Assessment of *Jatropha curcas* for bio-energy production

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The 2nd JatroMed International Workshop, Algeria 8th May 2014

EuropeAid/128320/C/ACT/Multi
Reference Number: DCI/ENV/2009/13/12

Biofuels: How they stand in different countries?

- **USA**: To Reduce dependence on foreign oil
- **Europe**: To control greenhouse gas emissions and reduce oil import
- **India**: Biodiesel becoming popular- assists in employment creation and in gaining energy independence.

What is Jatropha?

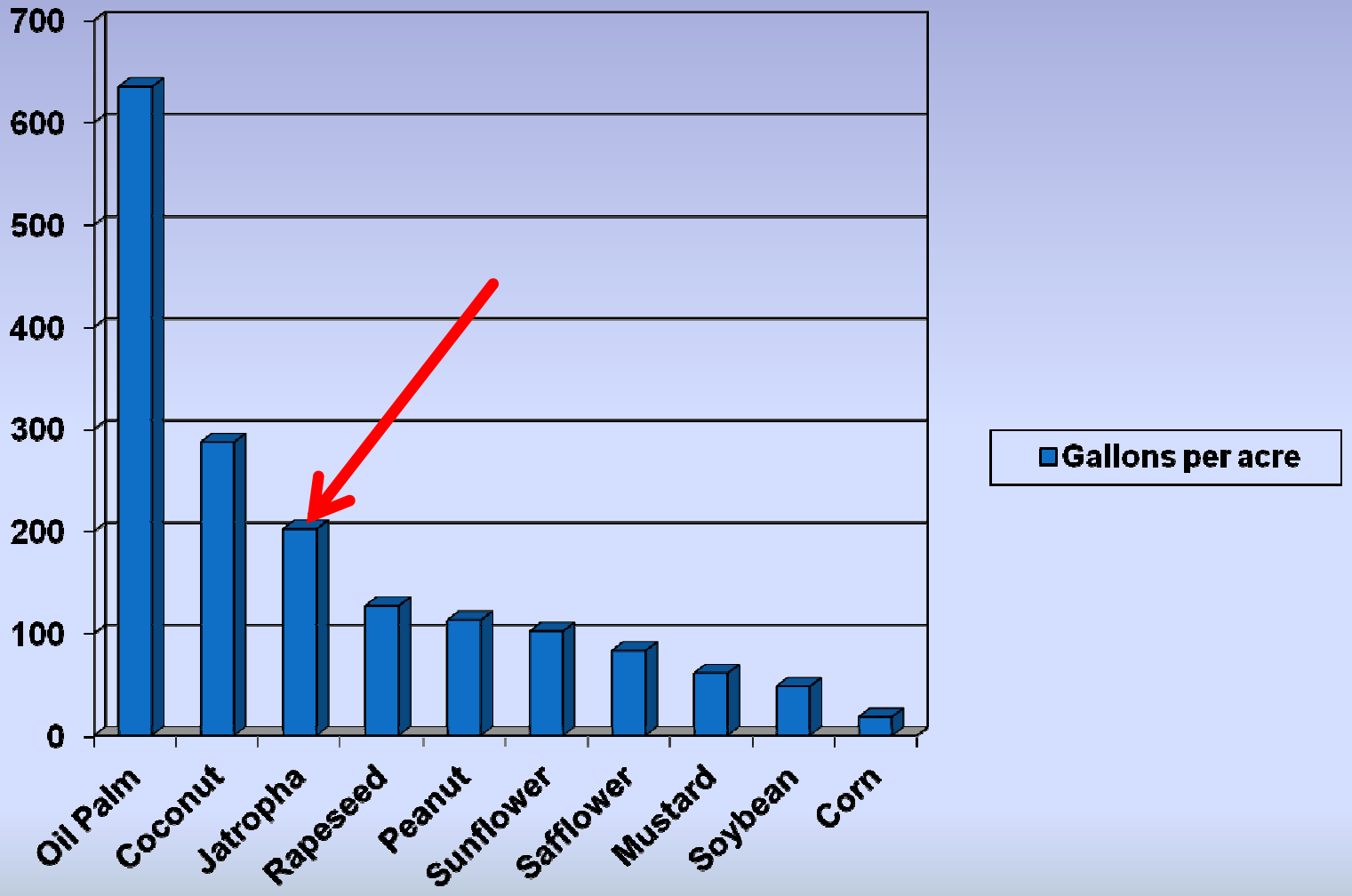
- Shrub or small tree

  3-5 meters in height
- Draught resistant, perennial
- Starts producing after 2-3 years of plantation (produces for 30-35 years)
- Seeds contain 35-40% oil (approx. 30% is extractable)
- Oil: non-edible
- Seed production: 0.8 to 12.0 tons per hectare per annum (depending on soil and irrigation)

Why Focus on Jatropha?

