Octa Journal of Biosciences
International peer-reviewed journal
Octa. J. Biosci. Vol. 1(1): 85-97

ISSN 2321 – 3663
May, 2013

Octa Journal of Biosciences
journal homepage: www.sciencebeingjournal.com

Review Article

Post Production system of Jatropha for use as Biodiesel

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Received 1nd Dec. 2012 Revised 12th March 2013 Accepted March 30th 2013

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Abstract: India, with a GDP of about USD 475 billion, is the fifth largest economy in the world. Seventy two percent of India's people live in rural areas and about 70% earn their livelihood from agriculture. India's rate of economic development is affected, as it needs to import about 70% of its petroleum demand. Wildly fluctuating world prices of oil have been a destabilising element for the country's balance of payments situation, particularly in recent times. The petroleum import bill is currently about 13 billion dollars (about 30% of total import bill) compared to the current trade deficit of about USD 11 billion. The current yearly consumption of diesel oil in India is approximately 40 million tonnes forming about 40% of the total petroleum product consumption. It is estimated that the demand of diesel in the country would rise to 52 thousand tones by 2006-07 and to 67 thousand tones by 2011-12 with simultaneous increase in consumption by the agriculture sector. India's developmental objectives base themselves on economic models that require a per capita consumption of fuel oil several fold higher than current Indian consumption levels. The environmental problems that might crop up from such increased fuel consumption also need to be taken into account. Present day concerns over the growing energy needs of a growing world population have shifted from limited fossil fuel supplies to climate change, air pollution, and inequity resulting from the lack of economic means to develop. Biodiesels can provide a suitable answer to address these issues.

Key words: Biodiesel, Jatropha, Production, energy

INTRODUCTION

Bio-diesel is an eco-friendly, alternative diesel fuel prepared from domestic renewable resources i.e. vegetable oils (edible or non- edible oil) and animal fats. These natural oils and fats are made up mainly of triglycerides. These are in similarity to petroleum derived diesel and are called "Bio-diesel". As India is deficient in edible oils, non-edible oil may be material of choice for producing bio diesel. For this purpose Jatropha curcas considered as most potential source for it. The existing tracts of degraded lands in the country, where the agro-climatic conditions are adverse can be easily used for planting hardy Tree borne oil seed species like Jatropha.

According to the Economic Survey (1995-96), of the cultivable land area about 100-150 million hectares are classified as waste or degraded land. After careful studies, experts have zeroed in on the Jatropha (Jatropha curcas, Ratanjyot, wild castor) as the most likely candidate for wide spread cultivation due to its multiple advantages. As per planning Commission report 65 Mha total waste land is available including 14 Mha waste land in forest under Joint Forest Management. Out of 14 Mha 13.4 Mha could be used for jatropha plantation (Ali, 2004). Jatropha Curcas has been identified for India as the most suitable Tree Borne Oilseed (TBO) for production of bio-diesel both in view of the non-edible oil available from it and its presence throughout the country. The capacity of Jatropha Curcas to rehabilitate degraded or dry lands, from which the poor mostly derive their sustenance, by improving land's water retention capacity, makes it additionally suitable for up-gradation of land resources. Presently, in some Indian villages, farmers are extracting oil from Jatropha and after settling and decanting it they are mixing the filtered oil with diesel fuel. The aim of this paper is to reviews the current status of postproduction machinery for *Jatropha* seed, set of machinery for the operation such as: (i) harvesting, (ii) husking, (iii) shelling, and (iv) cleaning; system for the proper (i) drying and (ii) storage of *Jatropha* seeds and the methods of transsterification for jatropha oil.

Jatropha as biodiesel

There is indication that viability of Jatropha, if not attained yet, is a question of time. If this is the case, then broad preparation to be commenced now is well justified. Changing factors are the following:

