

# **Tamanu (Calophyllum Inophyllum) Biodiesels Alternative Fuel for CI Engine: Review**

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**ABSTRACT:** The increasing industrialization and motorization of the world has led to a steep rise for the demand of petroleum products. Petroleum based fuels are obtained from limited reserves. These finite reserves are highly concentrated in certain regions of the world. Therefore, those countries not having these resources are facing a foreign exchange crisis, mainly due to the import of crude oil. Hence, it is necessary to look for alternative fuels, which can be produced from materials available within the country. Biodiesel can be extracted from vegetable oils and waste fats. The Tamanu (Calophyllum Inophyllum) oil has a new possible source of alternative fuel. Tamanu biodiesel can successfully alternate diesel fuel and help in decreasing the import of the crude oil used in diesel engine. This review has been taken up to identify the performance and emission using Tamanu biodiesel.

**KEYWORDS:** Tamanu biodiesel, performance, combustion, blends, CI engine, emissions.

## **I. INTRODUCTION**

Increasing number of automobiles has led to increase in demand of fossil fuels (petroleum). The increasing cost of petroleum is another concern for developing countries as it will increase their import bill. The world is also presently confronted with the problem of fossil fuel depletion and environmental degradation. Fossil fuels have limited life and the ever increasing cost of these fuels has led to the search of alternative renewable fuels for ensuring energy security and environmental protection. Biodiesel as a vegetable oil, biodegradable and nontoxic, has low emission profiles and so is environmentally beneficial. Biodiesel is a chemically produced vegetable oil to replace the traditional Diesel fuel. The chemical process is known as transesterification and consists of treating vegetable oils, like soybean, sunflower and rapeseed, with reactants (methanol or ethanol) to obtain a methyl or ethyl ester and glycerine. The reaction is catalysed by a reaction with either an acid or base and involves a reaction with an alcohol, typically methanol if a biodiesel fuel is the desired product.

### **A. TAMANU OIL**

Scientific name: Calophyllum inophyllum

Other names: Alexandrian laurel, Punnai, Tamanu, Kamani.

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Fig-1: Tamanu fruits



Fig-2: Tamanu seed's shell and kernel

## ***B. ADVANTAGES OF TAMANU OIL***

- Calophyllum inophyllum has high survival potency in nature, still productive up to 50 years.
- It does not compete with food crops.
- Its trees serve as windbreaker at the seashore where it can reduce abrasion, protect crops and provide ecotourism and conservation of coastal demarcation.
- It has higher oil yield than *Jatropha curcas*.
- It has high heating value.

## ***C. TRANSESTERIFICATION REACTION***

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification.

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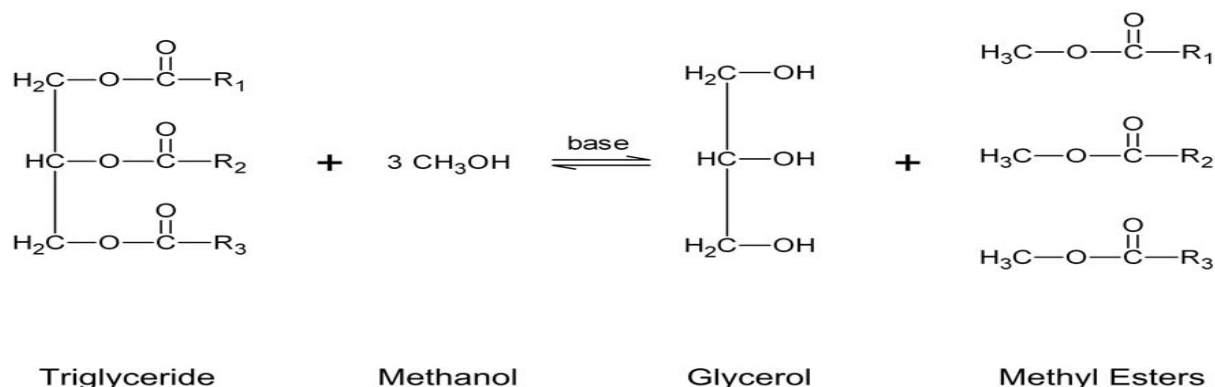


