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### **Compatibility of Metals in Jatropha Oil**

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### **ABSTRACT**

Environmental factors and depleting reserves of crude oil are becoming the main driving forces in the quest for cleaner and alternate fuels. A large variety of biofuels are available but very little is known about the corrosion mechanism related to them. The introduction of biofuels is associated with difficulties in transport and storage as well as their use. Construction materials for tankers, storage tanks and pipes normally consist of metals, which are prone to corrosion. Hence the present study is on the corrosion aspect of jatropha oil on various metals like carbon steel, aluminum, copper and brass.

Key words: biofuels, jatropha oil, corrosion

### **INTRODUCTION**

The earth's limited reserves of fossil fuel have been a matter of global concern as these are under threat of depletion due to exploitation. Because of the increase in petroleum prices especially after the petrol crisis in 1973 and the gulf war in 1991, geographically reduced availability of petroleum and more stringent regulations on exhaust emissions, researchers have turned on to alternative fuels. Moreover, deteriorating environmental conditions have become an issue of ever increasing worldwide public concern. Currently, the combustion of fossil fuels is the dominant global source of CO<sub>2</sub> emissions. There are efforts around the globe to protect the environment from further deterioration. These factors have led to an innovative global search for renewable sources of energy. Consequently, some alternatives, particularly renewable options have been discovered and explored.<sup>1,2</sup>

Although the majority of the renewable technologies are more eco-friendly than conventional energy options, their adoption is very slow because of various factors including economic constraints, lack of supply, and technical know-how of users. Further the use of these technologies is still limited primarily to stationary operations, mainly due to technological limitations and poor economics.<sup>3</sup> Biofuels are generally considered as offering many priorities including renewability, sustainability, reduction of greenhouse gas emissions, regional development, rural manufacturing jobs and biodegradability.

## Sources of biofuel raw materials

A variety of biolipids can be used to produce biofuel. These are (a) virgin vegetable oil feed stock - rape seed and soybean oils are most commonly used, though other crops such as mustard, palm oil, sunflower, hemp and even algae show promise (b) waste vegetable oil (c) non edible oils - jatropha, neem oil, castor oil and tall oil.<sup>4</sup>

Soybean is used in United States and rapeseed oil is used in many European countries for biodiesel production, whereas coconut oil and palm oil are used in Malaysia and Indonesia for biodiesel production.<sup>5-7</sup> In India and southeast Asia, the Jatropha tree (*Jatropha curcus*),<sup>8</sup> Karanja (*Pongamia pinnata*)<sup>9-10</sup> and Mahua (*M.indica*)<sup>5</sup> are used as significant fuel sources.

**Table 1**  
**Typical biodiesel yields<sup>11-12</sup>**

Plant species	liters/hectare	Gallons/hectare
Castor bean	2000	528
Coconut	1750	462
Cotton	160	42
Groundnuts	800	211
Jatropha	3500	925
Linseed	700	185
Mustard Seed	570	151
Palm oil	3800	1004
Rapeseed	800	211
Safflower	780	206
Sesame	1270	335
Soybean	320	85
Sunflowers	850	225
Tung oil	1700	449
Pongamia	2300	608

## Jatropha as a feedstock for biodiesel

*Jatropha curcus* (Linnaeus) is a multipurpose bush/small tree belonging to the family of Euphorbiaceae. The name *Jatropha curcus* is derived from a Greek word "Jatros" meaning "Doctor" "and trophe" meaning 'nutrition' because of the potential of this plant for medicinal purposes.<sup>13</sup> It is believed to be a native of South America; but today it is found in almost all the tropical and sub-tropics in Africa/Asia. In India, *Jatropha curcus* known as ratanjyote or seemaikattamanakku is found almost in all the states and is generally grown as a live fence for protection of agricultural fields from damage by livestock as it is not eaten by cattle. Jatropha oil can not be used for nutritional purposes without detoxification; hence its use as energy or fuel source is attractive.