- Jatropha is a top candidate for future large-scale biodiesel production
- Could yield approx. 5 tones of biodiesel per hectare
- Jatropha oil can be processed to produce a high-quality biodiesel
- Jatropha contains 35-40% of oil in the seeds
- Jatropha's oil contains 21% saturated fatty acids and 79% unsaturated fatty acids.
- Jatropha's seed cake is rich in Nitrogen, Phosphorous and Potassium and can be used as an organic fertilizer

Oil producing crops



There are two ways to extract oil from seeds

Mechanical extraction	90-95%
Solvent extraction	Up to 99%

Mechanical Extraction

Factors affecting Oil recovery from seeds

Throughput: The amount of material that is processed per unit of time (kg/hr). The higher throughput the lower oil recovery per kg of seeds.

Oil point pressure: The pressure at which the oil starts to flow from the seeds. At high pressure more oil is recovered from the seeds (50-150 bar)

Nozzle size: small nozzle size leads to high pressure and therefore high oil yield.

Moisture content of the seeds: 2-6% as optimum.

Hull content of the seeds: The hull appears vital to pressure build-up inside the press.

Removal of the hull would require less energy for pressing and result in zero presence of hull fibers in the crude oil.

Press technologies

Ram press **1-10 kg seed/hr**

Expellers **>10 kg seed/hr**

Ram press

- The capacity is limited to 2-3 kg/hr.
- Oil recovery rate of 70-80%
- Oil density of 0.918 kg/liter this means < 1liter/hr

Expellers

Cylinder-hole type

- Oil outlet is in the form of holes at the end of the cylindrical press cage
- small capacities up to 200 kg seeds/h

Strainer

- The strainer is actually a cylindrical cage built-up of separate horizontal bars or vertical rings arranged at a small interspacing
- Capacity range from 15 kg to 10 tones of seed/hr.