Fig-3: Transesterification reaction

## D. PROPERTIES OF FUELS

Properties	Diesel	Tamanu Biodiesel
Density (kg/m <sup>3</sup> )	820 – 860	852 – 905
Kinematic viscosity at 40°C (cSt)	3.06 – 3.12	4.21 – 5.72
Flash point (°C)	47 – 65	145 – 162
Fire point (°C)	54 – 73	156 – 166
Calorific value (MJ/kg)	42 – 43.5	39 – 41.3

Table-1: Properties of diesel and Tamanu biodiesel

## II. LITERATURE REVIEW

### 1. Arun B [1]

Conducted experiments on, production, performance and emission analysis of Tamanu oil – diesel blends in a CI engine. In this work, diesel and Tamanu oil methyl ester (B10, B20, B30, B40) fuel blends were used for conducting the performance and emission in terms of 25% load increments from no load to full load.

Results showed that, BTE of all blends were constantly increases based on the load condition and B40 have higher BTE. B10 have higher mechanical efficiency at various loads but at the full load condition B20 has the higher efficiency than the B10. Fuel consumption has increased in all load condition for diesel fuel. Among all other blends, B10 has the lower fuel consumption rate. B10, B20 has lower CO emissions when compared with petroleum diesel at full load. The CO<sub>2</sub> emissions for all blends except B40 were less as compared to diesel at all loads. Increasing the blend percentage of Tamanu oil decreases the UBHC emissions. All the blends have lower UBHC emissions after about 75% load. Among the blends, B30 has lower UBHC emissions. NO<sub>x</sub> emissions for all blends were less as compared to diesel at all loads. With increasing the percentage Tamanu blends there was a trend of decreasing NO<sub>x</sub> emissions. The EGT increases with increase in load for all blends. Among the blends B30 has the lowest EGT than diesel.

### 2. Mohan T Raj, Murugumohan Kumar K Kandasamy [2]

Conducted experiments on, Tamanu oil – an alternative fuel for variable CR engine. In this work, an experiment was conducted to obtain the operating characteristics of the variable CR engine run by chosen esterified oils and the results were compared with esterified Tamanu oil.

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Results showed that, the specific fuel consumption decreases with the increase in compression ratio. Specific fuel consumption was found to be lower at a compression ratio of 18. The specific fuel consumption of the esterified Tamanu oil at the compression ratio of 18 was 0.24 kg/kW-hr, whereas at the compression ratio of 14, it was 0.29 kg/kW-hr for maximum load. The BTE of biodiesel was slightly higher at the compression ratio of 16 and lower at the compression ratio of 18. The BTE of the esterified Tamanu oil for the compression ratio of 18 was 30.4% at maximum load. The variation in the volumetric efficiency was comparably less for all range of compression ratios and it was high at compression ratio 18. The volumetric efficiency of esterified Tamanu oil for compression ratio of 18 was 62.91% at maximum load. The variation in exhaust gas temperature was very minimal when the compression ratio was varied from 14 to 18. The highest temperature obtained was 446.35° C at the compression ratio of 14 and 430.5° C at compression ratio of 18 at maximum load. The delay period was consistently low for esterified Tamanu oil by increasing the compression ratio from 14 to 18. The delay period was 8° crank angle (CA) at the compression ratio of 14 and 6° CA at 18 for maximum load. The peak pressure increases linearly from 64 to 81 bar as the compression ratio increases from 14 to 18 for maximum load. The rate of pressure rise decreases when the compression ratio was increased from 14 to 18. The duration of injection was 38° CA at the compression ratio 14 and 34° CA at compression ratio 18 for maximum load. The combustion duration was 40° CA at the compression ratio of 14 and 43° CA at the compression ratio of 18 for maximum load. The smoke intensity was 3.9 HSD at the compression ratio of 14 and 3.4 HSD at the compression ratio of 18 for maximum load. The CO emission of the esterified Tamanu oil was found to be lower for high compression ratio of 18 and it was 0.18% at maximum load. The CO<sub>2</sub> emission was 3.3% at the compression ratio of 14 and 5.1% at the compression ratio of 18 for maximum load. In case of, esterified Tamanu oil, the HC emission decreases with increase in compression ratio. The HC emission was 152 ppm at the compression ratio 14 and 125 ppm at the compression ratio of 18 for maximum load. The NO<sub>x</sub> emission for esterified Tamanu oil was higher with the increase in compression ratio. The NO<sub>x</sub> emission for esterified Tamanu oil at the compression ratio of 18 was 201 ppm at maximum load. The particulate emission decreases with the increase in compression ratio from 14 to 18 for all loads. The particulate emission was 1900 mg/m<sup>3</sup> at the compression ratio of 14 and 1600 mg/m<sup>3</sup> at the compression ratio of 18 for maximum load.