- Increased demand and casts for diesel, higher foreign exchange needs for diesel; an increase of non-cultivated, non-forested and eroded lands; higher rural energy demand and energy costs; and, at the same time, a decrease of rain and water availability, as well as decreasing rural incomes.
- A main concern of the international discussion on bio energies is whether less food is available with increased Jatropha cultivation to the low-income population**.**
- In the Indian Government program, officially mainly non-used land is targeted for Jatropha and present price levels do not indicate that Jatropha can directly and successfully compete with agricultural crops and vegetables grown yet.
- If indeed lands were cultivated, which lay idle so far, employment generation would reach women and low-income groups in the villages**.**
- Additionally, Government plans to support an approach, which focuses self-help activities, social forestry, cooperatives and the like, to assist organizations of rural poor to improve their living conditions through increased Jatropha cultivation.
- Whether it would be more advisable to cultivate other crops cannot be judged on an abstract level; it is assumed and hoped that growers themselves will make a rational investment decision, if conditions and guarantees given are favorable**.**
- Here policy has to avoid a negative change and fluctuations in prices and markets, since Jatropha is a long-term investment and can ruin a farmer, if minimum revenue cannot be maintained**.**
- If irrigation and fertilization is considered necessary and installed, then obviously other crops could be established in those lands as well and possibly increase benefits.

Post harvest processing

The physico-chemical and mechanical property of the jatropha seed is given in the Table-1.

Table–1: Physico-chemical and mechanical property of the jatropha seed (Mangaraj and Singh, 2006)

Properties	Average value
Mass of 1000 grains, g	604
Kernel to shell mass ratio	0.60
Bulk density of grains, kg/m^3	341.56
True density, kg/m^3	630
Porosity, %	44.78
Sphericity	0.61
Geometrical Mean Diameter	9.89
Moisture content, % (db)	6.1
Compressive strength, N/mm^2	4.62
Shear strength, N/mm^2	3.58
Oil content, %	35.00
Protein (%)	18.20
Fat (%)	38.00
Carbohydrate (%)	17.98
Fibre (%)	15.50
Ash (%)	04.50

Drying

The seed needs to be dried before dehulling. The fruits are just heaped out side the house or in the field for 7 to 10 days for drying. It is seldom spread on a threshing floor for drying. The best method is to spread a thin layer of fruits on a plastic sheet or on a surface of concrete for sun drying (Joshi and Bharodia, 2004). If the seeds are to be planted they should not be dried in full sunshine, because the heat can reduce the germination capacity. If the seeds are going to be used for oil extraction they may be dried to lower moisture content. It is important to keep the seeds free of sand or small stones, as it may damage the processing or oil extracting machines and also results in poor quality oil and cake.

Decapsulation

Decortications of jatropha fruits are in general done by beating the dried fruits with sticks on threshing yard. Decapsulation by hand is time consuming process. A small tool makes this task much easier. The dried fruits are placed in a thin layer on hard surface i.e. on table or on a concrete floor. If a small wooden board is moved over them while pressing it down. The fruit husk split and the seeds come out. The husk and seed can be separated by winnowing and sieving. The jatropa fruit, seed and husk are shown in Figure-1.

Fig-1: Jatropha fruit, seed and husk

Storage and viability

The seeds should be dried to low moisture content (5-7%) and stored in airtight containers. At room temperature the seeds can retain high viability for about one year. However because of the high oil content the seeds cannot be expected to be stored for long as most of the other orthodox species.

Dehulling

Jatropha seed contain about 38% hull/shell. The hull does not contain oil and rather obstructs the oil extraction/expression from the kernel inside. So it is necessary to dehulling the jatropha seeds before the oil extraction. At present no machine or technology is available for dehulling the jatropha seeds on large scale however APPEU, AAU, Anand working on the development of this machine.

Oil extraction/expression

Oil can be extracted manually and mechanically with an oil press (Fig.2) (Ali, 2004) an expeller, or even with a wooden mortar and pestle—a traditional method that originated models that an individual can build to power driven commercial presses. Expellers have arotating screw inside a horizontal cylinder that is capped at one end. The screw forces the seeds or nuts through the cylinder, gradually increasing the pressure. The material is heated by friction and/or electric heaters. The oil escapes from the cylinder through small holes or slots, and the press cake emerges from the end of the cylinder, once the cap is removed. Both the pressure and temperature can be adjusted for different kinds of feedstock. The ram press uses a piston inside a cage to crush the seed and force out the oil. Oils can also be extracted with solvents, but solvent extraction is a complex operation. Solvent extraction is not suitable for small-scale processing because of high capital and operating costs, the risk of .re and explosions from solvents, and the complexity of the operation.” Waste management would probably be a problem, also. The process flow chart for the mechanica expression of oil and solvent extraction is given in Fig. (3&4) (Singh and Shukla 1991).

