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# Circular Economy Approach for Sustainable Tree Litters Waste Management, study case in Universitas Diponegoro

*Ambariyanto[1,4], Yos Johan Utama[2], Denny Nugroho Sugianto[1,4], Dessy Ariyanti[*3,4,5], Farida Diyah Hapsari[4,5]*

[1]Faculty of Fisheries and Marine Science, Universitas Diponegoro
Jl. Prof. Soedarto, SH Tembalang, Semarang, Indonesia 50275
[2]Faculty of Law, Universitas Diponegoro
Jl. Prof. Soedarto, SH Tembalang, Semarang, Indonesia 50275
[3]Faculty of Engineering, Universitas Diponegoro
Jl. Prof. Soedarto, SH Tembalang, Semarang, Indonesia 50275
[4]SDGs Center Universitas Diponegoro
Jl. Prof. Soedarto, SH Tembalang, Semarang, Indonesia 50275
[5]Center of Advanced Material for Sustainability Universitas Diponegoro
Jl. Prof. Jacub Rais, Tembalang, Semarang, Indonesia 50275
*corresponding author: dessy.ariyanti@che.undip.ac.id

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**Abstract.** Universitas Diponegoro, with an open forest area and planted vegetation of 30 – 40%, produced vast amounts of organic waste, especially tree litter. Piles of tree litter are everywhere if it is not properly managed. Universitas Diponegoro has taken a comprehensive approach to handling leaf and tree litter by converting it into economically valuable and beneficial products to meet the objectives of SDGs 12, which are focused on Responsible Consumption and Production. Through the Technical Implementation Unit for Occupational Safety, Health, and Environment (UPT K3L) Universitas Diponegoro has pyrolyzed tree branches to create liquid smoke and anaerobically converted leaf waste into compost. Later, the liquid smoke produced by pyrolysis and compost can achieve the consumer demand standard. In addition, from the policy approach, it is mandatory for every building to handle tree litter surrounds into compost using composting pits and composting bags. The circular economy idea has been incorporated into waste management at Universitas Diponegoro.

## Keywords:

Circular economy, waste management, tree litter

## 1. Introduction

Material deemed to have little or no value by producers or consumers is referred to as waste [1], [2]. Different types of waste streams exist, such as non-hazardous and hazardous waste from homes, businesses, industries, and institutions. The amount of waste produced is rising quickly. In addition, practically all human activity—including that of universities—produces garbage [1]. Indirect or direct effects on the environment are caused by energy, water, and resource usage patterns that are influenced by student, faculty, administrative, and other activities. There could be an increase in rubbish production, particularly from leaves and twigs, as well as air and water contamination [3].

The term "leaf litter and twigs" denotes the desiccated remains of leaves and twigs fallen from trees. As a result of inadequate watering, plants may shed their foliage. In response to the reduced water reserves in the soil, the quantity of leaf litter and dried twigs increases during the dry season, which prompts trees to lose their leaves. This occurs frequently in tropical regions such as Indonesia. The unpredictable weather that global warming generates is causing trees to lose their leaves more frequently. As a result, the quantity of leaves and branches increases. Twigs and leaf detritus constitute an enormous environmental concern. Leaf debris and twigs that are not properly managed can result in long-term environmental issues and exacerbate existing environmental conditions. Disease, ecosystem damage, and drainage line obstruction are all adverse consequences of inadequate refuse management [4], [5].

Regardless of how long waste management strategies have been in place, there is always space for improvement. The most recent initiatives to enhance waste management procedures, notably for leaf litter and twigs, have concentrated on improving trash treatment by implementing well-known concepts such as the 3Rs (Reduce, Reuse, and Recycle). These programs fail to maximize waste's potential value. Circular economy principles seek to create a closed-loop economy by maximizing the use value of materials, as opposed to improved waste management or treatment technologies that still send resources to landfills [6], [7].

