DISCUSSION AND CONCLUSION:

The acetone wash has improved the salt removal capacity of both materials that were used as electrodes in this study. The increase in removal capacity is higher (about 92%) in case of carbon aerogel than that of carbon block electrodes (66.7%). The acid wash of the cell prepared with acetone washed carbon block electrodes provided significantly high removal (216%) compared to untreated carbon block electrodes. The increase in salt removal is about 90% when compared to only cell prepared with acetone treated electrodes. The possible reasons for the increase in removal capacity maybe cleaning up of pore spaces by acetone wash and enhancement of capacitance by oxidation with nitric acid. Further experiments will be done to investigate the actual reason for this change in removal capacity.

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Green Power Production from Pinnata

Rajesh Venkatesan[1]; Karthik Dampuri[2]; Dr. Rajab Challoo[3]; and Aasha Shankar[4]

[1]Master of Science student at Texas A&M Univ.- Kingsville, Dept. of Electrical Engineering and Computer Science, 1300 W Corral Ave., Kingsville, TX 78363. E-mail: rajesh.venkatesan@students.tamuk.edu
[2]Master of Science student at Texas A&M Univ.- Kingsville, Dept. of Electrical Engineering and Computer Science, 1300 W Corral Ave., Kingsville, TX 78363. E-mail: kartik.dampuri@students.tamuk.edu
[3]Texas A&M Univ.- Kingsville, Head of Electrical Engineering and Computer Science Dept., MSC 192, 700 University Blvd., Kingsville, TX 78363. E-mail: rajab.challoo@tamuk.edu
[4]Master of Science student at Univ. of Florida, Dept. of Environmental Engineering Sciences, 2601 SW Archer Rd., Gainesville, FL 32608. E-mail: aasha.shankar@ufl.edu

Abstract

Biofuel from Corn as a feedstock is used in the U.S. for over a decade. Although the production and use of biofuel has seen an increase, it is still debatable in food versus fuel criteria. The purpose of this study is twofold: (1) assess the potential of producing higher yield of the seeds due to which higher quantity of biodiesel is produced, and (2) compare and assess the generated pollutant.
A potential legume tree species, Pongamia Pinnata is known for the production of biofuel. Non-edible oil is largely extracted from seeds. Pongamia seed oil as a bio-fuel has physical properties very similar to conventional diesel. It is, however a clean fuel (eco-friendly) than conventional diesel. Thus, the oil extracted from the seeds can be used in power generators as a substitute for diesel and thereby help in the production of green power and encourage a carbon neutral environment.
The following results were arrived at, (1) the potential for biofuel obtained from Pongamia Oil to be used in industrial grade generators as a backup for power generation, (2) Expanding the Pongamia biodiesel system to include biogas production from seed cake exploits the energy available in the system, and (3) Higher yield of Pongamia seeds are obtained by using the sapling provided by VayuGrid who own proprietary rights.

Keywords— *Pongamia Pinnata, Biodiesel, power generation.*

INTRODUCTION

Vegetable Oil as Fuel:

Vegetable oil can be used to fuel diesel engines as straight vegetable oil (SVO) or as biodiesel following conversion. It can be used either for cars, cooking or for stationary use to power machinery or an electricity generator. The more advanced the engine technology, the more complicated or limited the use of SVO. Hence for use in modern cars with direct injection engines the conversion of SVO to biodiesel is mandatory. However, SVO can be directly used as fuel for most simple stationary diesel engines used in generator sets or pump stations. Special SVO engines are also available. For robust stationary (non-vehicle) engines, the use of pure SVO is the most attractive option. This way the additional and somewhat dangerous biodiesel conversion process (due to some highly inflammable components) can be avoided; furthermore, the energy yield per gallon of vegetable oil is higher when using SVO directly.

Almost all vegetable oils have a calorific value that is equivalent to that of diesel fuel. However, vegetable oil differs from diesel considerably regarding viscosity, which is 10–20 times higher for SVOs. Furthermore, the solidification points of SVOs can be rather high. Coconut oil for example solidifies at temperatures below 22°C. This can cause major problems particularly in cold regions. Oil characteristics can differ considerably between different types of SVOs as their composition of fatty acids varies. This can lead to plugging and gumming of lines, filters and injectors, as well as cause deposits inside the motor or excessive engine wear. Other oils like palm oil, sunflower, soybean, coconut, Jatropha and cotton oil have also been used to fuel motors.