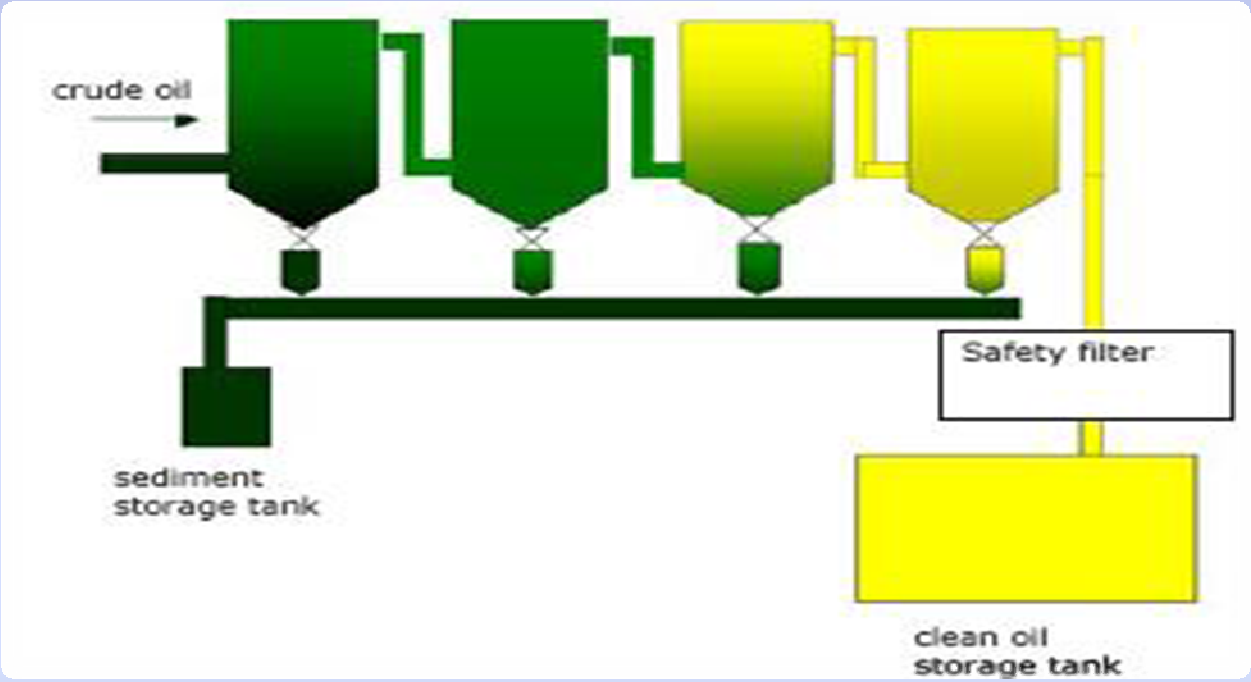
Oil purification

- Based on Particle Size
  - Filtration
- Based on specific gravity
  - Sedimentation and Centrifugation

Sedimentation

is the simplest and cheapest way of cleaning, it is only recommended for small processes.

production rate < 50 liters/hr



Flow diagram of a sedimentation system

Filtration

The basic principle of filtration is blocking any particles bigger than the membrane pore size

Filtering is easier at lower viscosity of the oil

A nominal capacity of 85% at optimal Temperature between 40-55°C

Filtration include several methods (Gravity filters, Band filter, Filter press, Candle filters)

Gravity filters

Bags with different pore sizes, ranging from 1 to 200 µm

It is recommended to leave the oil to settle for 4-7 days before filtering

Takes between 5 minutes to 1 hour per 20 liters

Band filter

Removes sediment without interrupting the filtration process

The moving cloth (5 µm pore size) on the band filter helps in reducing clogging problems and enables easier cleaning

The capacity of this model is 20-60 liters/hour.

Filter press

Widely applied in the food industry

The oil is forced through the cloth and the filter cake remains in the cavities

The filter press is capable of removing particles <0.01µm

Candle filters

Polishing filters as they perform the final touch in the cleaning process

Particle >1µm are removed at a nominal efficiency of 92%

Need to be replaced every 6-8 weeks

Throughput of 200 liter/hr

Centrifugation

Disc centrifuge

Centrifugation system with a bag filter

Oil quality

Different applications of jatropha oil require different levels of quality

Soap-making, Lamps and stoves: proper filtering of the oil is sufficient for these applications

Diesel engines: oil should comply with DIN 51605 norm to minimize the chance of engine damage.

FFA and phosphorus most problematic and require chemical cleaning (degumming and neutralizing)

Several things have to be kept in mind:

Contamination:

describes how much foreign material (particles) may be present in the oil

Acid value:

is a measurement of the content of free fatty acids in the oil

Oxidation stability:

The oil should not degrade in a hot environment

Ash content:

Reflects the amount of material that remains unburned after combustion of the oil in the engine

Water content:

water causes the fuel filter material to swell and hence block.
water causes oxidation inside the injection equipment

