CHAPTER- 4
CHARACTERISATION OF FUELS

In this chapter the fuel characteristics of the various non-edible oils used for the experimentation as fuels, viz. tobacco seed oil, pongamia oil (pongamia pinnata), mahua oil (madhuca indica) were evaluated and presented in Table 4.1.

4.1 DESCRIPTION AND SOURCE OF THE SELECTED NON-EDIBLE OILS

The plant details, process of extraction of oil from the seeds and their availability are given below.

4.1.1 Tobacco Seed Oil

Tobacco plant shown in Plate 4.1 with large oval leaves used for cigarette and beedi manufacturing grows to a height of 90-180cm. It has small pink flowers and green capsules containing numerous very small seeds as shown in Plate 4.2. The seeds can be stored in dry conditions at ordinary temperatures and are resistant to high humidity. The average mass of 1000 seeds is in the range of 0.08 to 0.09g. The oil content of the seed ranges from 36% to 41% by weight. The remaining part consists of proteins, crude fiber, carbohydrate and inorganic material. The tobacco plant is grown in 119 countries in the world. The leaf of the plant is a commercial product and used in the production of cigarettes in the tobacco processing industries. Tobacco seeds are a by product of tobacco leaves production. Since tobacco seed oil is non-edible oil, it is not used as a commercial product in food industry. But in India the oil is being used in the paint industry and for lighting lamps in the villages. Only a small amount of tobacco seeds are collected from fields for next year
plantation, most of them are left unused in the fields and go as waste. For present experimentation the tobacco seed oil was procured from Sri Lakshmi Venkateshwara Oil Mill, Santhanuthalapadu, Prakasham Distrit, Andhra Pradesh. According to the above mentioned manufacturer of the tobacco seed oil the left out seeds are collected from the fields, cleaned and dried. Later these seeds are cooked in the kettle with steam produced from a boiler and sent to the standard expeller for oil extraction and yield is about 20 – 30 %. The oil cake produced will be used as manure for the fields. The fatty acid composition of tobacco seed oil is dominated by linoleic, oleic, palmitic, stearic fatty acids plus much less proportions of linolenic, eicosanoic, palmitoleic, eicosenoic, heptadecanoic and behenic acids. The major fatty acid in the oil is linoleic (67.75%-69.49%), similar to Soya bean, sun flower and cotton seed oils (Table 4.2) [135,136,140 &141]. The fatty acid composition of the oil would allow prediction of important properties of tobacco seed oil. Plate 4.3 shows the sample of tobacco seed oil.
Plate 4.1 Tobacco plant with flowers

Plate 4.2 Tobacco seeds (Left) & capsules (Right)

Plate 4.3 Sample of Tobacco seed oil
4.1.2 Pongamia Oil (Pongamia Pinnata) or Karanja Oil

Pongamia plant (pongamia pinnata or karanja) shown in Plate 4.4, is widely distributed in both dry and moist Indian plains, especially along watercourses. Traditionally, pongamia oil has been used to burn household oil lamps and for curing skin diseases and mouth ulcers. Pongamia or Karanja plant is a medium sized, hardy, dense tree belongs to Leguminaceae family and grows under a wide range of agroclimatic conditions. The tree reaches its adult height within 4 to 5 years and yields 9 to 90 kgs of seed (Plate 4.5). The yield potential per hectare is 900 to 9000 Kg/Hectare. As per statics available pongamia oil has got a potential of 135000 million tonnes per annum and only 6% is being utilized. Karanja oil consists of Palmitic acid 44.5 - 71.3%, Linoleic acid 10.8 - 18.3%, Myristic 3.7 – 7.7%, Stearic acid 2.4 - 8.9%, Oleic acid 2.4 - 8.9 (Table 4.2). The total karanja tree has got excellent medicinal properties. The fruits can be used as medicine in ailments like piles, skin and eye. Leaves can be used for anthelmintic, digestive, and laxative, for inflammations, piles and wounds. Their juice is used for colds, coughs, diarrhea, dyspepsia, flatulence, gonorrhea, and leprosy. Root and bark (as alexipharmic, anthelmintic) used for abdominal enlargement, ascites, biliousness, diseases of the eye, skin, and vagina itch, splenomegaly, tumors, ulcers and wounds as cleaning gums, teeth and ulcers. Kernel is used for oil extraction and the oil can be used as fuel, soap production, insecticide and medicinal use. Fruit hull can be used as green manure, biogas production and combustibles. Oil cake can be used as fertilizer and combustibles. De oiled cake constitutes flavonoids, uranoflavonoids, furanoderivatives and are used in treating skin diseases and bio pesticide.
The meal cake can be used as fertilizer, pesticide and used for organic farming. Seed shells can be used as combustibles. The oil for experimentation is obtained from Power Guda, Adilabad district Andhra Pradesh. Plate 4.6 shows the sample of pongamia oil.