## Plant profile<sup>14</sup>

- The oil yielding plant *Jatropha curcas* is an evergreen, multipurpose and drought resistant soft wooded shrub, 3-4 meters high, with long petioled leaves and yellowish green flowers at the ends of the branches.
- It grows rapidly, is hardy to dry weather conditions and can withstand a light frost.
- Plant that can grow almost anywhere - even on gravelly, sandy and saline soils.
- Its water requirement is extremely low and it can stand long periods of drought by shedding most of its leaves to reduce transpiration loss.
- Its seed yield ranges from 7.5 to 12 tons per hectare per year, after five years of growth.

- The oil yield obtained from a whole seed is 30-35 % by weight basis.
- This vegetable oil can be used as it is crushed – i.e., unrefined in diesel engines as a substitute for commercial diesel.
- The plant serves for ornamental purpose, medicinal purposes, as a fence, prevent soil erosion, oil crop, raw material for industrial use, for enrichment of soil, potential feed stock (to feed tusser silk worm), as insecticide/pesticide etc. Being rich in nitrogen, the seed cake is an excellent source of plant nutrients.

These characteristics along with its versatility make it vital for developing countries



**Figure 1 : *Jatropha curcas***

### **Corrosion of biofuels**

Biofuel induced corrosion in storage (both in tanks and automobiles) and transportation (pipelines) occurs by an electrochemical mechanism – wet corrosion which is mostly due to the presence of entrained water. Biodiesel is not corrosive but as the fuel tank is emptied, air enters through the vent pipes to displace the fuel in the tank. Free water may enter from carry-over from the fuel distribution system or leakage through the fill cap or spill containment wall or pipelines. Entry of moist air and accumulation of water in the tank creates favorable conditions for corrosion occurrence.<sup>15</sup> As of today, the knowledge of the wet corrosivity of biodiesel appears to be incomplete since the corrosivity of biodiesel is usually reported based on whether it meets a standard copper strip measurement (ASTM D 130, ASTM D849 or ASTM D1838) which simply measures the color change (metallic to black).<sup>16-17</sup> However, this does not reveal the corrosivity of biodiesels to other materials and corrosivity data of various metals in biodiesel should be established. The objective of this paper is to investigate the corrosion behaviour of *Jatropha* oil on metals including carbon steel, aluminum, copper and brass. The data thus obtained is compared with biodiesel obtained from *Pongamia pinnata*.<sup>18</sup>

## **METHODS AND MATERIALS**

### **Selection and Preparation of Metal Samples**

Biodiesel and biodiesel blends form sediments when in contact with brass, copper, tin, bronze, lead and zinc in storage tanks.<sup>19</sup> Hence carbon steel, aluminum, copper and brass have been selected.

For mass loss measurements the sheets of commercially available metals were machined into coupons of an area of 33.9 cm<sup>2</sup> as per ASTM G184. Table 2 gives the composition, density and equivalent weight of the materials.

**Table 2**  
**Composition, Density and Equivalent weight of Materials**

Element	% Composition			
	Carbon Steel	Aluminum	Copper	Brass
Zn	-	0.010	3.00	36.80
Al	0.023	99.48	<.010	<.010
Sn	<.005	-	0.029	0.027
Pb	<.010	0.002	<.001	<.001
Si	0.018	0.082	0.009	0.002
Ni	0.014	<.005	0.012	<.010
Fe	99.559	0.22	0.068	0.056
Mn	0.27	0.008	<.002	<.002
P	0.009	-	0.004	<.001
S	0.005	-	0.045	<.005
Bi	-	<.010	<.001	<.001
Sb	-	-	<.005	<.005
As	-	-	0.002	<.001
Co	<.005	<.0005	<.010	<.010
Ag	-	-	0.002	0.001
Mg	-	0.009	0.001	<.001
Cu	0.030	0.110	96.828	63.114
Ti	<.002	0.019	-	-
Cr	0.019	0.009	-	-
V	<.005	0.011	-	-
Sr	-	0.008	-	-
C	0.049	-	-	-
Mo	0.002	-	-	-
Nb	<.001	-	-	-
B	<.0005	-	-	-
Zr	<.005	-	-	-
Ca	0.002	-	-	-
Density(g/cm <sup>3</sup> )	7.87	2.73	8.96	8.75
Equivalent weight	27.92	9.09	31.77	31.91

### Selection of Oil and Characterization

*Jatropha curcas* oil was procured from a commercial source in India and used as such for the present study. The characterization of the oil was performed as per ASTM standards and is given in Table 3.