There is a growing need for energy security as any disturbance in the supply of petroleum fuels or increase in petroleum prices can have negative impact on the growth of economy. Indigenously produced biofuels are being considered as one of the options to partially substitute petroleum fuels and reduce dependence on imported oil.

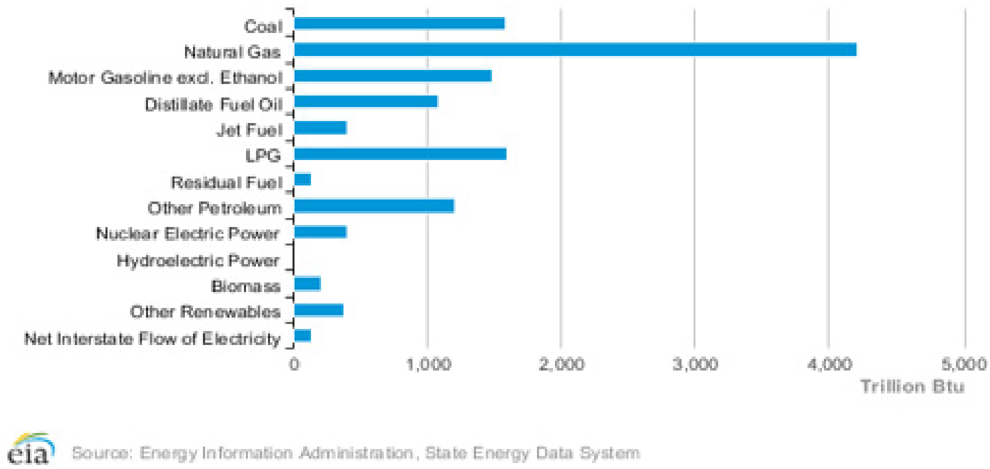
Market research:

Renewables account for only 18% of global total final energy consumption. Half of the total renewables demand comes from the traditional use of biomass. In view of the increasing demand for energy, particularly in developing countries, this also poses important concerns because of its unsustainable supply and the negative effects of indoor air pollution.

In view of these challenges, in 2011 the United Nations Secretary General launched the Sustainable Energy for All (SE4ALL) initiative.

The EIA forecasts crude prices will be $120/b in 2030 and $141/b by 2040. In a high-price scenario, in which demand is stronger than expected or supply falls short of projections, oil could top $200/b by 2040. Figure 1 indicates the energy consumption estimate for one state in the United States for the year 2014.

Figure 1: Texas energy consumption estimate for the year 2014



Further Remap 2030 estimates the reference Price of the Liquid biofuel $ 257/b The Study results show that Pongamia Biofuel could be produced at $ 97.5 by 2030.

According to the FAO, worldwide there are approximately 13 billion hectares (ha) of land available, of which 4.5 billion ha are suitable for crop production. Out of this 4.5 billion ha, 1.8 billion ha is not available for crop production as they are used for non-agricultural purpose (e.g., urban and protected areas) or needs to be protected for environmental protection (closed forests6). Thus, the total amount of suitable land available for crop production is estimated at approximately 2.7 billion ha. The current production of food crops utilizes some 1.5 billion ha of land, of which 1.3 billion ha falls under this category of "suitable land". As a result, about 1.4 billion ha additional land is suitable but unused to date and thus could be allocated for bioenergy supply in future.

Jatropha:

Jatropha- a plant species producing SVO came to light. Jatropha a tree which starts to harvest after 6 months, although higher yields are accounted after 4-5 years. Jatropha is extremely a hardy plant, growing in sandy soil with little nutrients availability and can sustain for long and dry climatic conditions. The plant produces seeds containing inedible oil that can be converted to biodiesel, which can be used in the transportation and energy sectors. The detoxified cake by-product from oil extraction can be used for fish and animal feed, biogas, or as an organic fertilizer. The crop can be mechanically harvested, and oil yields are comparable or higher than soybean and rape seed without genetic improvement. *Jatropha* produces renewable energy in the form of biodiesel, which emits 80% less CO_2, 100% lower SO_2, and has a higher flash point than fossil diesel fuel.