### 3. P. Navaneetha Krishnan, D. Vasudevan [3]

Conducted experiments on, performance, combustion and emission characteristics of variable compression ignition engine fuelled with biodiesel. In this work, tests has been conducted using the Tamanu biodiesel blends of 10%, 20%, 40% and 60% biodiesel with standard diesel, with fixed compression ratio 19, and an engine speed of 1500 rpm at different loading conditions.

Results showed that, as the applied load increases, the BTE of the fuel blends also increases. The maximum BTE at full load was 41.72% for B40. The BTE of B20 and diesel were 39.68% and 36.49% respectively. When the load increases the specific fuel consumption of the fuel will maintain a gradual decrease. The specific fuel consumption values were 0.2234 kg/kW-hr, 0.2268 kg/kW-hr and 0.2201 kg/kW-hr for the fuel blends B20, B40 and diesel respectively. The fuel blends B10, B20, B40 and B60 have decreased BP while comparing with standard diesel. The BP values were 3.7149 kW and 3.6973 kW for B40 and standard diesel respectively. The indicated mean effective pressure for blend B40 and standard diesel at 50% load was 1.908 bar, 1.919 bar and for 75% load was 2.834 bar and 2.841 bar respectively. As the load increases, mechanical efficiency for all the blends were also increases. Blends B40 and B10 at full load were having maximum mechanical efficiency and it was 93.77% and 87.62% respectively. Exhaust gas temperature decreases for different blends when compared to that of diesel. Standard diesel having highest exhaust gas temperature and it was 323.97° C, whereas the blends B20 and B40 were having lower temperature 306.23° C and 312.93° C respectively. The Tamanu oil blend B40 gives higher combustion pressure. The peak pressure values for standard diesel and Tamanu oil blends B10, B20, B40 and B60 were 72.89 bar, 73.07 bar, 70.76 bar, 71.30 bar and 69.16 bar respectively, at full load. The combustion duration for the fuel blends B10, B20, B40, B60 and diesel at full load condition were 36.37, 35.38, 34.17, 29.85 and 38.94° CA respectively. The maximum heat release rate for blends B10, B20, B40, B60 and diesel were 17.23, 17.61, 17.45, 16.10, 17.92 J/° CA. The heat release rate decreases at the start of combustion and increases further. The heat release rate of Tamanu oil blends decreases compared to diesel at full load. At crank angle 340° - 360°, the

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mass fraction burnt for the fuel blend B40 was higher than diesel. At crank angle  $360^\circ - 390^\circ$ , the mass fraction burnt was slightly closer to each other. The ignition delay decreases with biodiesel in the diesel blends with increase in load. The ignition delay period for B10, B20, B40 and B60 at full load conditions were 5.34, 1.61, 3.68 and  $3.39^\circ / \text{CA}$  respectively. At higher load condition the HC emission of various blends were higher except the blend B20. For blend B40 increase in load increase the HC emission. The other blends B10, B20 and B60 produce lesser HC emission at 50% and 75% load while comparing with diesel. The  $\text{NO}_x$  emission for diesel was lower than that of biodiesel and its blends except B40 at lower loads. For 50% load,  $\text{NO}_x$  emission from Tamanu oil blend B40 was slightly lower than that of diesel. At 100% load condition, the  $\text{NO}_x$  emission from B40 blend was higher than that of diesel. The  $\text{NO}_x$  emission for fuel blend B40 and diesel for 50% load was 18 ppm and 22 ppm respectively.

#### 4. R. Rajappan, K. Udhayakumar, V. Suresh, D. Anbuselvan [4]

Conducted experiments on, performance and emission characteristics of a variable compression ratio direct injection diesel engine using Tamnu oil. In this work, the experiment was conducted at 15 kg load with engine speed of 1500 rpm and at compression ratio varies from 16:1 to 18:1.