The circular economy ideas go beyond traditional approaches to waste management. These guidelines prioritize the recycling of resources from items at the end of their useful lifetimes as raw materials for the production of new ones, as well as the development of more efficient design and manufacturing techniques to eliminate the concept of waste. Incorporating the principles of the circular economy is not without its challenges [8]. Tree litter waste management in a circular economy entails the establishment of a closed-loop system that continuously repurposes tree litter, including fallen leaves, twigs, and branches, thereby mitigating waste and optimizing resource efficiency. This method assists in the reduction of the environmental impact of refuse and transforms what is traditionally regarded as waste into valuable resources. The circular economy approach for sustainable tree debris waste management was the subject of this paper, which also included a case study of its implementation within the university that can be a best practice for university waste management.

Incorporating the principles of the circular economy into tree litter waste management in higher education institutions offers multiple environmental, economic, and educational advantages. The circular economy, focused on minimizing waste and maximizing resource efficiency, encourages reusing, recycling, and regenerating materials. By applying these principles to tree litter waste, higher education institutions can address sustainability challenges while fostering innovation and awareness among students. Effective waste management is often a significant expense for higher education institutions. Traditional disposal methods like landfill use or incineration incur costs, including transportation fees and tipping charges. By implementing a circular economy model for tree litter waste, universities can reduce these expenses. For example, producing compost or mulch from tree litter can offset the cost of purchasing commercial soil amendments for campus landscaping projects. Institutions can also explore using bioenergy technologies, such as biomass gasification or anaerobic digestion, to convert tree litter into renewable energy. This energy can be used to power campus facilities, contributing to lower energy costs and greater energy self-sufficiency. The economic benefits extend beyond immediate cost savings. Universities that adopt circular economy practices in tree litter management can attract grants, partnerships, and funding opportunities for sustainability initiatives. Many governmental and private organizations offer incentives for institutions that demonstrate a commitment to sustainability and resource efficiency.

One of the most significant benefits of applying a circular economy approach to tree litter management in higher education is the potential for educational enrichment. Universities are hubs for learning, research, and innovation. By integrating circular economy principles into waste management, institutions can create hands-on learning opportunities for students studying environmental science, agriculture, engineering, and economics. Students can participate in tree litter composting projects, research bioenergy technologies, and explore sustainable waste management practices in real-world settings. These experiences prepare students to become leaders in sustainability and circular economy practices, equipped with the knowledge and skills necessary to tackle global environmental challenges. Additionally, universities can become living laboratories for sustainable practices. Research on optimizing composting processes, developing new bioenergy technologies, and enhancing nutrient recycling can flourish within the framework of a circular economy. Collaborative projects between students, faculty, and external partners can drive innovation and contribute to the development of new, sustainable technologies.