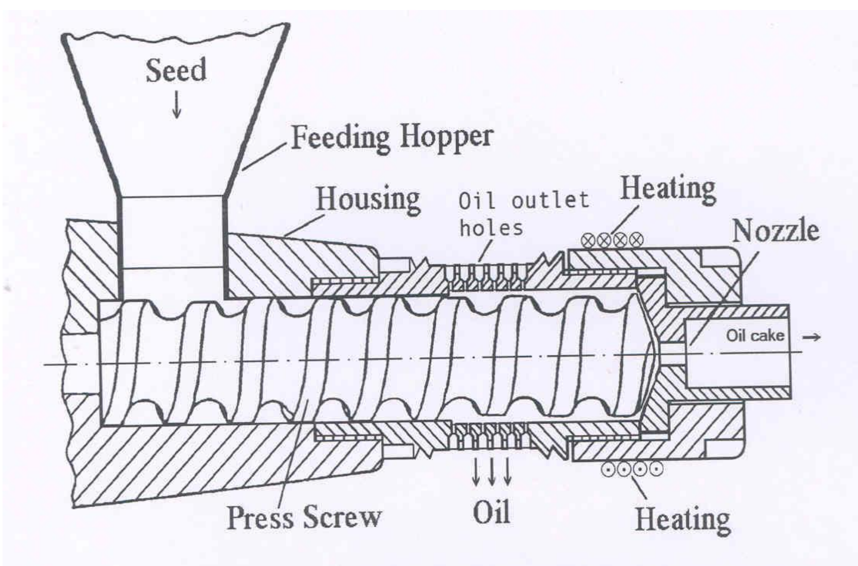

Fig.2: Mechanically operated oil press/expeller for jatropha

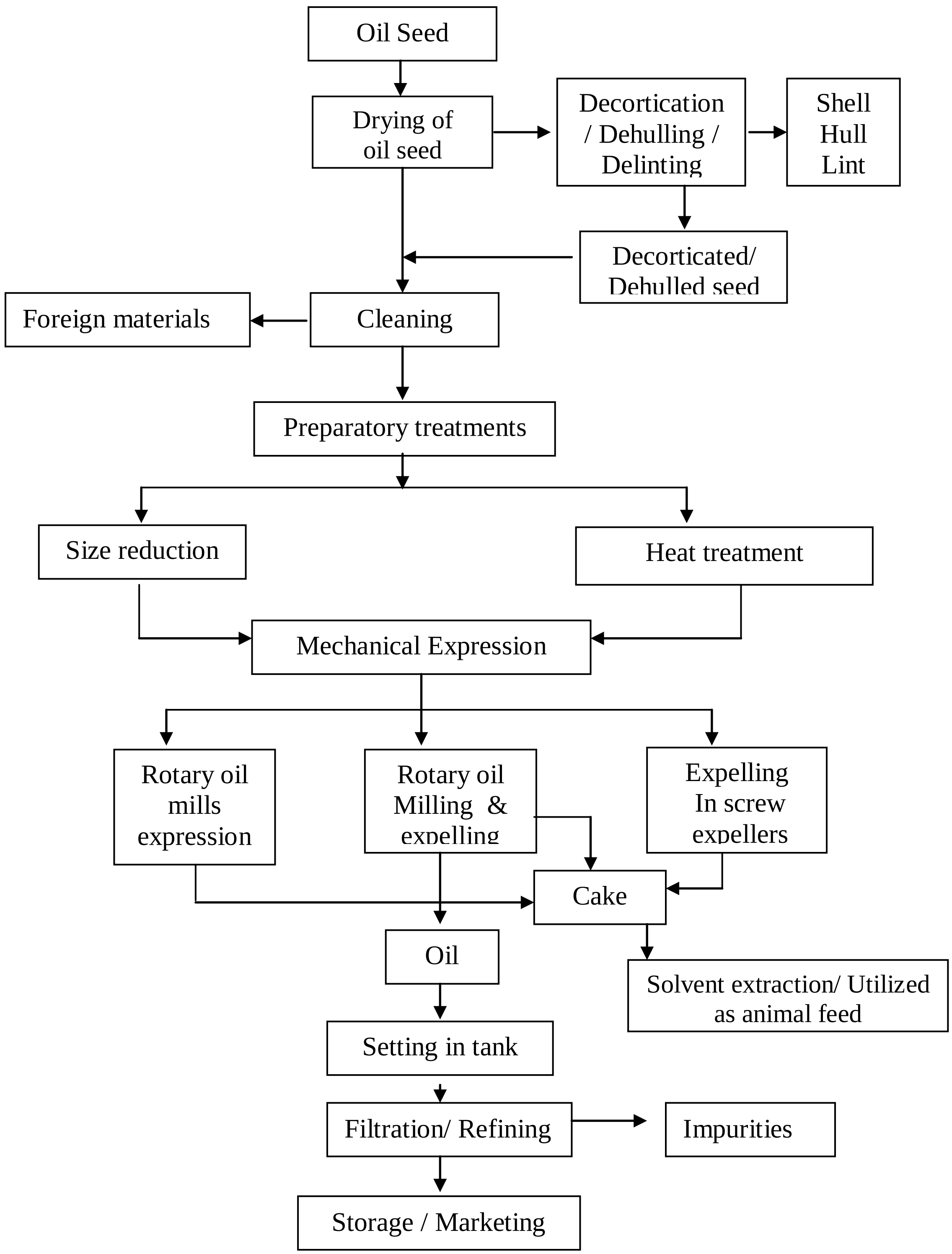

Fig-3: Process flow chart of mechanical expression of oil source

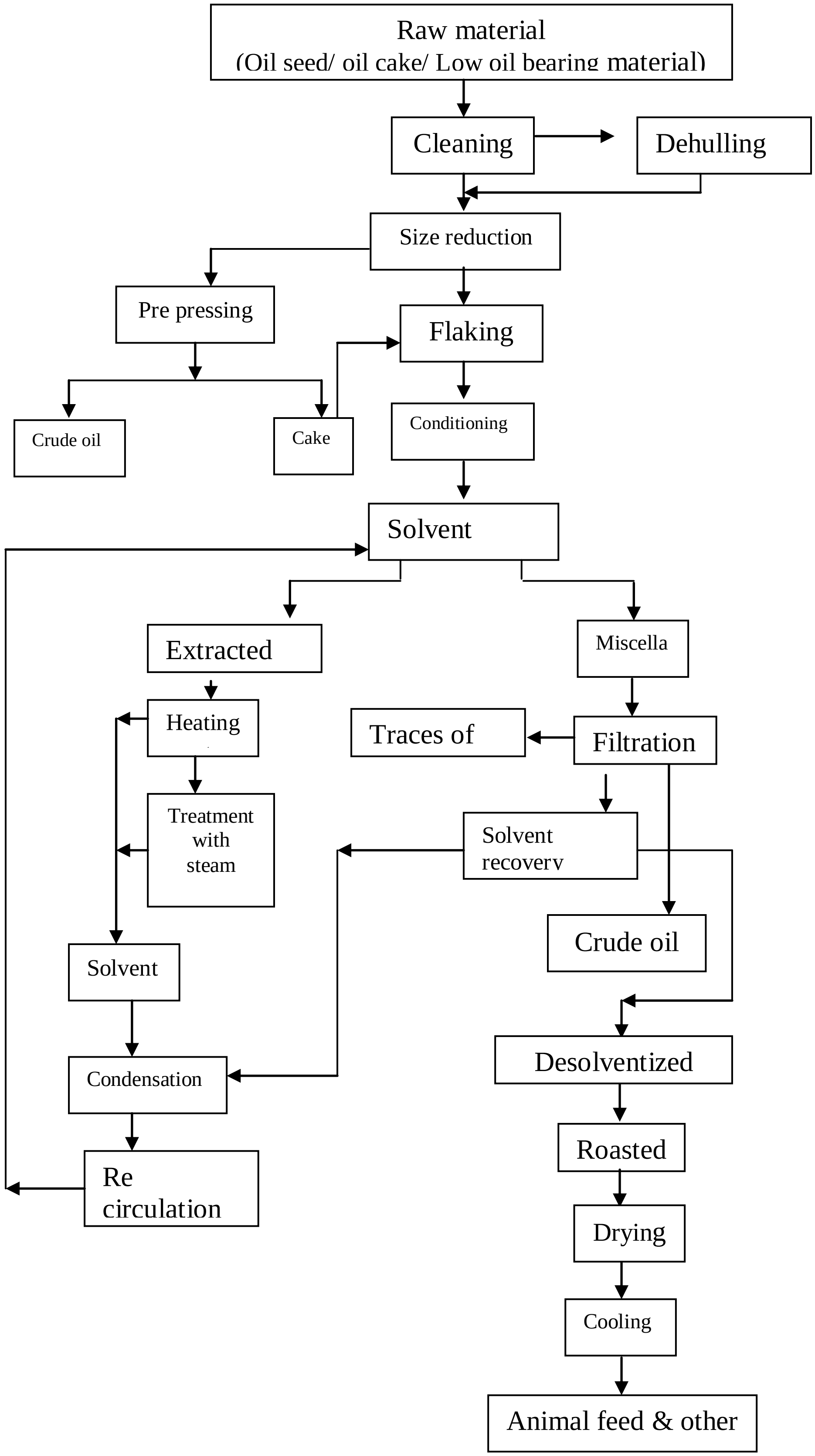

Fig-4: Process flow chart of solvent extraction of oil.

Status of expression/extraction of oil from jatropha

Harbinsons Biotech Pvt. Ltd., has set up a batch process pilot plant of 1 ton per day capacity at Gurgaon (on outskirts of New Delhi), based on *Jatropha curcas*.

Punjab Agricultural University has developed a 12-liter batch reactor used for bulk production of biodiesel, which was later scaled up to 60 liters. Biodiesel has been prepared from a number of plant oils (edible as well as non-edible) and used successfully in existing diesel engines.

