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The Effect of Variations In The Composition And Type of Adhesive For Mixed Peat And Gelam Wood Briquettes on The Physical Characteristics of The Briquettes

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Abstract*— South Kalimantan has quite extensive peatlands, spread across various regions such as Barito Kuala, Banjar, Tapin, and Hulu Sungai Regencies. In these peatlands, gelam trees are often found growing rapidly and possessing various benefits, both for industrial and environmental purposes. With wise management, peat can be used as an environmentally friendly raw material for briquettes, while gelam wood can be utilized to improve the quality of the briquettes. In this study, mixed peat and gelam wood briquettes were made with various compositions (100%:0%, 80%:20%, 60%:40%, 50%:50%, 40%:60%, 20%:80%, and 0%:100%) and types of adhesives (palm sugar and damar resin). To determine the performance of the briquettes, physical characteristics were tested in the form of water content, ash content, volatile matter content, calorific value, and fixed carbon. Test results show that gelam increases the calorific value and volatile matter content but reduces the fixed carbon content, while peat increases the fixed carbon content but lowers the calorific value. Damar adhesive is superior in increasing calorific value and reducing ash content compared to palm sugar. The best briquette combination is ≥60% gelam with damar adhesive for fast, high-energy combustion. For slow, stable combustion, a dominant peat composition with damar adhesive is more suitable.

Keywords— Peat, Gelam wood, briquettes, Physical characteristics of briquettes.

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I. INTRODUCTION

Indonesia's energy needs continue to increase in line with population growth and economic activity. However, heavy dependence on fossil fuels such as oil and coal poses a serious problem due to its environmental impact and limited resource reserves [1,2]. Therefore, the development of alternative energy sources that are renewable, environmentally friendly, and easily accessible to the public is crucial, especially in areas rich in biomass potential such as South Kalimantan [3,4]. South Kalimantan has significant potential in peat and local woody biomass resources. The vast peatlands spread across the Barito Kuala, Banjar, and Tanah Laut regions store substantial carbon reserves and can be utilized as an alternative fuel in the form of briquettes [5,6]. However, using peat as a sole fuel has drawbacks, such as high water and ash content and significant exhaust emissions [7] [8].

Meanwhile, gelam wood (Melaleuca cajuputi), which grows abundantly in swampy areas and marginal lands of South Kalimantan, has a high calorific value, low ash content, and sustainable availability [9,10]. The combination of peat and gelam wood as the base material for briquettes has the potential to produce products with more stable, efficient, and environmentally friendly combustion characteristics [11,12]. Several studies have shown that mixing the two types of biomass can improve briquette quality in terms of density, compressive strength, moisture content, calorific value, and combustion rate [13–15]. Furthermore, the use of mixed briquettes can also be a low-cost energy solution for rural communities, especially those living near peatlands and production forests [16][17].

The development of mixed briquettes is highly relevant in supporting national renewable energy policies and sustainable peat management. In South Kalimantan, this potential has not been optimally utilized, so further research is needed to evaluate the physical and combustion characteristics of mixed peat and gelam wood briquettes [18–20]. The briquette research aims to identify the effect of material composition on the physical quality (moisture content, ash content, density, compressive strength) of mixed peat and gelam wood briquettes sourced from South Kalimantan. The results of this research are expected to provide scientific and practical contributions to the development of local biomass-based energy [21,22].

II. METHOD

To produce briquettes from a mixture of peat and gelam wood, the following steps must be taken.

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A. *Material Preparation*

The preparation of materials to be used in this research is as follows:

1. The peat material was sourced from the Landasan Ulin area of Banjarbaru, and the gelam wood was sourced from the Trikora area of Banjarbaru.

Figure 1. Peat

2. The peat was sun-dried for 3 days to reduce its water content.
3. The gelam wood was chopped using a chopper to obtain gelam wood powder and then dried for 2 days.

Figure 2. Gelam Wood Was Chopped

4. The sun-dried peat was then oven-dried for 1 hour at 100°C–120°C to further dry the peat.
5. The sun-dried gelam wood was then oven-dried for 1 hour at 100°C–120°C to further dry it.
6. The peat and gelam wood are then sieved using an MBT sieve shaker and a 40-mesh sieve. This is done to ensure uniform particle size for the briquettes.