Oil degumming

Oil

Heating 70-80° C

↓

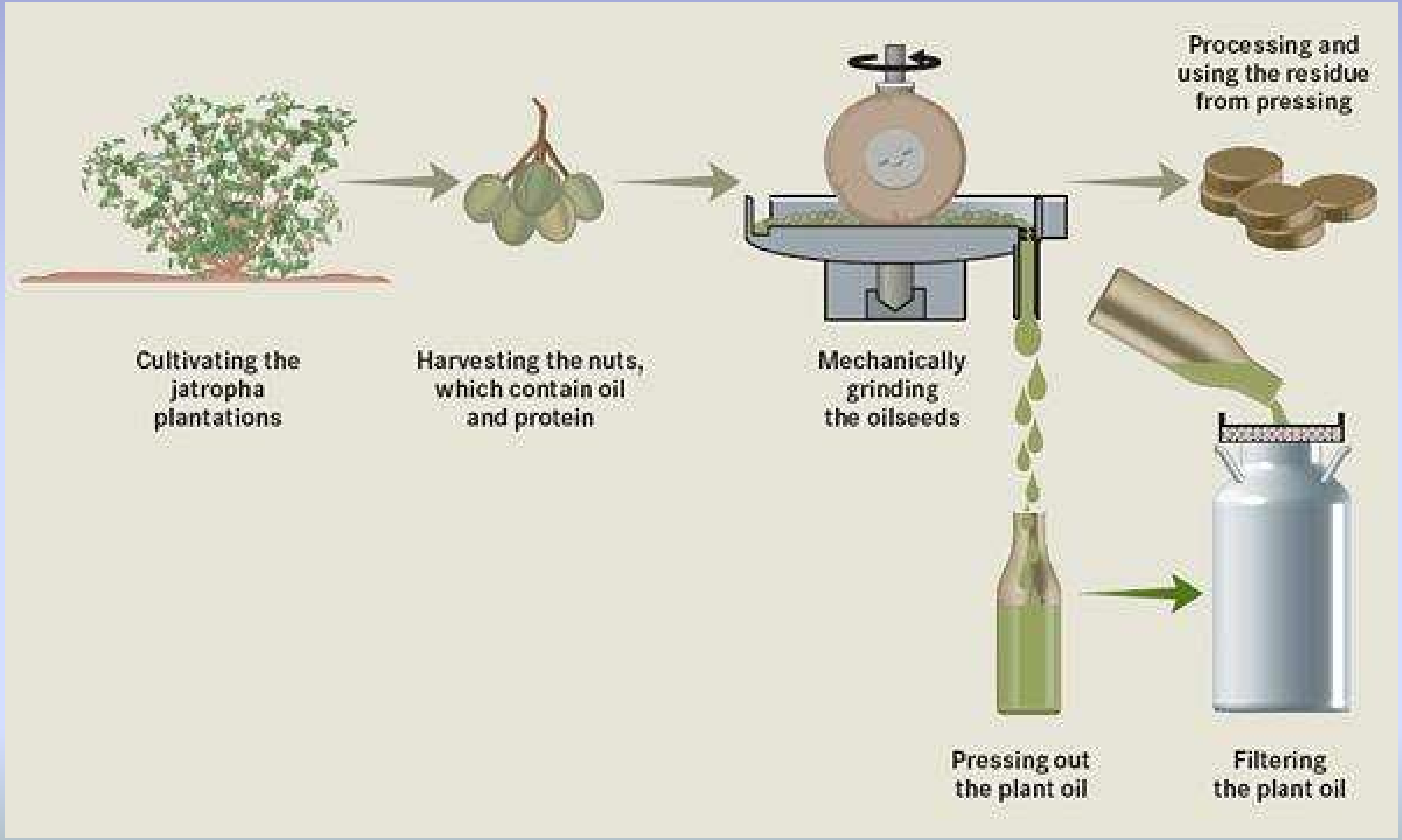
Add water

↓

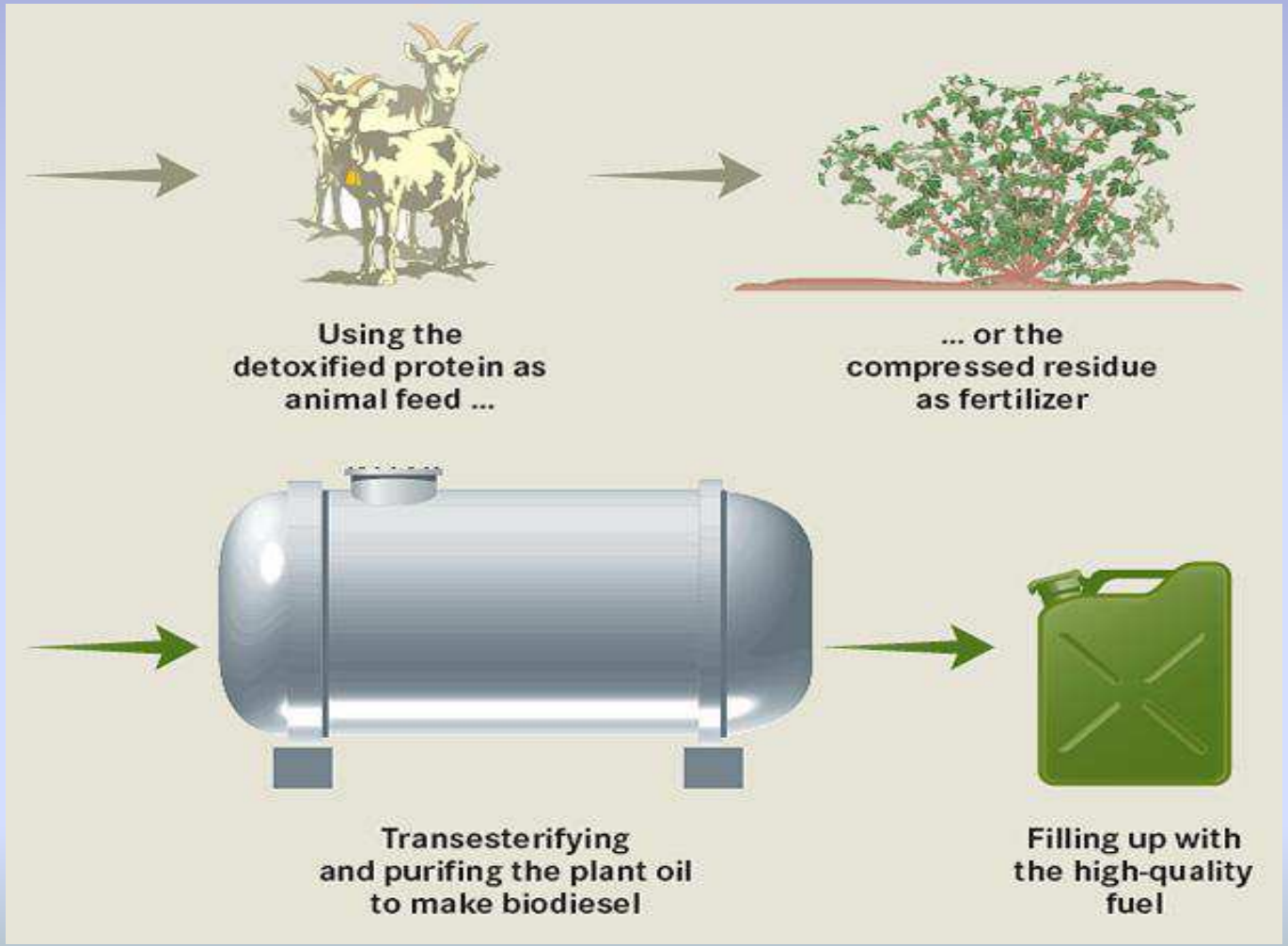
Remove gums (contains phosphatides)