Results showed that, the specific fuel consumption of the esterified Tamanu oil blend B20 at the compression ratio of 18 was 0.24 kg/kW-hr and for B60 was 0.28 kg/kW-hr at maximum load. The BTE of the diesel engine was reduced at higher concentration of biodiesel blends. The BTE of B20 was higher than pure diesel. The BTE of the esterified Tamanu oil for the compression ratio of 18 and B20 was 32.6% at maximum load. The CO emission of the esterified Tamanu oil was found to be lower for high compression ratio of 18 and B60 blend was 0.06% at maximum load. The HC emission of diesel was 44 ppm at the compression ratio of 18 and for blend B60 was 30 ppm for maximum load.  $\text{NO}_x$  emission for esterified Tamanu oil at compression ratio of 18 and for blend B40 was 500 ppm at maximum load. There was significant reduction in the smoke opacity with increase in biodiesel concentration.

#### 5. G. Deepankumar [5]

Conducted experiments on, performance and emission characteristics of Tamanu oil as alternative fuel in CI engine. In this work, diesel and Tamanu oil methyl ester (B15, B25, B50, B100) fuel blends were used for conducting the performance and emission in terms of 20% load increments from no load to full load.

Results showed that, the maximum BTE obtained was about 30% for B15, which was higher than that of diesel. Among the blend B15 was having specific fuel consumption lowest at all loads. B100 have higher mechanical efficiency at all load condition. Smoke density increases with increase in load and B100 produces more smoke at all load condition. At low loads, the CO emission for B15 and diesel were found to be same but at higher loads, B15 produced more CO. the blend B15 gives less  $\text{CO}_2$  emission at full load condition. Oxygen emission tends to decrease with the increase in load. HC emission tends to increase with increase in load. Almost all blends give higher HC emission than that of diesel. The  $\text{NO}_x$  emission increased as the engine load increased. All blends produces lower  $\text{NO}_x$  compared to diesel over entire load range. B100 gives less  $\text{NO}_x$  over entire load range. The exhaust gas temperature tends to increase with increase in brake power. All blends gives low exhaust gas temperature when compared to that of diesel.

#### 6. Murugan K., Udhayakumar K [6]

Conducted experiments on, performance and emission characteristics of biodiesel with Tamanu oil in single cylinder four stroke diesel engine. In this work, the blend of 20% Tamanu oil with 80% diesel can be used in unmodified diesel engine.

Results showed that, for all fuels tested, BSFC was found to decrease with increase in the load. Using lower percentage of biodiesel in biodiesel – diesel blends, the BSFC of the engine was lower than that of diesel. The specific fuel consumption of Calophyllum Inophyllum oil was higher than that of diesel. BTE has the tendency to increase with increase in applied load. The maximum BTE obtained was about 28% for B20, which was higher



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than that of diesel. CO emissions were decreases as the load increases. NO<sub>x</sub> emissions were low for B20 fuel than diesel at low and medium loads but emissions were higher than diesel at maximum load condition.

### 7. M. Parthasarathy, J. Isaac Joshua Ramesh Lalvani, P. Muhilan, B. Dhinesh, K. Annamalai [7]

Conducted experiments on, acetylene enriched air in DI diesel engine powered by biodiesel – diesel blends. In this work, Tamanu oil methyl ester (TME) and its blends such as 80%, 60%, 40% and 20% (volume basis) with diesel were used as an alternative fuel in diesel engine.

Results showed that, the BTE increases with higher enrichment of acetylene. A higher BTE of 29.69% was achieved by diesel at full load. The BTE of TME 20 and TME for acetylene enriched air was 28.87% and 25.12% respectively. The specific energy consumption of TME20 decreases from 19.87 MJ/kW-hr to 12.46 MJ/kW-hr, when 4 lpm of acetylene enriched air was introduced in the combustion of biodiesel, it slightly increases by 8.06% compared to neat diesel. When the mass flow rate of acetylene enriched air of 4 lpm with TME 20 was injected at full load condition, NO<sub>x</sub> emission increases from 80 ppm to 480 ppm, compared to neat diesel, it shows in an increase of 11%. CO emission was recorded as 0.12%, 0.113%, 0.105%, 0.122% and 0.11% with diesel, TME 20, TME 40, TME 60, TME 80 and neat TME respectively, at full load condition.