Plate 4.4 Pongamia plant with seed  Plate 4.5 Pongamia seeds (Right) & Cotyledons (Left)

Plate 4.6 Sample of Pongamia oil
4.1.3 Mahua Oil (Madhuca Indica)

Mahua plant shown in Plate 4.7 is a large deciduous tree growing widely under dry tropical and sub tropical climatic condition. It is an important tree for the rural people especially for tribals, greatly valued for its flowers and its seeds. The flowers of this tree have got religious value and are distributed as prasadam at Lord Sri Rama Temple at Bhadrachalam, located in Khammam district, Andhra Pradesh (Plate 4.9). The tribal People prepare alcohol (called vippa or ippa sara in Telugu) from this flower by their own brewing techniques and consume in their social and cultural gatherings. Its botanical name is Madhuca Indica and common English name is Mahua or Butter tree. In Indian languages it is called Mahua /Mauwa in Hindi, Hippe in Kannada, and Vippa or Ippa in Telugu. These trees are widely found in India, are grown in Uttar Pradesh, Madhya Pradesh, Gujarat, Andhra Pradesh and Karnataka and monsoon forest of Western Ghats. The trees in Andhra Pradesh are tall and reach a height of 20-25 feet. Flowering of mahua occurs in February-April. The fruits ripen in June-July and fall off soon after ripening (Plate 4.8). They start giving flowers and fruits between 10th and 15th year after plantations. An average sized tree yields about 50 -100 kg flower in a season that lasts around a month. One mahua tree has an annual average yield of 62.5 kg of flower and 59 kg of gully. Plate 4.10 shows the sample of Mahua oil. The major fatty acid contents are oleic (37.21), Stearic(25.96), Palmitic(19.93 ) and Linoleic(14.74 ) (Table 4.2).
Plate 4.7 Mahua plant with flower

Plate 4.8 Mahua plant with fruit

Plate 4.9 Mahua dried flower (Right) & cotyledons (Left)

Plate 4.10 Sample of Mahua oil.
4.2 USE OF VEGETABLE OIL BLENDS

Sometimes the farmers may possess small quantities of many species of vegetable oils. Usually they dispense these oils for the purpose of cart wheel greasing, lighting the lamps, tanning of animal skin etc. In such situations if we can suggest the methods to mix few oils or all these oils for increased quantity for better utilization in fuelling their diesel engines for emergency and short term applications. And also to explore the possibility of mixing a high calorific value fuel to a low calorific value oil to enrich its fuel properties so that all the oils can be consumed in a better way to gain economic benefits. Basically this idea was implemented with a view to benefit the farmers, an attempt has been made to mix two and three different vegetable oils to prepare a vegetable oil blend. Hereafter the term blend is used to denote the vegetable oil blend.

4.2.1 Preparation of blends of oils

The various blends of oils prepared for the proposed experimental work are 1) tobacco seed oil (50 %) and mahua oil (50 %) 2) tobacco seed oil (50 %) and pongamia oil (50 %) 3) pongamia oil (50 %) and mahua oil (50 %) 4) tobacco seed oil (33.3 %), pongamia oil 33.3 %) and mahua oil 33.3 %).

For making the blends, equal volumes of above selected combination of oils were taken and 1% Span-80, a lypophilic synthetic surfactant was added to avoid separation of oils. The amount of surfactant addition was optimized by trial and error method and found 1% surfactant addition was best by which all the blends were not separated even after one year of their storage. Small quantities of the mixtures in a small container were thoroughly mixed by using a household mixer blender for
10-15 minutes. Later these small quantities are transferred to a big container and the total mixture is mixed once again thoroughly for obtaining a homogeneous mixture. Small quantities of sediments were observed but no separation of oils. The blends containing mahua oil the sediments were slightly higher when compared to other blends. Plate 7.1 to 7.4 shows all the blends used in experimental work.

