1. Introduction

Biofuels have become one of the major solutions to issues of sustainable development, energy security and a reduction of greenhouse gas emissions. Biodiesel, an environmental friendly diesel fuel similar to petro-diesel in combustion properties, has received considerable attention in the recent past worldwide. Biodiesel is a methyl or ethyl ester made from renewable biological resources such as vegetable oils (both edible and non-edible), recycled waste vegetable oil and animal fats. The use of vegetable oils as alternative fuels has been in existence long ago but was set aside due to the availability of petroleum products which appears to be cheaper.[1]

Biodiesel is now recognized as an alternative because it has several advantages over conventional diesel. It is safe, renewable and non-toxic. It contains less sulphur compounds and has a high flash point (≥130°C). It is almost neutral with regards to carbon dioxide emissions, and emits 80% fewer hydrocarbons and ~50% less particles. It enjoys a positive social impact, by enhancing rural revitalization. It is the only alternative fuel currently available that has an overall positive lifecycle energy balance.

2. Oil Extraction Process

Various techniques such as mechanical extraction, solvent extraction, traditional extraction and super critical fluid extraction are used to obtain the oil from the seeds. The solvent extraction has become the most popular method of extraction of oil because of its high percentage of oil recovery from seeds. Solvent extraction bridges the gap between mechanical extraction which produces oil with high turbidity metal and water content and supercritical fluid extraction which is very expensive to build and maintain its facilities. Temperature is increased for oilseeds after pre-treatments such as cracking, dehulling and milling by heating, roasting and steaming of oilseeds prior to extraction and is termed thermal treatment of oilseeds.

Better extraction is achieved by heating, which reduces the oil viscosity and released oil from intact cells, and also reduces moisture in the cells. Temperature plays an active role in the seed treatment for mechanical extraction and ensures an effective solvent process by heating the solvent which hastens the extraction process. At the right temperature and moisture content, the individual oil droplets unite to form a continuous phase and flow out maximizing oil yield. Solvent extraction is the use of chemicals as solvents in the extraction of oil from oilseeds. Solvent extraction is known for its high yielding oil output, ease and swiftness to carry out; relatively cost effective, high overhead cost, and hazardous effects during and after operations. The use of this method requires a complete refining process to ensure traces of the solvents to be removed totally. Solvent extraction of cleaned, cracked, dehulled and conditioned flakes with hexane is commercially practiced to extract oil.[2]

3. Biodiesel Production

Generally two stage transesterification process is used for the production of biodiesel. This process consists of a sequence of three consecutive reversible reaction i.e. conversion of triglycerides to diglycerides followed by diglycerides to monoglyceride. The glycerides were converted into glycerol and one ester molecule at each step. If the oil contains more than 4% free fatty acids (FFA), then a two step transesterification is applicable to convert the high FFA oils to its mono esters. The first step, the acid catalyzed esterification reduces the free fatty acid content of the oil.

\[
\text{Vegetable oil} + \text{Alcohol} \xrightarrow{\text{acid}} \text{Triglyceride} + \text{Water}
\]

The second step, alkaline transesterification process converts the products of the first step to its mono-esters and glycerol. In this process vegetable oils are heated to temperature of 80-85°C by placing in water bath. Similarly alcohol is heated to 65°C in the presence of alkali catalyst.
Both vegetable oil and alcohol are combined together at a temperature of 60-65°C. The reaction results in the formation of esters and glyceride. If water is mixed to the mixture, soap will be formed which reduces the formation of biodiesel. The chemical reaction is

\[
\text{Triglyceride + alcohol} \xrightarrow{\text{alkali}} \text{Glycerol} + \text{alkyl esters}
\]

Simple alcohols are used for transesterification and this process is usually carried out with a basic catalyst (NaOH, KOH) in the complete absence of water. The bonding of alcohol and organic acid produces ester. An excess of alcohol is needed to accelerate the reaction. With methyl alcohol glycerol separation occurs readily. In the transesterification process alcohol combines with triglyceride molecule from acid to form glycerol and ester. The glycerol is then removed by density separation. Transesterification decreases the viscosity of oil, making it closer to diesel fuel in characteristics. [2]

4. Various Fruit Seeds

1) Sapindus Mukrossi (Soapnut) oil seeds:

Free fatty acid composition in percentage [5]
- Linoleic: 4.73
- Oleic: 52.64
- Stearic: 1.45
- Palmitic: 4.67
- Palmitoleic: 0.37
- Arachidic: 7.02
- Eicosenic: 23.85
- Erucic: 1.09
- Alpha or Gamma linolenic: 1.94
- Behenic: 1.45
- Lignoceric: 0.47

Physico chemical properties of Soapnut seed oil:[5]
- Oil content: 30-35%
- Calorific value (KJ/Kg): 38171
- Kinematic viscosity mm²/s (40°C): 3.5
- Flash point (°C): 236
- Fire point (°C): 238
- Density (Kg/m³): 902
- Cetane number: 58

Physico chemical properties of Soapnut seeds Methyl ester:[5]
- Calorific value (MJ/Kg): 38-40
- Kinematic Viscosity (30°C): 5.6
- Density (Kg/m³): 910
- Carbon Residue (%): 0.23

2) Terminalia Chebula (Hirda) oil seeds:

Free fatty acid composition [5]
- Linolenic: 1.1
- Linoleic: - 23.3
- Oleic: 54.8
- Stearic: 9.6
- Palmitic: 1.4
- Myristic: 1.9