Implementation of the plant species as a substitute for diesel, vastly addressed the growing issue of food versus fuel challenge. Jatropha implementation was greatly affected by the low yield of seeds due to lack of nutrient supply and water.

Pongamia:

Self-reliance in energy is vital for overall economic development. The need to search for alternative renewable, safe and non-polluting sources has been accords top priority. Further, uncertain supplies and frequent price hikes of fossil fuels in the international market are also posing serious economic threats for developing countries. On a per-acre basis, Pongamia produces 8 times the amount of oil than a soybean, with a fraction of the inputs (water, fertilizer, pesticides, etc.) and is thus cheaper to maintain while being much more sustainable and environmentally friendly.

Pongamia Pinnata found as one of the most suitable non-edible oil plant species in India due to its good N2 fixing ability and not grazable eatable by animal. It can be grown in water logged, saline and alkaline soil, waste land/ fellow land and can withstand harsh agro-climates.

Pongamia oil is a non-edible oil extracted from seeds of Pongamia Pinnata commonly known as 'Karach', 'Karanja'. It is a hardy tree of 12-15-meter height. It can be grown in different types of flood free soil and matured tree withstand water lodging. Pongamia grows very well along water ways. Its propagation is by direct seedlings or by planting nursery raised seedlings. Propagation by branch cuttings and root suckers are also possible. Its seeds can immediately be sown after removing from matured pods and start germination after 7 days of sowing and cent percent seeds germinate. Fruits setting of Pongamia starts from third year onwards of plantation. A full-grown tree may yield up to 100 kg or even more fresh seeds per annum up to 60-70 years. In North East India cattle, do not graze Pongamia though in other parts of the country its leaves are used as fodder.

Pongamia seeds have about 30-35% oil and up to 27-28% oil can be expressed in crusher and most of the physical and chemical properties of the oil is almost similar to those of the diesel. Though carbon residue is higher in case of it and due to high viscosity preheating is needed to start a diesel engine. Oil is also used as a lubricant, water paint binder, pesticide and in soap making and tanning industries.

Oil cakes are good organic fertilizer and bears nitrogen 4%, phosphorous 1% and potassium 1% which is better than vermicomposting. Root nodules formation due to *Rhizobium* strains in nursery and in fields is common by which nitrogen is replenished in soil. Dense network of lateral roots of Pongamia control soil erosion. Leaves are good manure.

Pongamia can be grown on lands not suitable for food crop while ensuring social inclusion, long-term economic sustainability and environmental compliance. The biodiesel and green coal (compressed briquettes) produced by elite Pongamia release only carbon originally taken from the atmosphere, making this solution uniquely beneficial to the environment for biofuels. Over 20 tons of carbon are sequestered every acre every year. The clean energy adds capacity for efficient transportation, energy, and mechanization to the most critical sectors of the economy such as agriculture.

Biofuel resources:-

Tree borne oil seeds:

The most cultivated oil plants of the tropics are oil palm, coconut, soy, castor, sunflower and cotton. In many cases oil is only a by-product that is rarely extracted.

Jatropha's reputation for wide environmental adaptability does not guarantee high yields. Recent observations of plantations across developing regions confirm that Jatropha may survive precipitation as low as 300 mm, but will not produce significant quantities of seeds at those levels. Apparently about 650 mm of precipitation and good soils are the minimum conditions for good production. Jatropha yields can vary considerably.

The main reason is that Jatropha is not a domesticated plant. Most of the Jatropha seeds used in Africa during the last few years were seeds of no origin.

The oil from cottonseed can be used as an energy source. Cotton oil can also be used for human consumption. However, it is of minor value and due to the intensive use of chemical pest control in cotton culture its agrochemical content can be problematic.