Kumar Industrial Works, Salem has developed a complete system for mechanical expelling of oil for jatropha (Fig.5). Oil expeller is basically a screw press working on principle of pressure volume ratio contraction to extract oil from variety of oil seeds. Based on the concept of efficient extraction in single pass with maximum capacity, recovery and minimum maintenance. The expeller works on the principle of milling. In this process the seed are pretreated through steam before it goes to the oil expeller. The oil expeller recovered around 25 kg of oil from 100 kg seed having 35% of oil content.

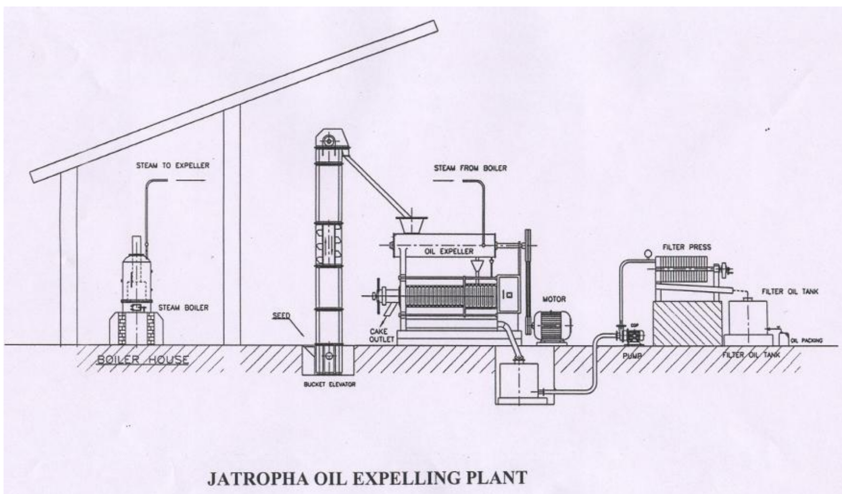

Fig.5: Kumar Yield King Oil

The expeller consists of double socket heating kettle, pressing box or cage surrounding horizontal shaft mounted with series of worms. At the feeding end of the cage there is an opening through which the meal is fed into the expeller. At the discharge end the cage there is a cone, which practically restricts the passage. The rotation of the horizontal shaft causes the meal to push forward by its screw action, thereby increasing the internal pressure and thus squeezing the oil the internal pressure of the expeller is regulated by the adjustment of the cone. The extracted oil flows through the perforated box, while the cake passes out through the opening around the cone. The oil which comes out of the expeller contains lot of foots, suspended particles of seed and cake. This oil requires filtration before it is stored in storage tanks. This filtration takes place by pumping the oil to the filter press, where it passes through a layer of the filter cloth. The liquid oil passes through the filter cloth and solid matter deposits on the filter cloth. The filtered oil from the filter press is usually pumped on to the storage tanks. The storage of oil cake is also as important as the storage of oil seeds. The fresh cake is hot & contains superficial moisture. This cake is cooled by spreading it in well ventilated for a period of about 24 -36 hours.