B. *Making the Palm Sugar and Resin Adhesive*

1. Prepare the palm sugar, then cook it with water in a ratio of 20 grams of palm sugar to 20 ml of water, and stir until thoroughly mixed. The resin, which is still in large chunks, is then ground into a powder.
2. In this study, 5 grams of starch adhesive was added to each briquette, per 100 grams of briquette weight.

C. *Mixing the Briquette Ingredients*

1. Peat, gelam wood, and resin were weighed using a digital scale to determine the percentage of each mixture. The peat and gelam wood mixtures were 100%:0%, 80%:20%, 60%:40%, 50%:50%, 40%:60%, 20%:80%, and 0%:100%.
2. The peat and gelam wood were then blended to combine the mixture. The adhesive was then added, and the briquette mixture was ready to be molded.

D. *Briquette Molding*

The briquette mixture, consisting of peat, gelam wood, and adhesive, is molded using a cylindrical mold. The briquette molding pressure is 40 kg/cm2 for each briquette variation, and the briquette is pressed for 1 minute.

E. *Briquette Drying*

To reduce the water content of the briquettes, which is mostly derived from the adhesive and peat, the briquettes are dried again in an oven for 1 hour at a temperature of 100°C–120°C.

Figure 3. Peat And Gelam Wood Briquettes

F. *Briquette Testing*

The dried briquettes are ready to undergo physical testing of the peat and gelam wood mixture, including moisture content, ash content, volatile matter content, calorific value, and fixed carbon. This is conducted at the Balai Standardisasi dan Pelayanan Jasa Industri (BSPJI) Banjarbaru Laboratory.

Figure 4. Physical characteristics test tool

III. Results and Discussion

The data from the test on the physical characteristics of the peat and gelam wood mixture briquettes are then processed into graphs and discussed.

A. *Water Content*

The water content of the peat and gelam wood briquettes in this study is shown in Figure 5.

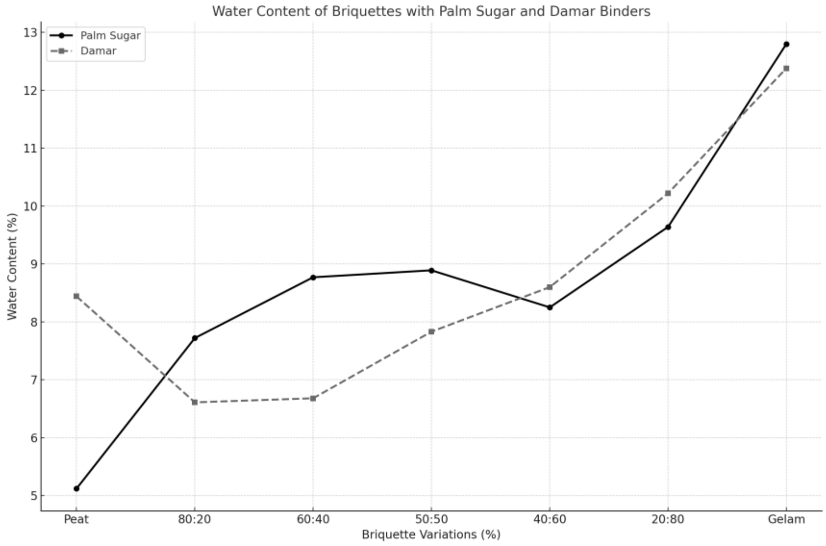

Figure 5. Moisture Content of Peat And Gelam Wood Briquettes.

Figure 5 shows the moisture content (%) of briquettes made from a mixture of peat and gelam wood with varying resin and palm sugar adhesives. For the resin adhesive, the initial moisture content of 100% peat briquettes was 8.44%, decreasing to 6.61–6.68% as the mixture contained more peat, then increasing sharply as the proportion of gelam wood increased, reaching 12.38% in 100% gelam wood briquettes. This indicates that resin has a high affinity for water when applied to gelam wood. Meanwhile, the palm sugar adhesive showed a lower initial moisture content of 5.12% (in 100% peat briquettes), gradually increasing to 9.64%, and reaching a peak of 12.8% in 100% gelam wood briquettes. Palm sugar moisture content was generally lower than that of resin in almost all compositions.