**Table 3**  
**Fuel Profile of *Jatropha curcus* Oil**

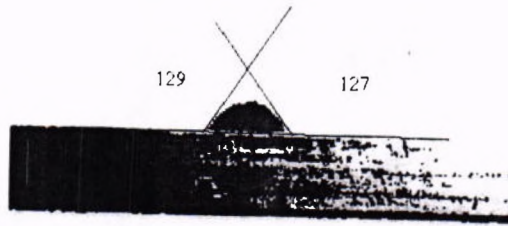
Parameters	Value	Unit
Flash Point	240/110	°C
Carbon residue	0.64	% mass
Kinematic Viscosity (at 40°C)	5.73	mm <sup>2</sup> /sec
Sulfur %	0.13	% vol
Cetane	51.0	---
Carbon Residue	0.64	% mass
Acid Number	1.2	mg
Free Glycerin	0.01	% mass
Total Glycerin	0.12	% mass
Phosphorus Content	0.00012	% mass
Distillation Temperature	295	°C
Calorific value	9470	Kcal/kg
Pour point	8	°C
Colour	4	
Viscosity (30°C)	52.6	cP
Specific gravity	0.881	kg/m <sup>3</sup>
Solidifying point	2	°C
Saponification value	188-198	
Iodine value	90.8-	
Refractive index (30°C)	1.47	
Palmitic acid	4.2	%
Stearic acid	6.9	%
Oleic acid	43.1	%
Linoleic acid	34.3	%
Other acids	1.4	%

Detailed experimental procedures are described in previous publication.<sup>18</sup> Briefly the metal samples were exposed for a period of 100 hours in 100% oil (O100), 99% oil and 1% of 3% NaCl (O99), and 100% of 3% NaCl (NaCl).

## RESULTS AND DISCUSSION

### Carbon Steel

The presence of water need not necessarily lead to corrosion, if the surface is covered with oil. An oil wet surface is not susceptible to corrosion where as a water wet surface is prone to corrosion. One of the methods to determine the wettability is by measuring the contact angle of the water-oil-solid surface interface. Criteria for establishing wettability based on contact angle measurements are also available.<sup>20-23</sup> The contact-angle measured through water phase for carbon steel is presented in Fig. 2. An angle of 128° was observed indicating that the oil preferably wets the carbon steel.



**Figure 2: Wettability on Carbon Steel by Contact Angle Method**

Table 4 provides the variation of the conductivity of Jatropha oil before and after exposure to carbon steel. The increased conductivities of the solution after the exposure of the carbon steel may either be due to the increased ionic content of the solution due to carbon steel dissolution or due to the degradation of oil in the presence of the carbon steel.

**Table 4  
Conductivity of Jatropha Oil exposed to Carbon steel**

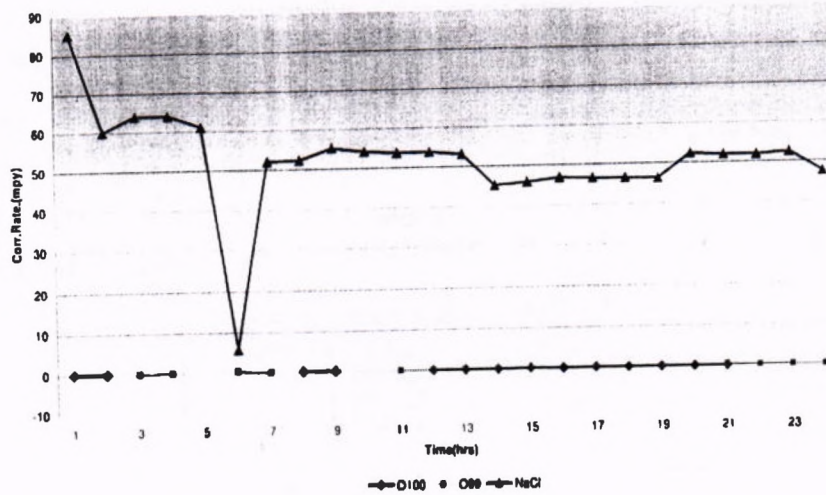
Medium	Conductance	
	Before immersion ( $\mu\Omega^{-1}$ )	After immersion ( $\mu\Omega^{-1}$ )
O100	0.12	0.38
O99	0.32	0.45
NaCl	3.58	14.57