Palm oil is produced at both industrial and small-scale levels. The oil palm is one of the most productive oil plants in terms of produced oil per hectare. Coconut and sunflower are also important sources of vegetable oil. All these oils have high value for human consumption and are therefore preferably used for nutritional purposes.

For the large-scale biodiesel program Jatropha and Pongamia have been found to be suitable as both the species grow well in rain fed semi-arid areas and are not grazed by livestock. A comparison of various characteristic features of these plants is presented in Table 1.

Table 1: Comparison of Jatropha and Pongamia

Characteristics	Jatropha	Pongamia
Ecosystem	Arid to semi-arid	Semi-arid to sub-humid
Rainfall	Low- medium (200-1000 mm)	Medium to high (500 -2500 mm)
Soil	Well drained soils	Tolerant to water logging, saline and alkaline soils
Nitrogen fixation	No Nitrogen fixation	Fixes Nitrogen
Plant suitability	Wastelands, degraded lands, live fence for arable lands, green capping of bunds, shallow soils	Field boundary, river-bank stabilization, wastelands, tank foreshore
Plant habit	Mostly bush, can be trained as small tree	Tree can be managed as bush by repeated pruning
Leaves	Not palatable by livestock	Not palatable by livestock, used as green leaf mulch
Gestation period	Short, starts yielding during 3rd year, attains maturity at 6th year	Long, starts yielding after 4th to 7th year. Yield increases with increase in canopy.
Harvest	Fruits to be plucked	Fruits to be collected
Oil content	27-38% in seed	27-39% in kernel
Protein	38%	30-40%
Oil cake use	manure (4.4% N, 2.09% P, 1.68% K)	manure (4.0% N, 1.0% P, 1.0% K)
Fire wood	Not useful	Good as firewood, high calorific value: 4,600 kcal/kg
Toxicity	Toxic	Non-toxic

Biodiesel:

The problems associated with SVOs can be overcome by converting them into alkyl esters of fatty acids (biodiesel) through a process known as trans-esterification. Biodiesel has properties very similar to those of diesel as shown in Table 2.

Table 2: Properties of biodiesel from different feedstock and fossil diesel

Fuel	Viscosity, e-3 (N. s / m2)	Cetane #	Lower Heating Value (MJ/kg)	Cloud Point (°C)	Density (g/cc)	Flash Point (°C)
Soybean Biodiesel	4.5	45	33.5	1	0.885	42 – 46
Sunflower Biodiesel	4.6	49	33.5	1	0.860	50.4 – 44.7
Jatropha (B20 and B100)	1.9 – 6.0	47 and 40 resp.	42.1 and 45.4 resp.	- 3 to 12	0.875	89 and 105 resp.
Pongamia Biodiesel (B20 and B40)	4.01 and 5.23 resp.	41.7 – 56	45.81	4	0.840 – 0.862	57 – 65
Diesel	3.06	50	43.8	- 40	0.851	40 – 52

Basic Test for biodiesel:

Measurement of different fuel properties:

The important physical and chemical properties of oil and biodiesel were determined by standard methods.

Relative density:

Density is an important property of biofuel. Density is the mass per unit volume of any liquid at a given temperature. Density measurements were carried out using a pycnometer at a temperature of 312K. According to Ideal Law, with increase in temperature there is decrease in density. The standard test method used for determination is ASTM D941.

Flash point:

The flash point temperature of biodiesel fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility. Minimum flash point temperatures are required for proper safety and handling of diesel fuel. Flash point of the samples were measured in the temperature range of 60 to 190°C by an automated Pensky-Martens closed cup apparatus, this corresponds to the ASTM D93 test standards methods.

Calorific value:

Calorific value of a fuel is the thermal energy released per unit quantity of fuel when the fuel is burned completely and the products of combustion are cooled back to the initial temperature of the combustible mixture. It measures the energy content in a fuel. This is an important property of the biodiesel that determines the suitability of the material as alternative to diesel fuels. The calorific value of vegetable oils and their methyl esters were measured in a bomb calorimeter as per ASTMD240 standard method.