## 2. Methods

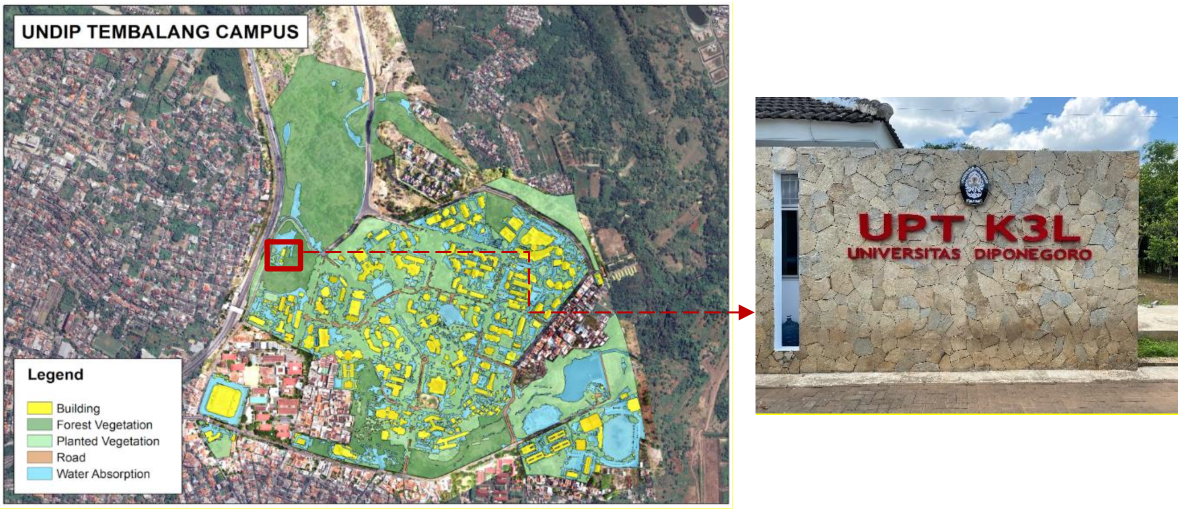


Figure 1. Undip Tembalang Campus Setting and Integrated Waste Management Site (TPST) location

This research was conducted in the campus of Universitas Diponegoro (Undip), Tembalang, Semarang. Data were collected from the waste management activity in every unit that has building and planted vegetation and pulled at the Integrated Waste Management Site (TPST) as depicted in Figure 1.

## 3. Results

Waste processing and recycling operations play a significant role in the development of a sustainable environment. Since there will be a lot of waste produced by university employees and students on campus, the institution should be concerned with waste management with a circular economy concept [9]. Undip has demonstrated a strong commitment to waste management as stated in Circular Letter No. 26 of 2022. All Undip academics, without exception, are obliged to participate in waste management in line with the tagline #UndipZeroWaste and the slogan "Your rubbish is your responsibility".

Undip's waste management falls under the jurisdiction of the Environmental and Occupational Safety and Health Technical Unit (UPT K3L) - specifically, the Environmental Subunit. The UPT K3L conducts initial assessments and initial observations of the current safety, occupational health, and environmental conditions to develop objective and precise plans [10]. The Integrated Waste Management Site (TPST) is specifically designed for the management of organic waste. The TPST is tasked with the collection, administration, and disposal of waste from 14 faculties, including Engineering, Social Science and Political Science, Medicine, Economics and Business, Law, Fisheries and Marine Sciences, Psychology, Animal and Agricultural Sciences, Humanities, Public Health, Sciences and Mathematics, Vocational School, and Postgraduate School, as well as other activity buildings [11]. The TPST mandates that every faculty unit must personally transport their organic trash to the TPST facility to optimize the efficiency of garbage collection. Consequently, the responsibility of managing organic waste falls upon both the academic community in every faculty. However, all buildings at the Undip main office consist of nonfaculty work units, and any organic waste produced is treated at the TPST Undip. Figure 2 displays the information.