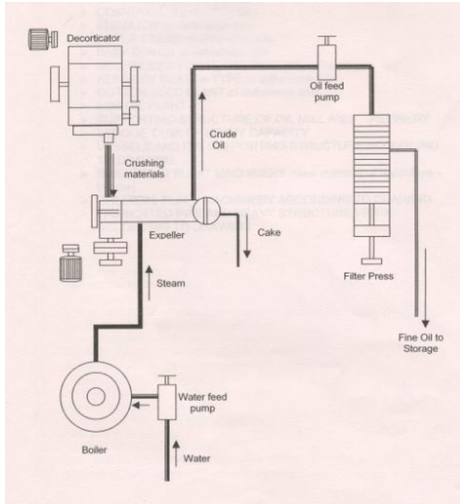

Fig.6: Oil expelling plant of Krishna Industries

Krishna Industries Co. Gujarat has developed (Fig.6) and establish oil extraction plant (2t/day) in different places namely Agriculture University, Junagarh; Anand Krishi University, Dairy Science Division, Anand; Anand Krishi University, APPE Division, Anand and soon. The complete plant consists of oil expeller, baby boiler, mini filter press, other accessories etc. The oil expeller recovers around 70% of oil from the seed.

Agricultural product process Engg. Unit, Anand, Gujarat has Established/developed a mechanical oil extraction unit. The complete plant consists of Decorticator, Dehulling unit, steaming through boiler, oil expeller, filter press, other accessories etc. (Joshi and Bharodia, 2004). This system recovers 25 kg oil from 100 kg of seed.

School of energy study, IIT, Delhi is carrying out work on extraction of oil using solvent in the laboratory scale. They claim that through solvent extraction 97% oil recovery could be achieved.

Indian Institute of Petroleum (IIP) is actively pursuing the utilization of non-edible oils for the production of biodiesel. A deals with the indigenous technology development for biodiesel production using *Jatropha Curcas*, Karanj Oil, Mahua Oil and Salvadora oil, as a networking project along with CSMCRI, Bhavnagar and NBRI Lucknow.

Indian Railways

Indian Railways, owned by the Government of India, consumes with 4000 locomotives about 4 % of the country's total diesel fuel and plans to blend Jatropha oil with diesel and to plant Jatropha along 25,000 km of the railway tracks and other wastelands to minimize petro-diesel consumption. Indian Oil Corporation will setup facilities for Fuel Oil extraction and supply it back to Indian Railways in 5, 10 and later 15% blends, in line with global norms and without asking for any modifications on locomotives. A first successful trial run of a passenger train on green fuel was conducted in 2003 with the Delhi-Amritsar Shatabdi Express with a 4000 HP engine, which used *5%* bio-diesel as fuel. bio-diesel is meant to enable Indian Railways to save on its rising fuel bill, while at the same time controlling pollution levels from sulphur and lead. "

Daimler Chrysler Project, Gujarat, Orissa as well Daimler-Chrysler, together with University of Hohenheim, Germany, and CSIRCouncil for Scientific and Industrial Research has started a public-private partnership project (600.000 Euro) to test and demonstrate feasibility of Jatropha bio-diesel on internal combustion engines. The project is probably the best-known Jatropha project and a major Jatropha promoter in India. Daimler-Chrysler wanted to have a test runs on their vehicles with Jatropha and tested their ignition performance throughout India. Daimler Chrysler just got the first sustainability price for their most environmentally friendly vehicles and lines of production out of 1500 competing cars by an eco test run independently by the Wuppertal based institute "Okotrend".

Central Institute of Agricultural Engineering (CIAE) Bhopal has taken up a project on Optimization of solvent extraction process and technology for oil extraction from Jatropha. The work being carried out includes the laboratory scale testing of decortications of jatropha, standardization of parameters which including numbers and size of grits from jatropha seed, cooking moisture content and drying level, thickness of flakes for oil extraction using solvent as well as by mechanical expression using expeller for maximum oil recovery.

