Progress on Pine Derivative Products as Fuel Source in Indonesia

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Abstract. Pine resin is a non-wood forestry product in Indonesia that can be converted into a much higher value product. Pine resin traditionally is converted into rosin and turpentine. Due to the scarcity supply of fossil fuel, turpentine has been studied as fuel for diesel substitution. Pinene, the highest component found in pine resin is the primary fuel source candidate. Pinene dimer, modified pinene using catalysts or ozone have a heating value similar to that of JP-10, a tactical fuel for rockets. This paper discussed the technological development of pinene and pinene dimers as a fuel. The opportunity and challenge for producing pine based fuel in Indonesia were also addressed.

1. Introduction

Oleoresin is one of the potential non-woods commodities in Indonesia, and raw pine resin is the main product derived. In 2018, the total production of raw pine resin in Indonesia was over 50,000 tons [1]. Figure 1 shows the spread of location of pine resin production. Three main pine producers in Indonesia are Java island, Sumatra and Celebes. It is clear that in 2015, 32.78 thousand tons (73%) of pine resin was produced in Java island, followed by 6.89 thousand tons (15%) in Sumatra Island. The remaining 5.23 thousand tons (11%) was produced in Celebes island [2].

![Figure 1. Raw pine resin production by location in Indonesia [2].](image-url)

Indonesia is among the highest resin exporters [3]. France, Sudan, India and Indonesia are the top four exporter. However, only Sudan and Indonesia are actually not among the highest importers. The high production of raw pine resin in Indonesia is an opportunity to be converted into a much higher value product. One of the high-value products is pinene, which can be used as a fuel and has a high...
energy density for fuelling jet engine. This paper will address the progress of pine resin research and development, especially the technological development of converting pinene into fuel. This paper will also discuss the opportunity and challenge the development of fuel from pine derivative product in Indonesia.

2. Pine Resin, Rosin and Turpentine Oil

Pine or *Pinus merkusii* is a tropical pine species with high economic importance. Pine is harvested for its wood and non-wood products. The non-wood product of pine is raw pine resin, which could be used in the production of soap, paints, adhesives, printing inks, coatings, paper-sizing, varnishes, perfume, disinfectants and cleaning agents [4]. The raw pine resin is a yellowish, sticky, opaque mass. The raw pine resin can be processed into rosin and turpentine via distillation. The raw pine resin, distilled at 3-30 mbar and 170-290 °C, produced 10-15% turpentine, 20-40% fatty acid, 25-35% rosin, and 20-30% pitch residue [4, 5].

Rosin is the heavy/solid fraction of pine resin distillation. Rosin is transparent, insoluble in water but soluble in many solvents. The turpentine oil is a colourless, volatile liquid with a specific odour. Table 1 shows the chromatogram profile of neutral fraction and turpentine oil. The oil contains α-pinene, *d-*camphene, β-pinene, Myrcene, α-phellandrene, Δ-carene, *p-*cymene, and *d-*limonene. The highest component of turpentine oil is pinene, followed by carene [6].

| No | Constituent       | Neutral Fraction | Turpentine oil |
|----|-------------------|------------------|----------------|
| 1  | α-pinene          | 73.1             | 82.9           |
| 2  | *d-*camphene      | 0.8              | 0.9            |
| 3  | β-pinene          | 1.8              | 2.2            |
| 4  | Myrcene           | 0.7              | 0.4            |
| 5  | α-phellandrene    | 0.2              | 0.4            |
| 6  | Δ-carene          | 16.0             | 11.0           |
| 7  | *p-*cymene        | 0.8              | 1.1            |
| 8  | *d-*limonene      | 1.9              | 1.3            |

Pinene, *C_{10}H_{16}*, is a bicyclic terpene hydrocarbon consisting of two isomeric forms, alpha- and beta-pinene. However, pinene described usually means alpha-pinene. Recent research on pinene is ranging from the production of pinene through a microbial process [7] to its utilisation for antibacterial [8], food flavour [9], and energy [10].

3. Turpentine Oil as a Fuel

Table 2 shows the thermodynamic properties of turpentine oil [5]. Turpentine oil can be employed as an alternative fuel. Table 2 shows that the distilled turpentine oil has a heating value of 46-47MJ/kg, slightly higher compared to the other fuels such as diesel (44 MJ/kg). Compared to diesel fuel, turpentine oil has lower autoignition temperature and comparable specific heat capacity and thermal conductivity. However, turpentine oil poses some challenges to be used as fuel. The low cetane number of turpentine oil makes it difficult/take longer time to ignite, and it has much higher viscosity which promotes difficulties in fuel injection.