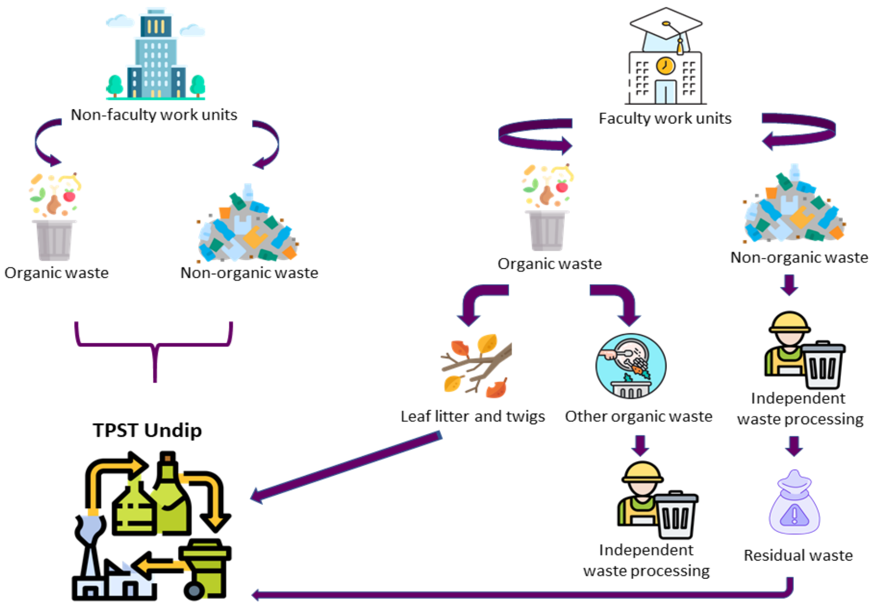


Figure 2. Regulations for waste processing at TPST Undip

In 2023, Undip produced an estimated 180.06 metric tons of organic waste. After being gathered and categorized based on their specific categories, they are subjected to treatment. From this organic waste, it is feasible to categorize it into two distinct types: food waste and leaves/twigs. The total quantity of food waste produced is 4.97 tons. This trash will be managed through the use of biopores and biogas generation. Specifically, 0.97 tons will be allotted for biopores, while the remaining 4.00 tons will be used for biogas production. Conversely, the combined quantity of leaves and twigs generated is approximated to be 175.09 tons. Figure 3 illustrates the monthly quantity of organic garbage generated.

Twigs and leaves constitute 97% of the total organic waste, while food comprises the remaining portion. The reason is that the proportion of land at Undip that is cultivated with plants is 30-40% of the whole area. Figure 4 displays the annual average of organic waste production for several faculties. The Faculty of Engineering generates a greater amount of organic waste compared to other faculties due to its larger department and student population. Every day, the Engineering faculty generates around 62.74 kg of organic waste.

Specifically, leaf litter and twigs will be further processed by TPST into compost and liquid smoke, respectively. This strategy offers a method to tackle environmental issues while adhering to SDG 12: Responsible Consumption and Production. Composting is a proven, efficient, and cost-effective process for recycling organic waste [12], [13]. It results in a final, stable, and sterilized product that may be utilized as an organic amendment [14]. Meanwhile, liquid smoke is a liquid that is produced by the breakdown of biomass. It can be produced by extracting biomass through pyrolysis [15], [16].