Transesterification

The most common way to produce biodiesel is by transerterification, which refers to a catalyzed chemical rection involving vegetable oil and an alcohol to yield fatty alkyl ester (i.e. bio diesel) and glycerol. Triacylglycerol (triglycerides), as the main component of vegetable oil, consist of three long chain fatty acids esterfied to a glycerol backbone. When triacylglycerols react with an alcohol (eg. Methonal), the three fatty acid chains are released from the glycerol skeleton and combine with the alcohol to yield fatty acid like alkyl esters (e.g. fatty acid methyly ester or FAME). Glycerol is produced as by-product. Methanol is the most commonly used alcohol because of its low cost and is the alcohol of choice in the process developed.

Pilot biodiesel plant at TNAU

The pilot biodiesel plant developed and utilized was alkaline catalyst based and having a limitation of free fatty acid content less than five percent in the vegetable oil used. The process flow chart for biodiesel production was given in the Fig-7. The pilot plant consist of transesterification reactor with heating and agitating device, chemical mixing vessel, settling tanks and washing tank (Venkatachalam et.al 2004). The catalyst used in the transesterification reaction was sodium hydroxide, which react with metals. The biodiesel pilot plant was fabricated with stainless steel and plastics materials to avoid corrosion problem. In addition to major components, the subcomponents such as chemical mixing tank, oil lifting pumps, glycerol tank, air compressor, pure biodiesel storage unit and control panel for monitoring the plant operation are also used in setting up the pilot plant.

The production process

For the esterification of Jatropha oil, alkaline based catalyst is used in this plant. The Jatropha oil is blended with alcohol and catalyst mixture. The oil extracted from the seeds of Jatropha is mixed with methanol at a proportion under a particular temperature. This solution is continuously stirred for two hours. During the above process, glycerol present in the solution separate out; which when settled, can be separated out. For settling three separate tanks are provided in the plant. After removing the glycerol, the liquid biodiesel is transferred to washing tank, where the fuel is washed twice, and then we get the purified biodiesel. By using the pilot plant, about 250 litres of biodiesel could be produced in a day. The cost of the unit is approximately 1.5 lakhs. This could be reduced by appropriate substitutions in the existing plant. Depending upon the need, the size of the unit can be scaled up to get higher capacity.

The fuel properties of biodiesel produced from Jatropha oil is given in the Table-2. The biodiesel produced was met the ASTM standards and it was similar to the diesel.