The corrosion rate of carbon steel in Jatropha oil is presented in Table 5. In O100, the corrosion rate was low. Addition of 1% NaCl to Jatropha oil increased the corrosion rate to a very small extent. As expected, the rate of corrosion was higher in 3% NaCl.

**Table 5  
Corrosion rate of Carbon Steel (as determined by Mass Loss Method)**

Medium	Corrosion rate (mpy)
O100	0.762 + 0.967
O99	1.339 + 0.559
NaCl	4.289 + 1.526

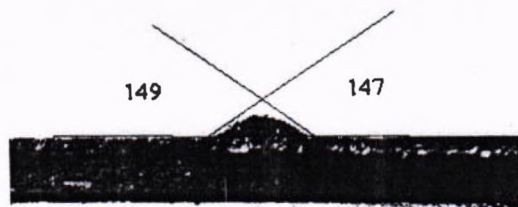
In general a higher corrosion rate of carbon steel was observed in the LPR method (Fig.3) than in mass loss method. LPR method measures instantaneous corrosion rate where as the mass loss measures time-averaged corrosion rates. Due to low conductivity of Jatropha oil, the corrosion rate determined by LPR may not be accurate. The results are nevertheless presented to understand the trend in the corrosion rate.



**Figure 3: Corrosion rate of Carbon steel in O100, O99 and NaCl as a function of time**

**Aluminum**

The contact angle determined for aluminum is as given in the Fig 4. An angle of 148° shows that the surface is oil wet.



**Figure 4: Wettability on Aluminum**

Conductivity measurements for aluminum are as shown in the Table 6. An increase in the conductance values indicates that metal dissolution has occurred or bio oil disintegrated in contact with aluminum.

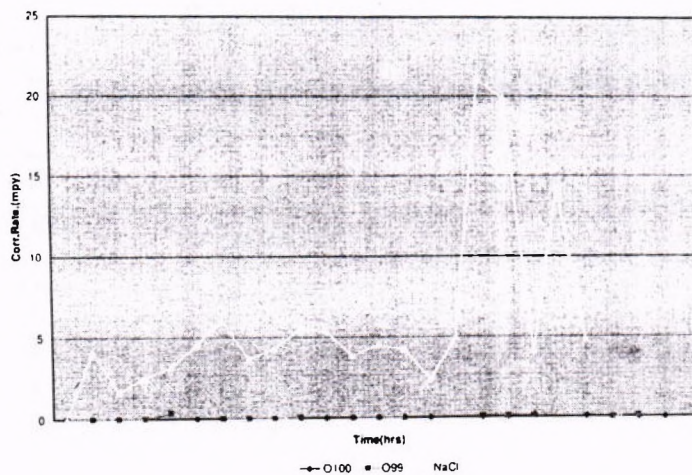
**Table 6  
Conductivity of Jatropha Oil exposed to Aluminum**

Medium	Conductance, ( $\mu\Omega^{-1}$ )	
	Before immersion	After immersion
O100	0.084	0.24
O99	0.080	0.20
NaCl	16.4	48.47

The corrosion rates of Al as determined by mass loss and LPR methods are presented in the Table 7 and Fig 5. The corrosion rates of Al in O100, O99 and 3% NaCl is much less than carbon steel. The addition of 1% solution NaCl does not alter the behaviour of oil. A lower corrosion rate was observed in NaCl solution, when compared to O100. This may be due to the lower corrosion rate and cleaning procedure.