4.3 WHY GARLIC TREATMENT?

Natural resources like petroleum and other fuels are getting depleted very fast and the demand for them is growing up day by day. So there is an urgent need for searching alternate sources of fuels. Vegetable oils are the promising answer as they are renewable. Almost all the researchers working in the area of alternate fuel research, particularly with vegetable oils are concentrating on the conversion of straight vegetable oils into bio-diesel by the process called transesterification to overcome the usual problems encountered by using straight vegetable oils. Transesterification is the process of treating triglycerides such as vegetable oils with alcohol in the presence of a catalyst to produce glycerol and fatty acids ester.

However the transesterification procedure involves costly chemicals like ethyle / methyle alcohol and the suitable catalyst and also the controlled temperature and stirring equipment. It is difficult for a lay man to prepare bio-diesel from transesterification process. Especially Indian farmers are not well equipped and they do not have the time and patience to undertake this kind of complicated procedure. To simplify this kind of exhaustive procedure the three oils were treated with garlic to explore the possibility and to study the effect of garlic treatment which can make the
oil suitable for the use in engines directly. From the ancient days garlic and its extracts are being widely used for reducing LDL cholesterol, atherosclerotic buildup (plaque) and blood clots within the arterial system of human beings.

The transesterification procedure involves costly chemicals like ethyle / methyle alcohol and a suitable catalyst and also special glass ware, temperature controllers and stirring equipment. It is difficult for a lay man to prepare bio-diesel from transesterification process. These facts have led to the idea that transesterification process of vegetable oils which leads to harmful effects of softening of natural rubber components used in fuel supply lines and if the ethyle/methyle alcohols are available within the reach of agriculturists, they may get tempted and mistake them for human consumption assuming it to be the real alcohol which may lead to health hazards of loosing eye sight, lever and kidney damage leading to the death. If the transesterification process can be replaced by garlic treatment to achieve the same effect of that of transesterification we can save time, money and the process becomes easy. As there is a striking analogy of lowering of LDL cholesterol in the blood by allicin and its breakdown products and the lowering of density and viscosity of vegetable oils by garlic treatment, with an assumption that same molecular mechanism is involved in both the system the present work has been taken up.
4.3.1 Preparation of Garlic Treated Oil

35 grams of peeled, chopped and crushed garlic cloves are mixed with one liter of the three selected vegetable oils in three separate bottles with air tight caps were kept in a refrigerator to maintain a temperature range of 5-10 ºC for a week. (http://plantanswers.tamu.edu.recipes/herbs/garlicoil.html). After one week the garlic infused oils from bottles are transferred to a separate container, are heated to 70 – 80 ºC for activation of molecular mechanism by which natural treatment for viscosity and density problems are addressed. After cooling the oils are filtered with an industrial filter cloth or a fine wire meshed filter into three separate air tight bottles for engine use as fuel. The above procedure in the same proportions was adopted for making more quantities of garlic treated oils depending on the fuel requirement.

4.4 Fuel Properties

The non-edible vegetable oils used as fuel in the form of straight or neat form, blends and garlic treated oil were subjected to various tests to determine their useful properties like, specific gravity, kinematic viscosity, flash and fire points, carbon residue and calorific value such that the improved performance of a particular oil can be analyzed in a more technical and scientific way.

4.4.1 Kinematic Viscosity

Viscosity is a measure of the resistance of a fluid which is being deformed by shear stress. It is the resistance of a liquid to flow and describes a fluid's internal resistance. Dynamic viscosity is measured with various types of viscometers viz. Red Wood Viscometer, Saybolt Viscometer and Engler Viscometer. Close temperature control of the fluid
is essential for accurate measurements, particularly in materials like lubricants, whose viscosity can double with a change of about 5 °C.

Redwood -1 viscometer was used for determining the viscosity of the selected non-edible oils, their blends and the garlic treated oils used as test fuels. Temperature of the oil sample is maintained within +/-0.5°C by adjusting the water bath temperature used for submerging the sample cup. 50ml of fuel sample is allowed to flow through a standard capillary tube and the time of flow is noted. The result is sometimes described in terms of time taken by oil to flow through a particular instrument at specified temperature. (ASTM D445)(52,53). The kinematic viscosity values are presented in Table 4.1 and the results reveal that all the test fuels used for experimentation are 6-9 times higher than base line diesel.

4.4.2 Flash and Fire points

The flash point of a flammable liquid is the lowest temperature at which it can form an ignitable mixture in air. At this temperature the vapor may cease to burn when the source of ignition is removed. A slightly higher temperature, the fire point, is defined as the temperature at which the vapour continues to burn after being ignited even after withdrawing the source of ignition.