Mixing fuel with a fuel that has better combustion properties can effectively increase the performance of fuel [11, 12]. The mixture of turpentine oil and diesel oil has also been a subject of interest [13]. Improved performance and lower emission of combustion of diesel blended with turpentine oil have been demonstrated [14]. The best mixture was 20% turpentine oil and 80% diesel, producing better performance and lower emission values compared to diesel fuel [14]. The mixing turpentine oil and linseed oil could substitute the energy produced from diesel fuel at high turpentine oil proportion. However, on the high linseed oil proportion, the power is decreased, and it consumed more fuel [13].
Table 2. Thermodynamics properties of turpentine oil [3, 15].

| Parameters                      | Turpentine oil | Biodiesel | Diesel |
|---------------------------------|----------------|-----------|--------|
| Molecular weight                | 136–140        | ~308      | ~200   |
| Specific gravity @ 20°C         | 0.84–0.87      | -         | 0.83   |
| Boiling point (K)               | 426.8–443      | 588-630   | 433-633|
| Composition (% wt)              | C: 88.2 H: 11.8| -         | C: 87 H: 16|
| Vapor pressure (kPa)            | 4              | -         | 2      |
| Flash point (K (cc))            | 303–319        | 422       | 328    |
| Autoignition temperature (K)    | 493–528        | 646       | 588    |
| Heating value (MJ/kg\textsuperscript{-1}) | 46.2 - 47.2 | 42.2     | 44.8   |
| Viscosity (mPa.s)               | 3.89           | 3.36 – 3.68| 2.20 – 2.59|
| Specific heat capacity (kJ kg\textsuperscript{-1}) | 1.72          | 2.2      | 1.8    |
| Thermal conductivity (Wm\textsuperscript{-1}K\textsuperscript{-1}) | 0.128         | 0.1490    | 0.1169 |
| Adiabatic flame temperature (K@973K) | -              | 2291      | 2413   |
| Flammability limit (% volume)   | 0.8            | -         | 1.0    |
| Cetane number                   | 20-25          | 51.7      | 47.4-63.9|
| Explosive limit (volume)        | LEL=0.8%;UEL: 6%| Insoluble | Insoluble |
| Solubility in water             | Insoluble      | Insoluble | Insoluble |

4. High Density Energy Fuel from Pinene Dimers

The heating value of conventional fuel/biofuel is too low to power energy-intensive equipment, such as rockets, missiles, and aircraft. Pinene dimers, however, shown to have a heating value similar to that of JP-10, a tactical fuel for rockets [16]. The pinene dimers, a modification of pure pinene structure, have similar thermodynamics properties close to that of tactical fuel. Figure 2 shows the comparison of heating value as a function of the density of conventional fuels to pinene dimers and JP-10 and RJ-5.

![Figure 2. Comparison of energy density various fuels [16].](image)

Therefore, research on \(\alpha\)-pinene as fuel is mainly pursuing pinene dimer production. Pinene dimer is created by dimerization of pinenes. The dimerization process can significantly increase the fuel density of pinene, which already has a high heating value due to its ring strain. There are many ways of pinene dimerization, such as using catalyst and ozone. One of the successful dimer production attempt is able to convert pinene into a mixture containing about 60% pinene dimers and 40% isomers via dimerization/isomerization over a chemical catalyst and porous catalyst [17, 18].

The catalytic process of pinene into pinene dimers showed that the catalyst pore size of 20-50µm and catalyst surface treatment using organic ligand was a better mean to produce pinene dimers [19]. In the ozone process, the effect of hydroxyl radicals, temperature, and relative humidity has also been investigated [20].

Pinene dimers provide an opportunity to produce high intensive energy from Indonesian pine. However, research on pinene dimers in Indonesia is scarce. Research on pinene in Indonesia is still in the first generation where it focussed on the production of raw pine resin and its utilization. However, the downstream process and product has yet to be considered [6].
5. Opportunity and Challenge
Biofuel based pinene dimer derived from pine has a bright future in Indonesia due to the high production of pin resin. The government policies to integrate biofuel in energy resource is also encouraging as stated by Government Regulation No. 79 of 2014 on National Energy Policy, new and renewable energy mix target is at least 23% by 2025 and 31% by 2050 [21]. However, due to government subsidy, the fossil fuel price is lower than that of biofuel, causing the bioenergy industry is not competitive yet. Therefore, research and production of biofuel such as pinene dimer require serious support from the government.

6. Conclusion
Pine resin is one of the precious non-wood forestry products in Indonesia, who among the leaders of the production of pine resin. Pine resin traditionally is converted into rosin and turpentine. Due to the scarcity supply of fossil fuel, turpentine has been studied as fuel as a diesel substitute. Pinene, the highest component found in pine resin has been studied as a renewable energy source. Pinene dimer, modified pinene using catalysts or ozone have a heating value similar to that of JP-10, a tactical fuel for rockets. However, despite the abundance production of pinene and government policies, more research support from Indonesia government is required to create a full-scale production of pinene based fuel.

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