**Table 7**  
**Corrosion rate of Aluminum (as determined by Mass Loss Method)**

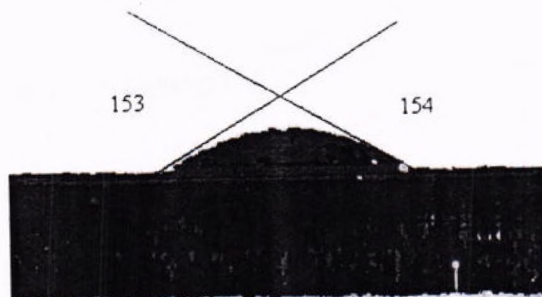
Medium	Corrosion rate (mpy)
O100	0.887 $\pm$ 0.085
O99	0.971 $\pm$ 0.144
NaCl	0.442 $\pm$ 0.229



**Figure 5: Corrosion rate of Aluminum in O100, O99 and NaCl as a function of time**

### Copper

The wettability data for copper by contact angle method is depicted in the Fig 6. The surface is found to be oil wet as the contact angle is 154°.



**Figure 6: Wettability on Copper**

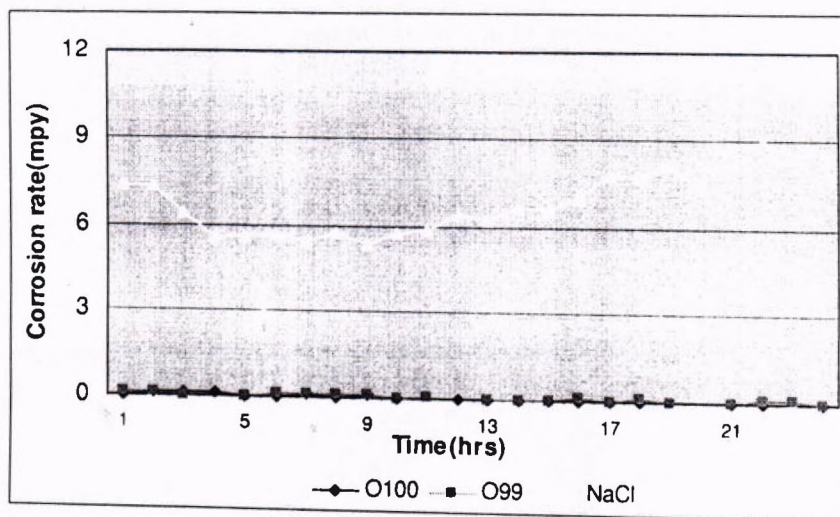
When compared to carbon steel and aluminum, the corrosion rate of copper in biodiesel is very less (Table 8). There is not much variation in the conductivities of the solutions before and after the immersion of the metal indicating the direct correlation between corrosivity and conductance of the oil. A higher corrosion rate is observed for the copper in NaCl solution as evident from the Fig 7. Though copper container may not be used for the storage of biodiesel, this data may be of significance in the usage of certain components in the infrastructure that may contain copper. The corrosion rates obtained from mass loss and LPR method is presented in the Table 9 and Fig 7.

**Table 8**  
**Conductivity of Jatropha Oil exposed to Copper**

Medium	Conductivity	
	Before immersion ( $\mu\Omega^{-1}$ )	After Immersion ( $\mu\Omega^{-1}$ )
O100	0.068	0.063
O99	0.068	0.062
NaCl	16.97	13.6

**Table 9**  
**Corrosion rate of Copper (as determined by Mass Loss Method)**

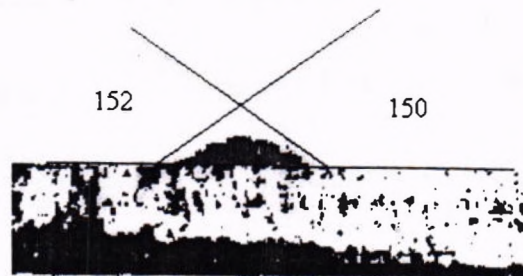
Medium	Corrosion rate (mpy)
O100	0.243 $\pm$ 0.329
O99	0.085 $\pm$ 0.441
NaCl	1.797 $\pm$ 0.769



**Figure 7: Corrosion rate of Copper in O100, O99 and NaCl as a function of time**

## Brass

A trend similar to that of copper was observed in the case of brass. The contact angle for brass in water phase was found to be  $151^\circ$  (Fig 8).