Peat tends to have a naturally low moisture content after drying due to its more porous nature [23]. Gelam wood has a relatively high hemicellulose and lignin content, which is more hygroscopic (readily absorbs moisture) [24], thus increasing the final moisture content of the briquettes. Damar adhesive is initially relatively hydrophobic, but can absorb water as it bonds with gelam wood due to the polar components in the resin. This explains the significant increase in moisture content at high gelam compositions. Palm sugar adhesive is more hydrophilic, but tends to form an even layer and retains moderate amounts of water, resulting in a relatively lower moisture content than damar, especially in peat-dominant compositions.

High moisture content (>10%) can reduce the calorific value of the briquettes because some of the heat energy is used to evaporate the water during combustion. Mixtures with a composition of 60:40 to 40:60 (peat:gelam) with palm sugar adhesive appear to have a moderate moisture content (8–9%), which is more suitable for fuel briquettes with good combustion quality. Selecting the right adhesive is important to balance mechanical binding strength and moisture content, in order to increase energy efficiency and shelf life of the briquettes [25].

B. Ash Content

The ash content of the peat and gelam wood briquettes in this study is shown in Figure 6.

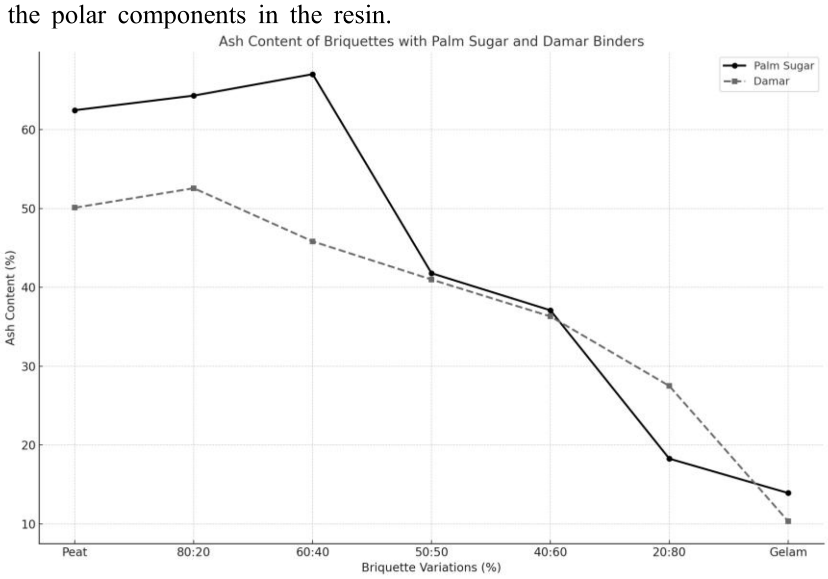

Figure 6. Ash Content of Peat And Gelam Wood Briquettes.

Figure 6 shows the ash content (%) of peat and gelam wood briquettes mixed with palm sugar and resin adhesives. Briquettes with a higher peat content have a higher ash content, reaching 62.46% for the palm sugar adhesive (100% peat), increasing to 67.03% for the 60:40 composition (peat:gelam). The ash content for the resin adhesive is lower, reaching 50.1% for 100% peat, gradually decreasing as the gelam proportion increases. Briquettes with a higher gelam content have a much lower ash content, dropping to 13.92% for the palm sugar adhesive, and even lower at 10.34%.

Peat naturally contains many inorganic minerals such as silica, iron oxide, and alumina [26], which do not burn completely, resulting in high ash content. Gelam wood has a higher organic content and lower mineral content [24], so the ash content decreases drastically with increasing gelam proportion. High ash content tends to be undesirable for fuel because it reduces combustion efficiency and increases the amount of residue that must be cleaned [27].

Palm sugar glue produces a higher ash content than damar, which is predominantly peat-based. This is related to the presence of mineral components such as potassium (K), calcium (Ca), and magnesium (Mg) in the palm sugar that remain after combustion [28]. Damar glue has a natural resin composition that leaves less inorganic residue [29], resulting in lower ash content, especially in mixtures with high gelam wood content. High ash content (>30%) reduces the calorific value because some of the material does not act as fuel [30]. Mixing higher gelam (≥50%) with damar glue produces a lower ash content (<20%), which is expected to improve combustion quality and simplify residue handling. The low ash content also supports the use of briquettes for household and small-scale industrial applications because it produces less crust and residual ash [31].