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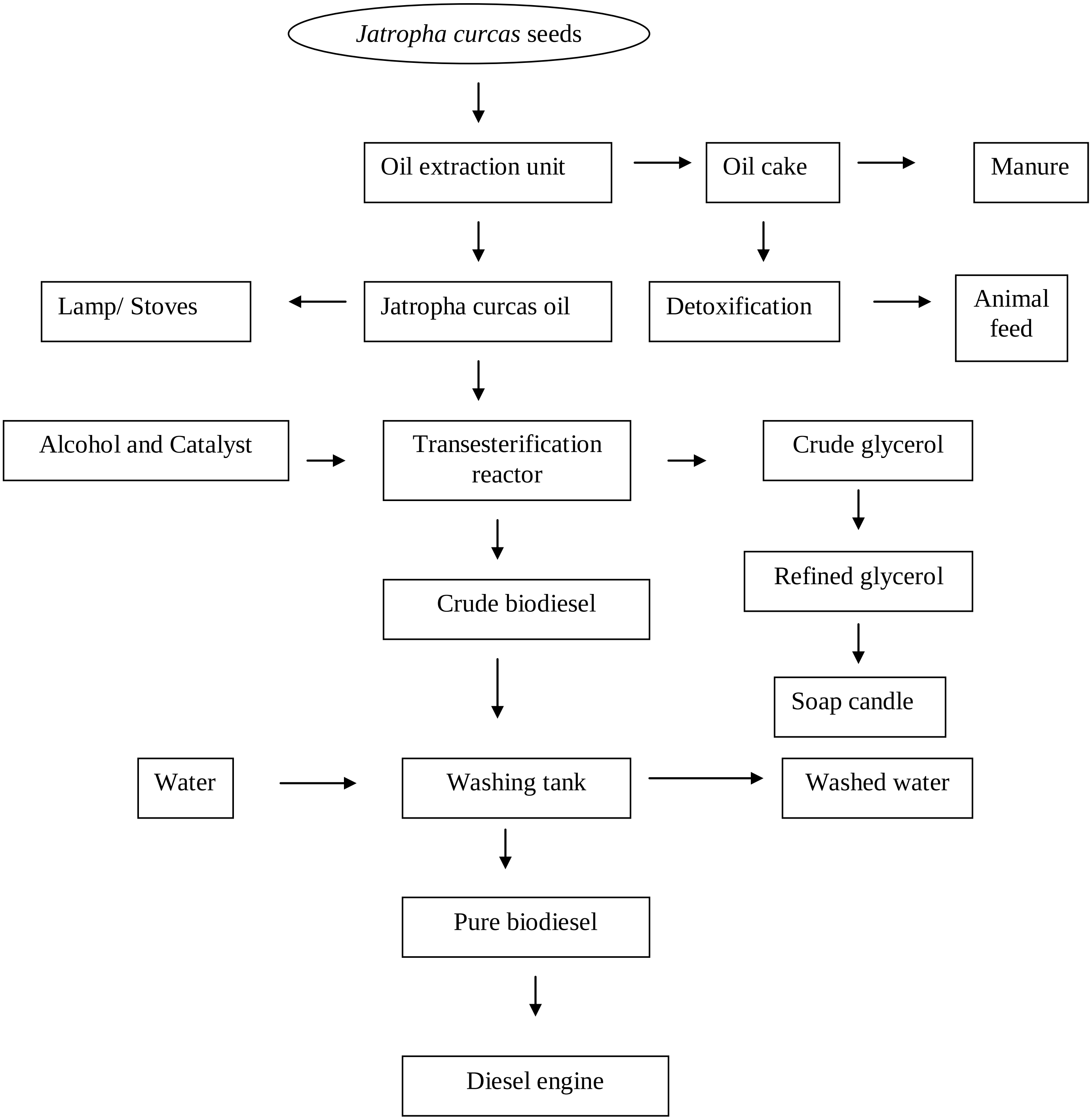

Fig.7: The process flow chart for biodiesel production.

Table-2: Properties of biodiesel from Jatropha

Properties	Diesel	Jatropha raw	Jatropha biodiesel	ASTM standards
Density, g/ml	0.8410	0.9198	0.8750	--
Viscosity @40^{0}C Cst	4.5	32.5	5.4	1.9 – 6.0
Calorific value kJ/kg	42	39.54	39.21	--
Flush point, ^{0}C	50	240	175	<130^{0}C
Carbon residue, %	0.21	0.53	0.21	<0.50
Free fatty acid, %	--	3.4	0.61	--
Acid value, mg of KPH/g	--	6.77	1.19	--
Methyl ester conversion rate, %	--	--	98.2	--

Clarification

Clari.cation removes contaminants, such as pulp, water, and resins. It isd done by allowing it to stand undisturbed for a few days and then removing the upper layer. If it needs further clarication, filtration is done through a filter cloth. The oil is heated to drive off traces of water and destroy any bacteria.

Packaging and Storage

Cleaned and dry containers are used for packaging and storage of oils to prevent from rancidity. Sealed glass or plastic bottles are adequate. Colored containers in a dark box help to increase shelf life. The shelf life of oil is usually 6 to 12 months, if it is properly packaged and kept away from heat and sunlight. (Fellows and Hampton, 1992).

CONCLUSIONS

The development of any country largely depends on the development of rural economy. Pro-poor development should be specifically prowomen in order to address the gender imbalance of access to economic opportunities, health and education in developing countries. Pro-poor development has to be sustainable, including the need for environmental sustainability. This paper depicts the importance of biofuels and the potential of jatropha for poverty reduction, together with the risks jatropha biofuel development presents to the livelihoods of the rural poor and to the environment. It further characterizes jatropha postproduction systems and the status of post harvest technology available in the country for jatropha oil expelling /extraction and transsterification. It was observed India has a long way to go to create facility for postproduction system of jatropha to meet the demand.

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