Flash and fire points are determined by various apparatus viz. Abel’s, Pensky Marten’s, Cleveland open cup apparatus. As the selected test fuels flash and fire points are beyond the boiling temperature of water the Pensky-Martens open cup and closed cup tester - ASTM D93 apparatus was used to determine the flash and fire points of the selected non-edible oils, their blends and the garlic treated oils used as test fuels.
Flash point measures the tendency of the test fuel sample to form a flammable mixture with air under controlled conditions. Flash point indicates the possible presence of highly volatile and flammable materials in relative nonvolatile or nonflammable material.

Pensky-Martens open cup and closed cup tester is one example, are sealed with a lid through which the ignition source can be introduced periodically. The vapour above the liquid is assumed to be in reasonable equilibrium with the liquid. Closed cup testers give lower values for the flash point (typically 5-10°K) and are a better approximation to the temperature at which the vapour pressure reaches the Lower Flammable Limit. The values are presented in Table 4.1 and the flash and fire points of all the non-edible oils are higher than base line diesel (53).

4.4.3 Carbon residue

Whenever the oils are heated in the absence of free air the oil distills and leaves the residue called Carbon residue. The lower carbon percentage indicates the good quality of the fuel.

For determining carbon residue Conradson’s carbon residue apparatus and Ramsbottom carbon residue apparatus are widely used. In the present experimental work Conradson’s carbon residue apparatus was used to determine the carbon residue of the selected non-edible oils, their blends and the garlic treated oils used as test fuels. This test is very simple and gives reasonably accurate values to assess the quality of the oil. More over previous researchers (53, 85) also conducted Conradson’s carbon residue test to test their experimental fuels/blends.

While conducting carbon residue test using Conradson’s carbon residue apparatus, the empty porcelain crucible is first weighed (W1) and
6 to 7 grams of test fuel is transferred to the porcelain crucible and again weighed (W2) to determine the weight of the fuel sample (W2-W1). After determining the sample weight the porcelain crucible containing the fuel sample is transferred to a Skidmore iron crucible and the lid is placed on the iron crucible. This Skidmore iron crucible containing the sample oil is placed in a wrought iron crucible containing sand bath and the lid is placed over the wrought iron crucible to stop the supply of free air to the heating porcelain crucible. The wrought iron crucible is placed on the heater and heated till the vapors seize from the porcelain crucible. The heating is continued till the fuel is totally distilled in the absence of free air to leave its carbon residue and the heating is stopped. The heated porcelain crucible is transferred to a desiccator containing calcium carbonate crystals to cool the crucible and to avoid moisture absorption by the sample. On cooling of the desiccator the porcelain crucible is weighed to know the weight (W3) of carbon content in the crucible and division of this carbon residue with the weight of the sample gives the percentage of carbon present in the test sample, i.e.

\[ \text{\% carbon residue in the sample} = \frac{(W3-W1)}{(W2-W1)} \times 100 \]

The test results were tabulated in Table 4.1 and the carbon residue values are higher than base line diesel.

4.4.4 Specific Gravity

Specific gravity of liquids can be measured with instruments like hydrometer, specific gravity bottle. In the present work specific gravity bottle has been used for the measurement of specific gravity of fuel oil and their blends.
The specific gravities of the selected non-edible oils, their blends and the garlic treated oils used as test fuels are determined as per American society for testing Materials (ASTM) method D1298,(ASTM D4052). The specific gravity is calculated at a temperature of 15 °C as specified in ASTM. First the empty specific gravity bottle (50 ml) is weighed (W₁) and the test fuel is filled up to the mark and again weighed to determine the weight of the specific gravity bottle and sample of oil (W₂). The difference in weights will give the weight of oil sample and mass/unit volume can be calculated. The specific gravity values are presented in Table 4.1 and all the test fuel values are higher than base line diesel.