Viscosity measurements:

Viscosity is a measure of the internal fluid friction or resistance of oil to flow, which tends to oppose any dynamic change in the fluid motion. As the temperature of oil is increased its

viscosity decreases and it is therefore able to flow more readily. The lower the viscosity of the oil, the easier the liquid flow.
Viscosity is measured using Redwood viscometer. The Redwood viscosity value is the number of seconds required for 50 ml of oil to flow out of a standard viscometer at a definite temperature. This test corresponds to the ASTM D445 testing methods

Cetane number:
The Cetane Number of the fuel is the one responsible for the delay period. Cetane number of a fuel is defined as the percentage by volume of normal cetane in a mixture of normal cetane and α-methyl naphthalene which has the same ignition characteristics (ignition delay) as the test fuel, when combustion is carried out in a standard engine under specified operating condition. A fuel of higher cetane number gives lower delay period and provides smoother engine operation. Biodiesel has a higher CN than petrodiesel because of its higher oxygen content. Ignition test corresponds to ASTM D613 standard methods.

Oxidation stability:
The oxidation stability of biodiesel from different feedstocks and their blends with automotive diesel was quantified by the induction period (IP). The IP was evaluated according to the Rancimat method EN 14112 for pure biodiesel and the modified Rancimat method EN 15751 for the biodiesel blends with petro-diesel. In the modified Rancimat method, several parameters were changed, mainly because of the higher volatility of hydrocarbon fuels compared to methyl esters, which may lead to higher sample evaporation.
When the conductivity of this measuring solution is recorded continuously, an oxidation curve is obtained whose point of inflection is known as the IP. This provides the good characteristic value for the oxidation stability. The oxidation stability is measured at a temperature of 283 K

Straight Vegetable Oil:
Sequence of operations employed to produce SVOs is shown in Figure1. For Pongamia oil, after filtration, de-gumming operation is recommended to remove seed particles, phosphatides, carbohydrates, proteins and metals. Of the various technologies used for oil extraction (Table 3), mechanical oil extraction is the most common for extracting non-edible oils. The typical recovery efficiency of good expellers is 80-85% of oil content in the seed.

Table 3: Oil extraction technologies:

EXTRACTION TECHNOLOGY	CAPACITY
Screw or hydraulic press	5 -30 kg/batch
Expellers	50 -3000 kg/h
Solvent extraction	200-4000 tonnes/day

PROCESSES

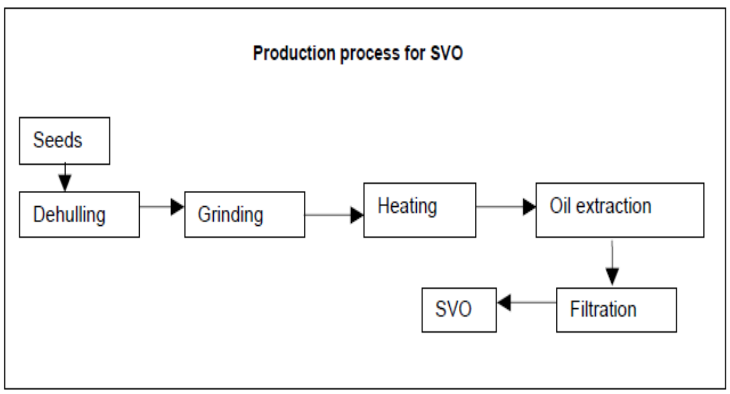
Oil extraction technologies:
The two main processes of extracting oil from seed feedstock are mechanical press extraction and solvent extraction.

The solvent process extracts more of the oil contained in the oilseed feedstock but requires expensive equipment. Oil extraction by a mechanical press is the standard technology for small-scale applications. During mechanical press extraction, the oilseed is crushed and pressed in a screw press. The oilseed is heated either before or during the pressing. After most of the oil is removed, the remaining seed meal can be used as animal feed.

Hand presses are not appropriate for extraction of larger seed quantities. Screw presses driven by combustion engines are standard and widely available in the market. The efficiency and durability of the different available presses will probably be a topic for future research and development.

After the crushing and pressing, the oil should be filtered. A schematic flow of production of SVO is as shown in the figure 2.