### 8. Ashish G. Bandewar, Rahul Krishna, S V Chanapattana [8]

Conducted experiments on, emission characteristics of VCR engine using Calophyllum Inophyllum biodiesel blends as a fuel. In this work, experiments were performed using pure diesel, 25%, 50% and 75% blends by varying the compression ratio.

Results showed that, for full load condition, when the compression ratio was varied from 14.5 to 17.5, the highest CO emission obtained was 1.054% for diesel, 1.585% for H25, 1.938% for H50 and 1.905% for H75, all were at the compression ratio of 14.5. The lowest CO emission obtained was 0.365% for diesel, 0.06% for H25, 0.066% for H50 and 1.187% for H75, all were at the compression ratio of 17.5. The CO emissions were higher at lower compression ratio and decreased at higher compression ratio. The CO emissions for biodiesel and its blends were higher, compared to diesel over entire range of fuel blends, except H25. The biodiesel and its blends emits lower percentage of CO<sub>2</sub> as compared to diesel at higher compression ratio. For full load condition, the highest CO<sub>2</sub> emission obtained was 4.47% for diesel with lowest emission obtained was 0.4% for H25, 2.86% for H50 and 3.19% for H75 all were at the compression ratio of 17.5. The lowest CO<sub>2</sub> emission obtained was 1.96% for diesel, with highest emission obtained was 5.04% for H25, 3.75% for H50 and 4.32% for H75, all were at the compression ratio of 14.5. For full load condition, the highest HC emission obtained was 103 ppm for diesel at compression ratio 15.5 and 100 ppm for H25, 214 ppm for H50 and 235 ppm for H75, all were at compression ratio 16.5. The lowest emission obtained was 34 ppm for diesel, 10 ppm for H25, 89 ppm for H50, all were at compression ratio 17.5, but 142 ppm for H75 at compression ratio 16.5. The NO<sub>x</sub> emission for entire range of fuel was higher at the compression ratio 15.5. For full load condition, the highest NO<sub>x</sub> emission obtained was 430 ppm for diesel at compression ratio 17.5 and 419 ppm for H25, 611 ppm for H50 and 629 ppm for H75, all were at compression ratio 15.5. The lowest emission obtained was 166 ppm for diesel at compression ratio 14.5, 89 ppm for H25 at compression ratio 17.5 and 250 ppm for H50, 301 ppm for H75 both at compression ratio 14.5.

### 9. Rahul KrishnajiBawane, S.V. Channapattana, NilimaBaliramGadge, Sandip M. Ingole [9]

Conducted experiments on, performance characteristics of Calophyllum Inophyllum biodiesel in CI engine by varying compression ratio. In this work, an experiment was conducted to obtain the operating characteristics of the variable compression ratio (VCR) engine run on biodiesel made from Calophyllum Inophyllum oil, at various compression ratio, and the results are compared with diesel.

Results showed that, there was a steady increase in brake thermal efficiency as compression ratio increases. Biodiesel and its blends results in decreased brake thermal efficiency as compared to diesel over the entire range of compression ratio. The brake specific fuel consumption (BSFC) decreases with the increase in compression ratio. BSFC for biodiesel and its blends were higher than that of diesel. When the compression ratio

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was increased, EGT decreases. The CO emission of the biodiesel and its blends were found to be lower for high compression ratio. The CO emissions for biodiesel and its blends were higher, compared to diesel over the entire range of fuel blends, except H25. The biodiesel and its blends emit lower percentage of CO<sub>2</sub> as compared to diesel at higher compression ratio. CO<sub>2</sub> emissions of H25 blend shows highest CO<sub>2</sub>. The HC emission decreases with increase in compression ratio for the entire range of fuels. The NO<sub>x</sub> emission for entire range of fuel was higher at the compression ratio 15.5. Highest NO<sub>x</sub> emission obtained at highest compression ratio 17.5. The O<sub>2</sub> emission increases continuously with increases in compression ratio. Biodiesel and its blends shown higher O<sub>2</sub> emission as compared to diesel for full load conditions.

### III. CONCLUSION

Tamanu biodiesel satisfies the important fuel properties as per ASTM specification of biodiesel. Engine works smoothly on Tamanu methyl ester with performance compared to diesel operation. The Tamanu biodiesel can be successfully substituted as alternative fuel for CI engine.

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