**Figure 8: Wettability on Brass**

The corrosion rates were found to be very low (Table 10 and Fig 9). The conductance measurements for brass in various solutions are presented in Table 10. The corrosivity data obtained by mass loss method is presented in Table 11.

**Table 10**  
**Conductivity of Jatropha Oil exposed to Brass**

Medium	Conductivity	
	Before immersion ( $\mu\Omega^{-1}$ )	After immersion ( $\mu\Omega^{-1}$ )
O100	0.061	0.068
O99	0.063	0.172
NaCl	15.7	25.47

**Table 11**  
**Corrosion rate of Brass (as determined by Mass Loss Method)**

Medium	Corrosion rate (mpy)
O100	0.237 $\pm$ 0.124
O99	0.266 $\pm$ 0.103
NaCl	0.734 $\pm$ 0.227

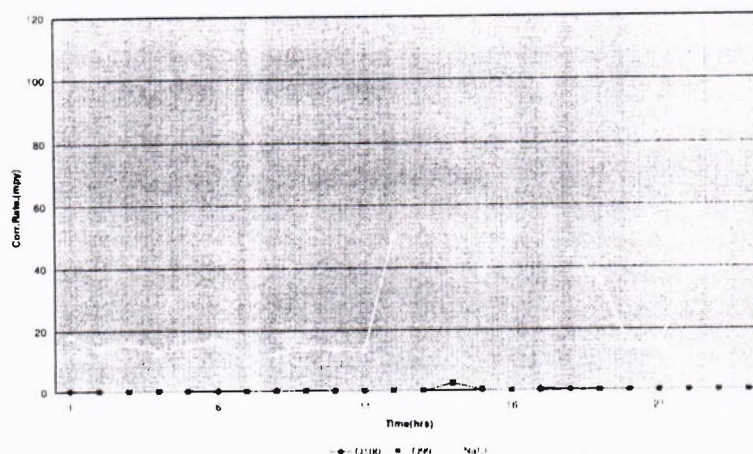


Figure 9 : Corrosion rate of brass in O100, O99 and NaCl as a function of time

### Comparison of Corrosivity of Jatropha oil and Pongamia biodiesel

A comparison of the corrosivity of the selected metals in Jatropha oil and *Pongamia pinnata* biodiesel is presented (Table 12). It is evident from Table 12 that the corrosion rates of all metals in Jatropha oil are lower than those in *Pongamia pinnata* biodiesel.

**Table 12**  
Comparison of corrosion rates of the selected metals in Jatropha oil and *Pongamia pinnata* biodiesel

Medium	Corrosion rate (mpy)							
	Carbon Steel		Aluminum*		Copper*		Brass*	
	Jatropha	Pongamia	Jatropha	Pongamia	Jatropha	Pongamia	Jatropha	Pongamia
O100	0.762	0.753	0.887	1.766	0.243	1.03	0.237	0.393
O99	1.339	3.85	0.971	2.91	0.085	0.76	0.266	0.323
NaCl	4.289	3.16	0.442	2.288	1.797	1.81	0.734	0.893

\*Composition of the aluminum, copper, and brass used in Jatropha Oil and *Pongamia pinnata* are slightly different. The composition on metals used in Jatropha oil is presented in Table 2 and that of metals used in *Pongamia pinnata* is presented elsewhere.<sup>16</sup>

### SUMMARY

- Wettability and corrosivity of Jatropha oil in contact with different metals - carbon steel, aluminum, copper and brass – have been investigated.
- All metal surfaces are wetted with Jatropha oil.
- All the metals studied exhibited lower corrosion rates.
- Under most conditions studied, the corrosivity of Jatropha oil is lower than that of biodiesel obtained from *Pongamia pinnata*.

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