Figure 2: Production process for SVO



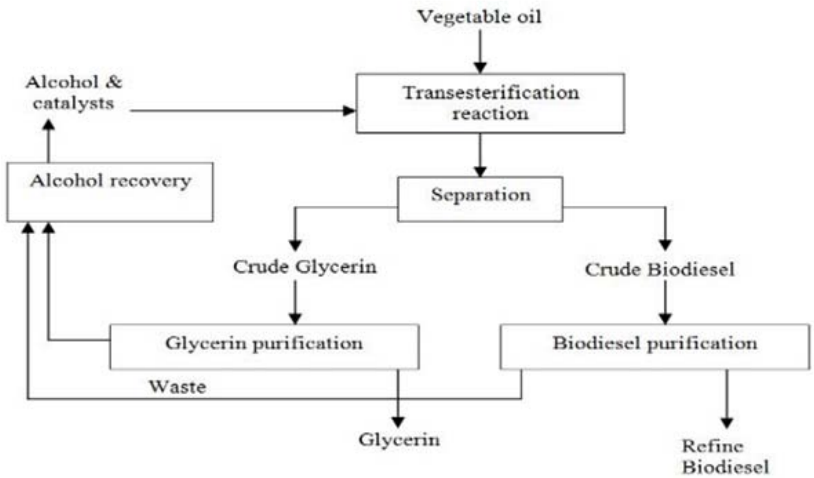
a) Oil extraction:

During oil expelling, about 65-70% of the seed kernel is obtained as de-oiled cake. De-oiled cake from non-edible oil seeds is a good organic manure (refer Table 1). During the interactions with the oil-expelling units, it was learnt that the de-oiled cake from the mills is used as manure in rubber plantations.

b) Trans-esterification by methanol:

Glycerol is a by-product of trans-esterification process. This glycerol is used in cosmetics and soap manufacturing. The vegetable oil was chemically reacted with an alcohol(methanol) in presence of a catalyst to produce methyl esters. The methyl ester was then blended with mineral diesel in various concentrations for preparing biodiesel blends to be used in CI engine for conducting various engine tests. The process is as shown in the figure 3.

Figure 3: Transesterification process of oil seeds



The preliminary evaluation of biodiesel fuel blends focused solely on the combustion performance of a single 20 percent biodiesel blend in home heating equipment. Follow-up activities that are recommended include the following.

1. Evaluate combustion performance and emissions reductions benefits for a range of biodiesel blends and for varying fuel sulfur contents of the fuel into which the biodiesel product is blended. This is needed to optimize performance improvement for various combinations of biodiesel and petroleum blends which may result from government actions which may include subsidies or tax credits.
2. Test the cold-flow characteristics of biodiesel fuels and biodiesel fuel blends for a range of temperatures to simulate the effect of storage in aboveground outdoor fuel storage tanks. Specifically, evaluate pour point, cloud point, and filter plug points to assure compatibility in colder climates.
3. Test the interactive effect of biodiesel when combined with ultra-low sulfur (0.0015 percent or 15 ppm sulfur) fuel oil. Some combustion problems have been observed with the ultra-low oil including damage to flame tubes caused by unexpected chemical reactions. The impact of using biodiesel blends with the ultra-low fuel oil needs to be evaluated.
4. Long-term tests of reductions in boiler and furnace fouling rates with the biodiesel and low sulfur biodiesel fuel blends needs to be evaluated similar to the work completed at Brookhaven National Laboratory for the low sulfur (0.05%) fuel oil. This is important to fully evaluate potential service cost savings by extending the intervals between vacuum cleanings.
5. Field Studies of biodiesel blends are needed to further test and demonstrate the advantages of these fuels in actual home heating installations. Field testing is now on-going in New York State and Rhode Island. Work similar to the low sulfur heating oil demonstration of by the New York State Energy Research and Development Authority (NYSERDA) is recommended. This is important for quantifying the benefits and identifying any problems that may arise related to using the biodiesel blends.

The methyl-ester blends on Pongamia as a potential Bio-diesel are to be tested on generators. The performance of these were compared to diesel. Theoretical data analysis has the following results,