C. *Volatile Matter Content*

The volatile matter content of the peat and gelam wood briquettes in this study is shown in Figure 7.

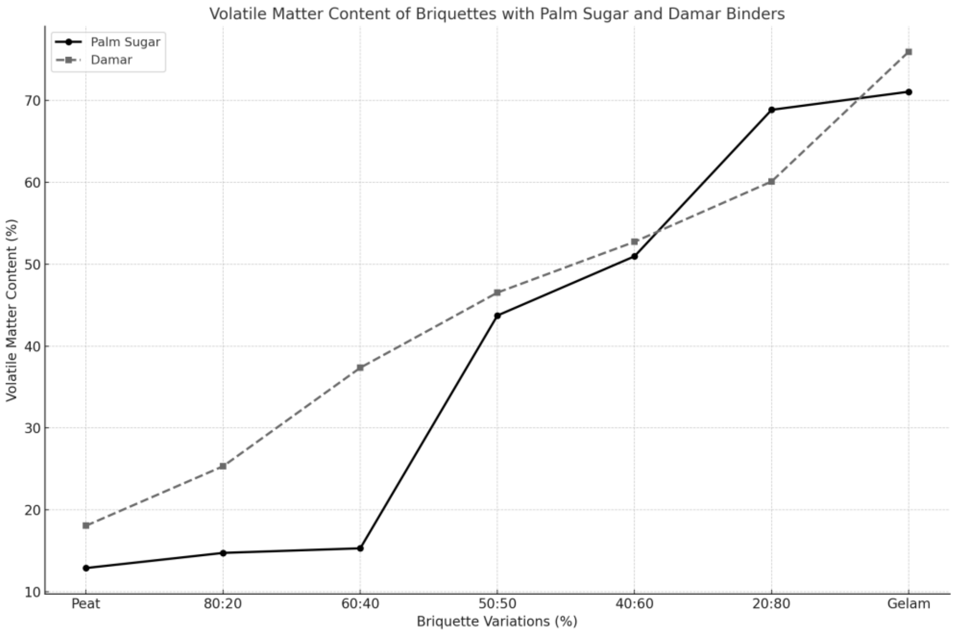

Figure 7. Volatile Matter Content of Peat And Gelam Wood Briquettes.

Figure 7 shows the change in volatile matter content (%) in peat and gelam wood briquettes mixed with palm sugar and resin adhesives. Briquettes with a higher peat content had lower volatile matter content: 12.91% (palm sugar) and 18.08% (resin). Increasing the gelam content significantly increased the volatile matter content, reaching 75.93% (palm sugar) and 71.05% (resin) in gelam briquettes (100%). This indicates that volatile matter content increases with increasing gelam proportion, regardless of the type of adhesive used.

Peat has a high mineral and bound carbon content, resulting in low volatile matter content [32]. Gelam wood contains more volatile components such as cellulose, hemicellulose, and lignin, which degrade at low to moderate combustion temperatures (200–500°C), thereby increasing volatile matter content [24]. The shift in raw material dominance from peat to gelam results in a significant increase in volatile matter content, which generally correlates with faster combustion and larger flames [33].

Palm sugar adhesive produces higher volatile matter levels than damar in almost all compositions due to its content of simple carbohydrates (sucrose, glucose, and fructose), which are more volatile during combustion [34]. Resin-based damar adhesive has a lower volatile fraction, resulting in slightly lower volatile matter levels. This difference is clearly visible in low-gelam mixtures, but becomes smaller in gelam-dominant mixtures due to the greater contribution of volatile matter from gelam wood.

High volatile matter levels (>60%) generally result in easy and rapid combustion [35], but can accelerate fuel consumption and therefore need to be balanced with adequate density and fixed carbon content. Briquettes with a high proportion of gelam and palm sugar adhesive are more suitable for applications requiring rapid combustion (e.g., household use). Briquettes with a higher proportion of peat and damar adhesive are more suitable for slow and sustained combustion (e.g., industrial processes).

D. Fixed Carbon Content

The fixed carbon content of the peat and gelam wood briquettes in this study is shown in Figure 8.