Phosphorus content should be below 12mg/kg

Processing of Biodiesel using Jatropha seeds



Possible utilization of Jatropha Plant



How Jatropha-biodiesel and Petro-diesel compare?

Fuel properties of jatropha oil, jatropha biodiesel and diesel

Property	Unit	Jatropha oil	Jatropha biodiesel	Diesel	Biodiesel standards	
					ASTM D 6751-02	DIN EN 14214
Density at 15 °C	kg m^{-3}	940	880	850	—	860–900
Viscosity at 15 °C	$mm^2 s^{-1}$	24.5	4.80	2.60	1.9–6.0	3.5–5.0
Flash point	°C	225	135	68	>130	>120
Pour point	°C	4	2	−20	—	—
Water content	%	1.4	0.025	0.02	<0.03	<0.05
Ash content	%	0.8	0.012	0.01	<0.02	<0.02
Carbon residue	%	1.0	0.20	0.17	—	<0.30
Acid value	mg KOH g^{-1}	28.0	0.40	—	<0.80	<0.50
Calorific value	MJ kg^{-1}	38.65	39.23	42	—	—

- **Low emissions: Reduction in unburned hydrocarbons, CO, SO_2 and particulate matter. Slight increase in NOX**
- **Energy content: 94% (~70% for ethanol)**

Source: Biomass and Bioenergy 31 (2007) 569–575

Tasks achieved in MuCSAT

Determination of oil content in Jatropha seeds at different maturity stages

Maturity stage	Oil content (%)
Green fruits 	3-5
Yellow fruits 	27-31
Yellow-Brown fruits 	34-40
Brown-Brown fruits 	35-41

This result is useful for mechanical harvesting task

Tasks achieved in MuCSAT

Designing a suitable prototype of the manual pressing machine

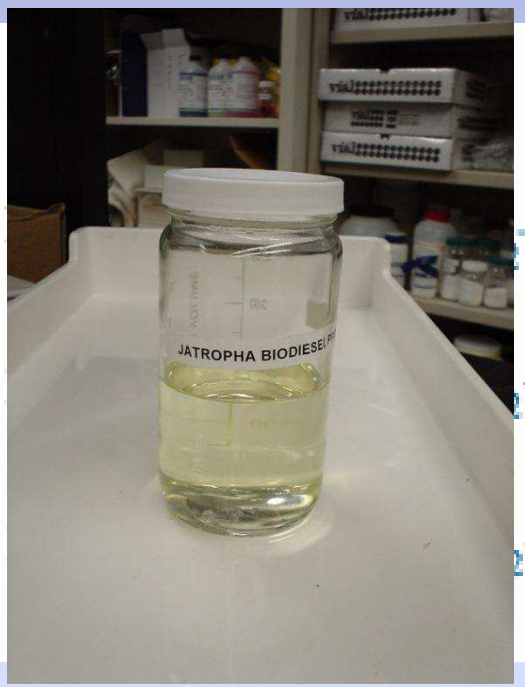
Analysis of Oil extracted from Jatropha seeds in MuCSAT demo field