4.4.5 Calorific value

Heat of Combustion is a measure of the energy available in a fuel, and is very much essential to determine the Calorific value or heating value of the selected non-edible oils, their blends and the garlic treated oils used as test fuels and to compare the heating value with diesel. The calorific value of the test fuels was determined by Bomb Calorimeter As per ASTM D240. The calorific values of all the test fuels are presented in Table 4.1 and all the test fuel values are lower than base line diesel (53,108).
### Table 4.1. Table showing properties of the various test fuels

<table>
<thead>
<tr>
<th>S.no</th>
<th>Fuel</th>
<th>Kinematic Viscosity at 40°C Centi stokes</th>
<th>Flash Point °C</th>
<th>Fire Point °C</th>
<th>Carbon Residue %</th>
<th>Specific Gravity at 15°C</th>
<th>Calorific Value kJ/Kg</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Diesel</td>
<td>4</td>
<td>52</td>
<td>57</td>
<td>0.1</td>
<td>0.820</td>
<td>42000</td>
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<tr>
<td>2</td>
<td>Tobacco Seed Oil</td>
<td>24</td>
<td>230</td>
<td>248</td>
<td>0.45</td>
<td>0.915</td>
<td>38438</td>
</tr>
<tr>
<td>3</td>
<td>Pongamia Oil</td>
<td>29</td>
<td>250</td>
<td>264</td>
<td>1.67</td>
<td>0.935</td>
<td>37150</td>
</tr>
<tr>
<td>4</td>
<td>Mahua Oil</td>
<td>30</td>
<td>220</td>
<td>244</td>
<td>0.4</td>
<td>0.904</td>
<td>38875</td>
</tr>
<tr>
<td>5</td>
<td>Tobacco Seed Oil + Mahua Oil</td>
<td>24</td>
<td>194</td>
<td>218</td>
<td>0.54</td>
<td>0.910</td>
<td>38600</td>
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<tr>
<td>6</td>
<td>Tobacco Seed Oil + Pongamia Oil</td>
<td>26</td>
<td>232</td>
<td>251</td>
<td>0.7</td>
<td>0.925</td>
<td>37748</td>
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<td>7</td>
<td>Pongamia Oil + Mahua Oil</td>
<td>29</td>
<td>238</td>
<td>260</td>
<td>0.65</td>
<td>0.935</td>
<td>37981</td>
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<td>8</td>
<td>Tobacco Seed Oil + Pongamia Oil + Mahua Oil</td>
<td>30</td>
<td>215</td>
<td>236</td>
<td>1.17</td>
<td>0.918</td>
<td>38111</td>
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<td>Treated Tobacco Seed Oil</td>
<td>21</td>
<td>222</td>
<td>243</td>
<td>0.43</td>
<td>0.915</td>
<td>38438</td>
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<td>10</td>
<td>Treated Pongamia Oil</td>
<td>27</td>
<td>221</td>
<td>238</td>
<td>1.2</td>
<td>0.935</td>
<td>37150</td>
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<tr>
<td>11</td>
<td>Treated Mahua Oil</td>
<td>29</td>
<td>217</td>
<td>240</td>
<td>0.4</td>
<td>0.904</td>
<td>38875</td>
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</table>
Table 4.2: Fatty acid composition of Common Vegetable Oils

(\% by weight) (135,136,140 & 141)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Tobacco seed oil</th>
<th>Pongamia Oil</th>
<th>Mahua Oil</th>
<th>Soya bean Oil</th>
<th>Sunflower Oil</th>
<th>Rape seed Oil</th>
<th>Cotton Seed oil</th>
</tr>
</thead>
<tbody>
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<td>Myristic</td>
<td>0.09-0.17</td>
<td>3.7-7.7</td>
<td>0.09</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>Palmitic</td>
<td>8.87-10.96</td>
<td>44.5-71.3</td>
<td>19.93</td>
<td>13.9</td>
<td>6.4</td>
<td>3.5</td>
<td>28.7</td>
</tr>
<tr>
<td>Oleic</td>
<td>12.4-14.54</td>
<td>2.4-8.9</td>
<td>37.21</td>
<td>23.2</td>
<td>17.7</td>
<td>64.1</td>
<td>13.0</td>
</tr>
<tr>
<td>Stearic</td>
<td>3.34-3.49</td>
<td>2.4-8.9</td>
<td>25.96</td>
<td>2.1</td>
<td>2.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Linoleic</td>
<td>67.75-69.49</td>
<td>10.8-18.3</td>
<td>14.74</td>
<td>56.2</td>
<td>72.9</td>
<td>22.3</td>
<td>57.4</td>
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<tr>
<td>Linolenic</td>
<td>0.69-4.20</td>
<td>0.0</td>
<td>0.28</td>
<td>4.3</td>
<td>0.0</td>
<td>8.2</td>
<td>0.0</td>
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