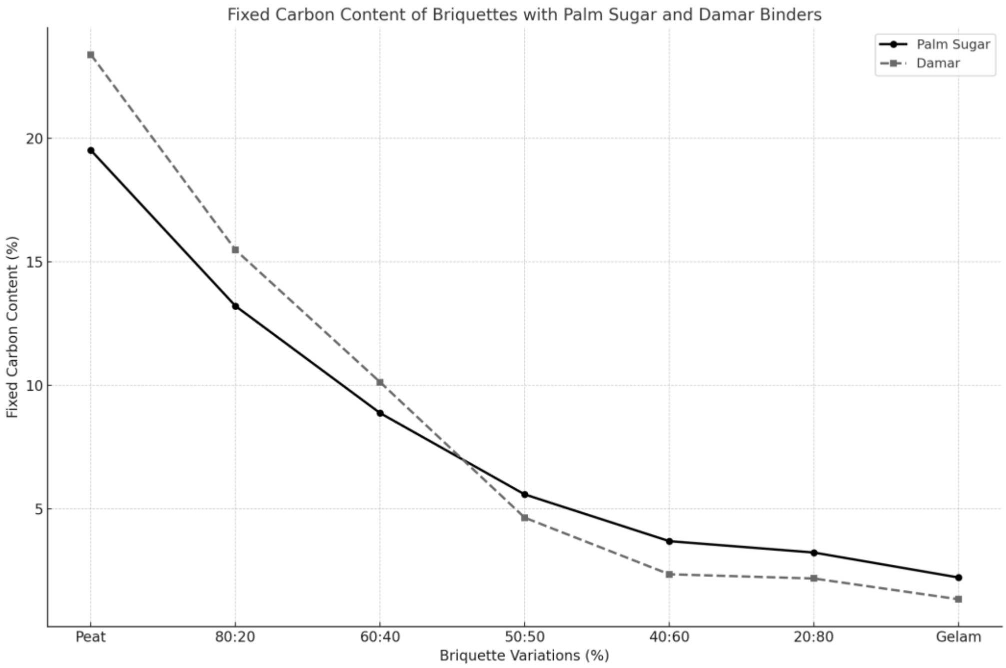

Figure 8. Fixed Carbon Content of Peat And Gelam Wood Briquettes.

Figure 8 shows a decrease in fixed carbon content as the raw material composition shifts from peat to gelam wood. Peat briquettes (100%) have the highest fixed carbon content, both for the resin adhesive (23.38%) and the palm sugar adhesive (19.51%). The fixed carbon content decreases gradually with increasing proportion of gelam wood, with a 60:40 (peat:gelam) mixture decreasing to around 8.88–10.13% and a 40:60 (peat:gelam) mixture decreasing to 3.7–5.59%. 100% gelam briquettes have the lowest fixed carbon content, both for the resin adhesive (1.35%) and the palm sugar adhesive (2.23%).

Peat has a high content of aromatic carbon and carbonized organic compounds, resulting in a larger fixed carbon fraction [36]. Gelam wood is dominated by volatile components (cellulose, hemicellulose, lignin) that readily decompose at low temperatures and produce little fixed carbon after combustion [24]. The greater the gelam wood fraction in the mixture, the lower the fixed carbon content.

Damar adhesive increases fixed carbon slightly more than palm sugar adhesive, especially in peat-dominant mixtures. This is because damar contains aromatic resins that leave a carbon residue after combustion [37]. Palm sugar adhesive contains simple carbohydrates that readily decompose and do not contribute much fixed carbon after combustion. The difference between the two is not significant in gelam-dominant mixtures, as the nature of the raw material is more dominant.

A high fixed carbon content (>15%) is important for slow combustion and a stable flame with more even heat release [25]. A low fixed carbon content (<5%) indicates a fuel that ignites quickly but burns quickly, making it less efficient for long-term applications. Briquettes with a high peat proportion (≥60%) and damar adhesive provide a higher fixed carbon content, making them suitable for industrial fuels requiring stable heat. Briquettes with a high gelam proportion are suitable for applications requiring fast combustion, such as household use.

E. Calorific Value

The calorific value of the peat and gelam wood briquettes in this study is shown in Figure 9.