Mineral Composition of Jatropha curcas seed meal

Mineral (g/kg)	JCL-Max	Michoacán **Non toxic**	GHS-B	Jat106
Ca	3.98	4.21	4.23	4.61
Mg	4.15	4.67	3.97	4.26
K	5.23	5.23	5.42	5.33
Na	0.04	0.05	0.06	0.06

Trans-esterification

$3CH_3OH \longrightarrow$



$-OH$

$-OH$

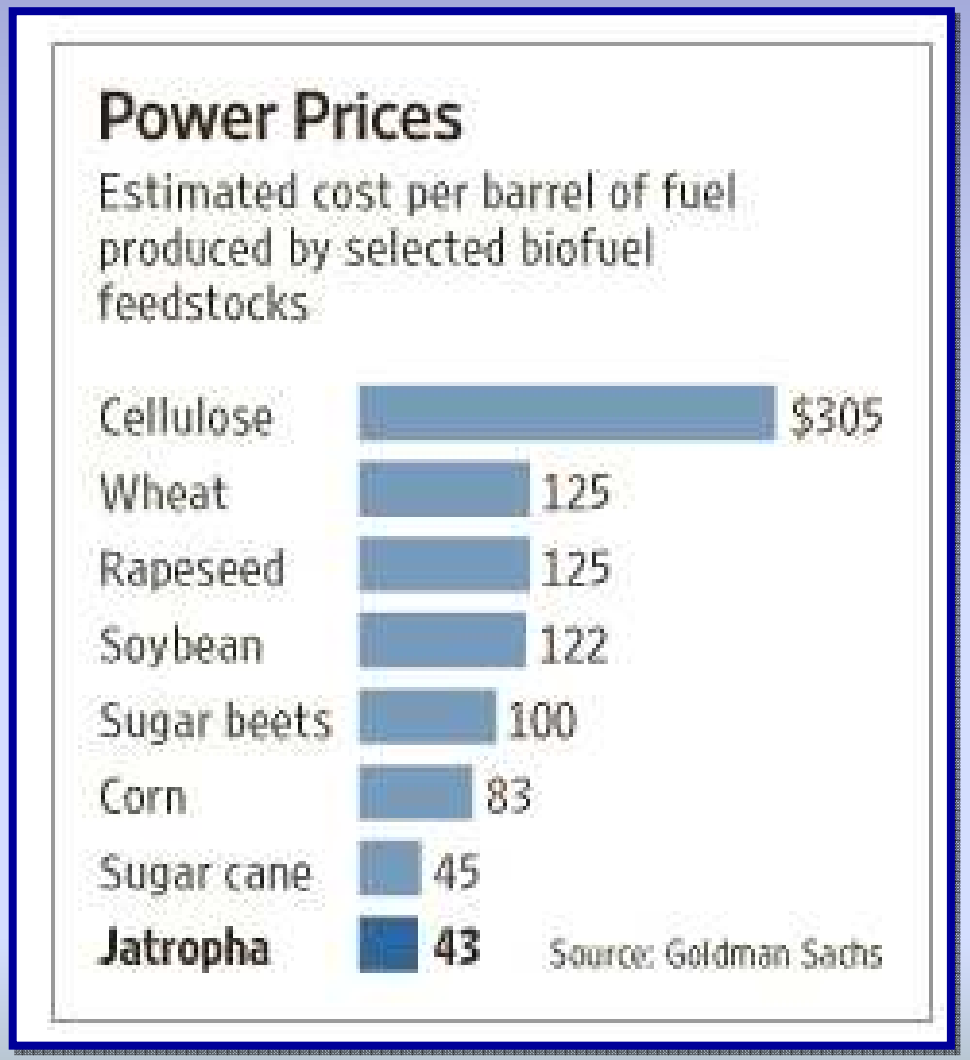
$-OH$

Jatropha oil **Jatropha Biodiesel**

Cost of production

One of the greatest concerns when it comes to biofuels is the cost per barrel of fuel. Recent studies have shown that ethanol, for instance, has huge costs in the refining stages which ultimately render it inefficient without large government subsidies.

A central question for this situation is whether the cost to produce Jatropha makes it inefficient without subsidy or whether the fuel source could exist in the free market without government support.



Thank you

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