossil fuel oil which takes about 175,000 to 200,000 years. The crop, though gifted with this capacity to synthesize oil (its strength), the amount that it can synthesize when expressed per plant or per hectare basis is simply low (its weakness). Biologically, this is traceable to its natural design. It photosynthesizes using the C3 pathway which sets its biological limit to produce oil. Oil requires large amount of gram glucose equivalence (for energy use in the plant) for its synthesis.

This inherently low potential oil yield makes the commercial production of Jatropha oil uncompetitive if the current price of diesel oil at P40/li is used as indexed price. Jatropha becomes acceptable as alternative source of biofuel at current prices of crude oil (P40 per liter) at high yields (36,000 kg/ha, high rates of oil extraction (34% and 38%) and byproducts included as added income aside from sales of oil.

This low *Jatropha* seed yield and oil extraction efficiency present challenging work for the countries researchers. It suggests at least two (2) R/D opportunities. One is for future biotechnology research to explore the possibility of increasing further the seed yield and extractable oil from *Jatropha* plant, and two, finding optimal crop mixes (multiple cropping schemes) that will increase the total farm income and reduce farm business risk.

Likewise, it should be recognized that the technology for *Jatropha* processing is yet to be established in the country. Process-related technologies should be discovered and identified such as i) processing of raw oil into trans-esterified oil before it can be used as biodiesel oil, ii) processing of by-products (oil press cake) into organic fertilizer or livestock feed and glycerol into high priced products, iii) and processing *Jatropha* oil into soap.

Should there be a decision to grow *Jatropha* in large scale, prospective growers have to bear in mind that *Jatropha* will be productive 5 years after planting. While it starts to bear fruits 2 to 3 years after planting, yields are low that they cannot even offset the costs of establishment, maintenance, and harvesting if the current price of diesel oil is used as index price.

Even if the price were to increase later on, still the farmers should be prepared to shoulder the cost burden within 4-5 years period. To lighten the burden and to cushion the impact of the shortfall in income during the initial five years of cropping and the impact of the downward changes in the market price of oil, farmers should plant short maturing income-yielding crops in addition to *Jatropha*. Although multiple cropping approaches to *Jatropha* propagation will compensate for the low oil yield set by nature, it decreases the effective crop area and yield per ha of the crop. This will affect the land area which should be planted to profitably operate the *Jatropha* oil mill. It is important to determine the correct mix of crops with *Jatropha* to be able to soundly project the minimum area to be planted that will ensure an adequate supply of materials for the optimum operation of *Jatropha* oil mill. Oil mill capacity should jibe with the supply of *Jatropha* fruits/seeds in various areas of crop mixtures and systems of planting.

The List of data gaps in coming up with a more precise financial viability estimates are summarized in the Box below.

Best provenance of indigenous tree as source of seeds or cuttings

Optimum plant spacing under Philippine condition ,especially under marginal/hilly land conditions

Yield performance of *Jatropha* grown under mixed cropping or intercropping system

Jatropha yield levels in different (soil and climate) environment

Jatropha yields under varying levels of management or input application

Pest management under large Jatropha monoculture plantation

Processing/farm level hauling/buying

Farm level purchase price of Jatropha considering not only the agronomic costs of production but also the cost of processing – primary (pulping, drying) ◊ raw oil◊– seed oil extraction

, processing of by-products into usable◊Trans esterification costs of raw oil form (organic fertilizer or animal feed) processing of glycerol

Plantation scale versus mill capacity

Big mill capacity means a large area will be dedicated to Jatropha culture to provide adequate supply of Jatropha seeds for processing in the mill; means longer hauling distance in the purchase of Jatropha seeds. It means more expensive hauling costs to the mill (more hauling trucks, more energy consumed to transport the seeds).

Small mills at the village level implies difficulties/added costs in quality control, it should be restricted only to raw oil processing as trans esterification process expose the rural folks to risk of pollution or poisoning, and risks/control mechanism in the storage tank or container of raw oil.

Optimum process of trans-esterification of raw oil

Handling/disposal of by-products: exocarp (fruit cover),press cake

Marketing and Distribution

Proper storage of trans esterified oil

Pump price of trans esterified oil

Conclusion and Recommendations

We have a long way to go to ascertain the clear viability of Jatropha as alternative source of biofuel. Little is known on the yield of Jatropha on large scale farm operations. The culture and farm management practices best suited to the crop to make good yields is likewise not clear yet. In addition, little is known on the best technology for processing, marketing and distribution of Jatropha products, and utilization of by-products.

The acceptability of the financial worth of Jatropha is not shown at all yield levels and at all rates of oil extraction with oil as the only sources of income of farmers at current prices of crude oil. The financial worth of Jatropha is shown at a point with a combination of high yields, high rate of oil extraction, and high prices of diesel oil (P60 or more per liter of oil).

The financial worth of Jatropha as alternative source of biofuel is manifested when the byproducts are imputed on the returns stream at high rates of oil extraction (34% and 38%) at current price of crude oil (P40 per liter). Making Jatropha a viable source of bio-fuel, high yielding trees, high extraction rate of oil, and efficient utilization of by-products should be present in the production and processing systems. This is not to exclude the important contribution of marketing and distribution systems.

The inherently low Jatropha yield level suggests at least two(2) R/D opportunities. One is for future biotechnology research to explore the possibility of increasing further the seed yield and oil extracted from Jatropha plant, and two, for finding optimal crop mixes (multiple cropping schemes) that will maximize total farm yield. The relatively long gestation period (5 years) before the crop reaches optimum fruiting also calls for diverse cropping involving short maturing crops and high value fruit/wood trees to increase the total farm income and to minimize the risk in farming.

The technology for Jatropha processing is yet to be established in the country. The following are the process-related technologies that must be defined: i) processing of raw oil into trans-esterified oil before it can be used as biodiesel oil , ii) processing of by-products (oil press cake) into organic fertilizer or livestock feed and glycerol into high priced products, iii) and processing of Jatropha oil into soap making. Which product is most profitable, soap or biodiesel from Jatropha?

Despite these limitations of Jatropha, it presents enormous employment opportunities in the rural areas if comprehensive programs are designed to tap the positive aspects of the crop. Likewise, the inflows of investments in the rural areas will jumpstart economic activities and it can be the key to finding lasting peace in insurgency- dominated poverty-stricken rural areas.

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