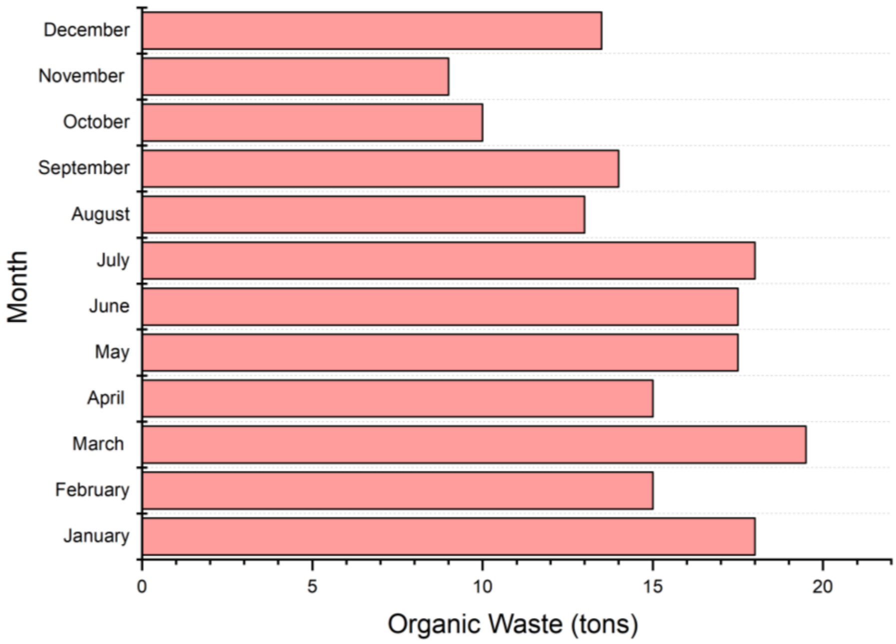


Figure 3. Undip's average monthly organic waste

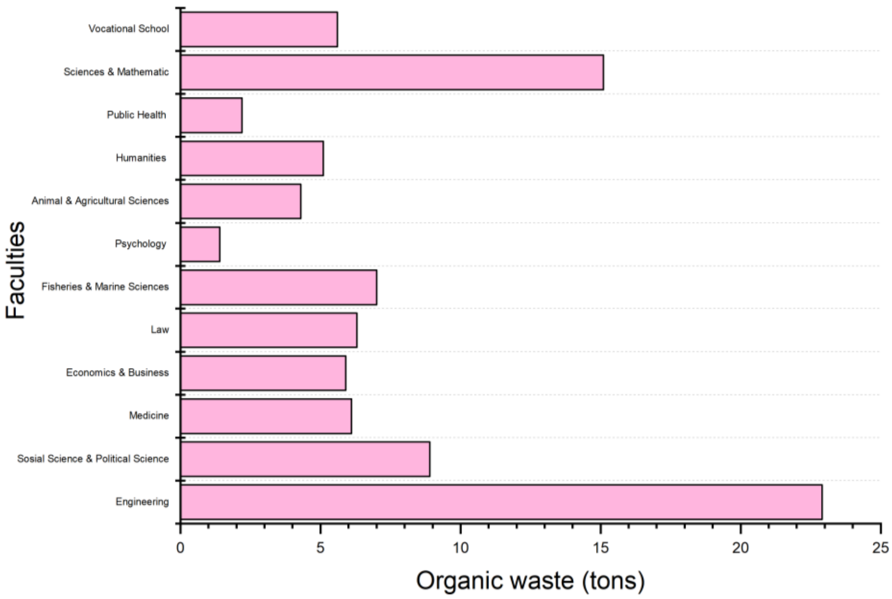


Figure 4. Annual average organic waste per faculty.

### 3.1 Processing leaf litter into compost

Composting, is one of the excellent methods for controlling leaf litter. Spontaneous occurrence happens when bacteria assist in the transformation of organic waste into humus. Microorganisms convert plant matter such as grass clippings, leaves, and twigs into compost, a substance that can be utilized as a soil amendment or as mulch. The composting technique aims to combine the natural processes of decomposition with the secure transformation of organic waste into organic fertilizer. Compost additionally improves soil structure, enabling the soil to retain the appropriate amount of moisture, nutrients, and water. It improves the composition of clay and sandy soils, resulting in increased richness, moisture retention, and a loamy texture. The chemical and physical qualities of compost can vary significantly depending on the type of organic material used for composting. Hence, the quality of compost plays a crucial role in determining its utility. There exist two categories of microorganisms that break down organic substances: (i) Anaerobic bacteria function in an environment without oxygen; (ii) Aerobic bacteria function in an environment with oxygen [17], [18].

The composting method used by TPST is anaerobic. There are a total of ten processing tanks available for the conversion of dry leaf litter into compost. Each tub has a capacity of three cubic meters for storing leaf litter and can produce one cubic meter of compost. The duration of the production process was three weeks. The image seen below depicts composting operations taking place at the Undip TPST. Undip's compost, referred to as U-Kompos, is available in two variants: coarse and fine. The process of transforming leaf litter into compost is depicted in Figure 5. U-Kompos has successfully fulfilled the specific requirements of the Indonesian national standard, SNI 19-7030-2004, and is available for purchase and sale. It is approximately 500-600 kg of compost can be produced per month. The price at which it is sold is approximately Rp—1,000 per kilogram. Table 1 displays the compost quality criteria outlined in SNI 19-7030-2004.