Physico chemical properties of Hirda seed oil: [5]
- Oil content: 32.6 %
- Density (Kg/m³): 913.2
- Refractive index: 1.47
- Acid Value (mg KOH): 4.9
- Saponification Value: 201.3
- Iodine value: 107.3

Physico chemical properties of Hirda seeds Methyl ester: [5]
- Calorific value (M/Kg): 38-40
- Kinematic Viscosity (30°C): 5.6
- Density (Kg/m³): 910
- Carbon Residue (%): 0.23

3) Delonix Regia (Gulmohar)

Free fatty acid composition in percentage [6]
- Linolenic: 18.6
- Linoleic: 41.2
- Oleic: 21.3
- Stearic: 6.1
- Palmitic: 9.1
- Arachidic: 17.5

Physico chemical properties of Delonix Regia seed oil:[7]
- Oil content: 30.8%
- Calorific value (KJ/Kg): 40020
- Kinematic viscosity mm²/s (40°C): 4.630
- Density at 15°C in Kg/m³: 874
- Flashpoint (°C): 165
- Cloud point (°C): -1
- Pour point (°C): -4
- Cetane number: 56

Free fatty acid composition in percentage [6]
- Linolenic: 18.6
- Linoleic: 41.2
- Oleic: 21.3
- Stearic: 6.1
- Palmitic: 9.1
- Arachidic: 17.5

Physico chemical properties of Delonix Regia seed oil:
- Oil content: 30.8%
- Density (Kg/m³): 933
- Kinematic viscosity mm²/s (40°C): 36.65
- Refractive index: 1.42
- Acid Value (mg KOH): 4.88
- Saponification value: 198.23
- Iodine value: 117.46
Peroxide Value (mg O₂/g oil): 3.82
Cloud Point (°C): 13

Physico chemical properties of Delonix Regia seed Ethyl ester: [8]
- Density (Kg/m³): 859
- Kinematic Viscosity (40°C): 4.0
- Pour Point (°C): -21
- Cloud Point (°C): 4.4
- Flash Point (°C): 110
- Calorific value (KJ/Kg): 37200
- Acid Value (mg NaOH): 0.3

Free fatty acid composition in percentage [10]
- Palmitic: 16.07
- Palmitoleic: 0.08
- Stearic: 7.74
- Oleic: 39.79
- Linoleic: 34.95
- Linolenic: 0.07

Physico chemical properties of Hingot seed oil: [10]
- Oil Content (%): 45%
- Acid Value (mg KOH): 0.43
- Iodine Value (g/100g): 95.7
- Saponification Value: 197.7
- Density (Kg/m³): 870
- Kinematic viscosity mm²/s (40°C): 22.3
- Pour Point (°C): -6
- Cloud Point (°C): -4

Physico chemical properties of Hingot seeds Methyl ester: [11]
- Kinematic viscosity mm²/s (40°C): 3.8
- Density at 15°C in Kg/m³: 836
- Pour Point (°C): 3
- Cloud Point (°C): 4
- Acid Value (mg KOH): 0.3
- Iodine Value (g/100g): 96.7
- Calorific value (KJ/Kg): 39650

Free fatty acid composition in percentage [13]
- Linoleic: 21
- Stearic: 6
- Oleic: 34
- Palmitic: 38.3
- Others: 0.5

Physico chemical properties of Acacia Raddiana seed oil: [13]
- Oil Content (%): 11%
- Acid Value (mg KOH): 0.4
- Iodine Value (g/100g): 63.32
- Density (Kg/m³): 912
- Kinematic viscosity mm²/s (40°C): 37.4

Physico chemical properties of Acacia Raddiana seed Ethyl ester: [13]
- Refractive index: 1.3896
- Kinematic viscosity mm²/s (40°C): 4.1
- Density (Kg/m³): 876
- Iodine value: 63.10
- Calorific value (KJ/Kg): 32780

Free fatty acid composition in percentage: [14]
- Linolenic: 1
- Linoleic: 54
- Oleic: 19
- Myristic: 0.4
- Stearic: 2
- Palmitic: 20
- Palmitoleic: 0.4

Physico chemical properties of Cotton seed oil: [14]
- Oil Content (%): 18-25%
- Iodine Value (g/100g): 105
- Density (Kg/m³): 912
- Flash Point (°C): 207
- Fire point (°C): 230
- Kinematic viscosity mm²/s (40°C): 55.61
- Cetane number: 52
- Calorific Value (KJ/Kg): 38000

Physico chemical properties of Cotton seed Ethyl ester: [15]
- Kinematic viscosity mm²/s (40°C): 3.5
- Density (Kg/m³): 862.4
- Flash point (°C): 200
- Fire Point (°C): 56
- Gross Caloric Value (KJ/Kg): 35660
- Cetane number: 38

5) Acacia Raddiana Seed:

5. Conclusion

Various non-conventional fruit seeds are found to be very good and viable feed stock for biodiesel production. The major limitations of all the oils were mostly high free fatty acid values. These high values make them more suitable for
two stage process of transesterification in order to obtain reasonable yields of the methyl ester. The various properties were compared with diesel and found to be quite closer and hence can be used in existing diesel engines without any modification.

6. Future Scope

In addition to the above there are so many non-conventional fruit seeds unutilized and underutilized for biodiesel production which can be taken for the studies.

References