Figure 9 shows the increase in calorific value (cal/g) as the raw material composition shifts from peat to gelam wood. Peat briquettes (100%) with palm sugar binder yield 425.88 cal/g, and those with resin binder yield 1633.58 cal/g. Significant increases occurred with increasing gelam fraction in the 80:20 (peat:gelam) mixture, reaching 1365.31–2830.06 cal/g, the 60:40 (peat:gelam) mixture reaching 2462.17–3293.58 cal/g, and the 40:60 (peat:gelam) and 20:80 (peat:gelam) mixtures continued to increase, reaching 100% gelam: 3999.65 cal/g (palm sugar) and 4136.75 cal/g (resin). In general, the resin adhesive produced a higher calorific value than palm sugar at each composition.

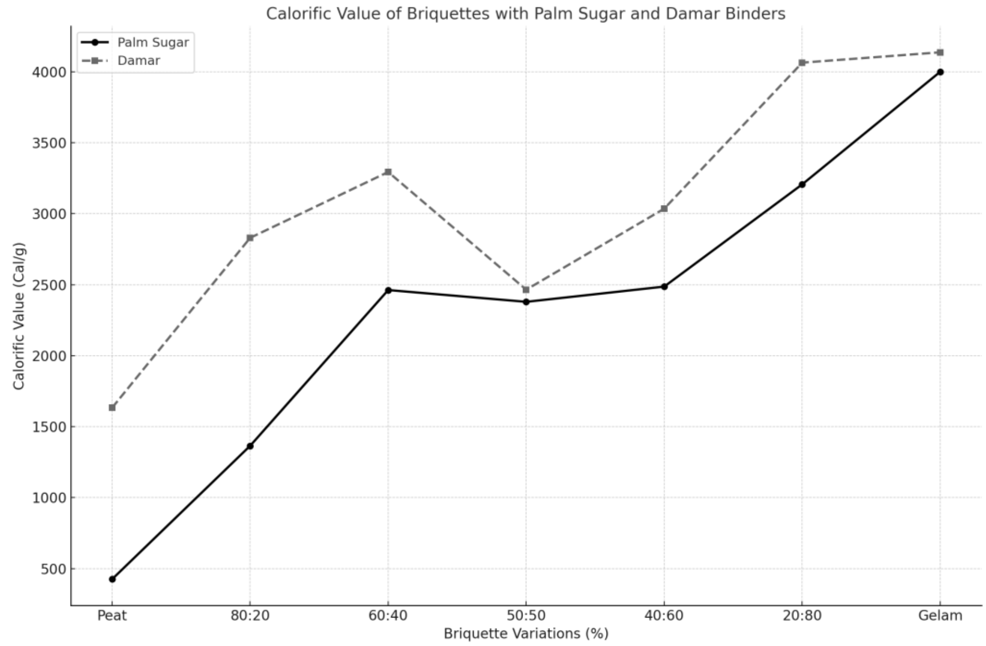

Figure 9. Calorific Value of Peat And Gelam Wood Briquettes.

Peat has a high ash content and lower fixed carbon content, resulting in a lower calorific value. Gelam wood is rich in solid organic compounds (cellulose, lignin) with a higher carbon content and lower ash, thus increasing the calorific value. Increasing the gelam proportion improves the quality of the briquette fuel.

Damar adhesive increases the calorific value because it contains aromatic resins that burn completely and add heat energy. Palm sugar adhesive contains more carbohydrate components that easily degrade into volatile substances and leave little residual energy, resulting in a slightly lower calorific value. The difference in calorific value between the two adhesives is most significant in mixtures with a high peat proportion.

A high calorific value (>4000 cal/g) indicates good fuel quality for both household and industrial applications [38]. A high gelam composition (≥60%) with damar adhesive provides the best performance, combining a high carbon content and more efficient combustion. Briquettes made with pure peat have a lower calorific value, making them less ideal for applications requiring high, sustained heat.

IV. Conclusion

The research results show that gelam can increase the calorific value and volatile matter but reduce the fixed carbon content, while peat increases the fixed carbon content but lowers the calorific value. Damar adhesive is superior in increasing the calorific value and reducing the ash content compared to palm sugar. The best briquette combination is with gelam ≥60% with damar adhesive for fast burning and high energy. For slow and stable burning, a dominant composition of peat with damar adhesive is more suitable.

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