Figure 5. The activity of processing leaf litter into compost in TPST Undip

### 3.2 Processing of twig waste into liquid smoke

Condensation of biomass pyrolysis smoke produces liquid smoke, a gaseous mixture of solid and liquid particles. The biomass that results from pyrolysis is rich in lignocellulose, which includes cellulose, hemicellulose, and lignin [20]. The main components of liquid smoke are water, acids, carbonyls, and phenols derived from lignocellulosic biomass. Table 1 shows five types of chemical makeup. Liquid smoke's organoleptic, antibacterial, and antioxidant properties are characterized by a complex blend of chemical components. Antibacterial chemicals such as phenolic and acid compounds used to preserve food, wood, and other materials are found in liquid smoke. The breakdown of lignin produces phenol, whereas acetic acid is created from hemicellulose, and cellulose is transformed into furan during the pyrolysis process [20], [21], [22].

The process of producing liquid smoke from twig litter waste at the TPST begins by breaking them into little fragments. The twig litter chips will be burned in a pyrolysis reactor, which will be kept at a constant temperature of 400 ˚C. This process will take place continuously for a duration of 6 hours, starting from 10.00 AM to 04.00 PM every Monday to Friday. The smoke generated during pyrolysis is condensed by circulating water that enters and exits the system. The condensation process has finished, resulting in the acquisition of grade-three liquid smoke. One operation requires 170 - 180 kg of small twigs, approximately 1 cm in size, and produces 15-30 L of liquid smoke, depending on the amount of water in the twigs. TPST Undip produces 30 L per month. An increase in the twig litter's water content leads to greater liquid smoke production [5]. The flow diagram and pyrolysis conditions in TPST Undip can be observed in Figures 6 and 7, respectively.

Table 1. Compost quality standards [19]

| No | Parameter | Unit | U-Kompos | Min | Max |
|---|---|---|---|---|---|
| 1 | Water content | % | 34.75 | - | 50 |
| 2 | Temperature | ˚C | | | groundwater temperature |
| 3 | Color | | | | nigrescence |
| 4 | Odor | | | | earthy fragrance |
| 5 | Particle size | Mm | | 0.55 | 25 |
| 6 | Water binding ability | % | | 58 | - |
| 7 | pH | | 6.87 | 6.80 | 7.49 |
| 8 | Foreign material | % | | * | 1.5 |
| | Macro elements | | | | |
| 9 | Organic material | % | | 27 | 58 |
| 10 | Nitrogen | % | | 0.40 | - |
| 11 | Carbon | % | | 9.80 | 32 |
| 12 | Phosphor ($P_2O_5$) | % | 0.14 | 0.10 | - |
| 13 | C/N ratio | | | 10 | 20 |
| 14 | Potassium | % | | 0.20 | * |
| | Microelements | | | | |
| 15 | Arsen | mg/kg | | * | 13 |
| 16 | Cadmium (Cd) | mg/kg | | * | 3 |
| 17 | Cobalt (Co) | mg/kg | | * | 34 |
| 18 | Chromium (Cr) | mg/kg | | * | 210 |
| 19 | Copper (Cu) | mg/kg | | * | 100 |
| 20 | Mercury (Hg) | mg/kg | | * | 0.8 |
| 21 | Nikel (Ni) | mg/kg | | * | 62 |
| 22 | Lead (Pb) | mg/kg | | * | 150 |
| 23 | Selenium (Se) | mg/kg | | * | 2 |
| 24 | Zinc (Zn) | mg/kg | | * | 500 |
| | Other elements | | | | |
| 25 | Calcium (Ca) | % | 2,20 | * | 25.50 |
| 26 | Magnesium (Mg) | % | | * | 0.60 |
| 27 | Iron (Fe) | % | | * | 2.00 |
| 28 | Aluminium (Al) | % | | * | 2.20 |
| 29 | Manganese (Mn) | % | | * | 0.10 |
| | Bacteria | | | | |
| 30 | Fecal coli | MPN/gr | | | 1000 |
| 31 | Salmonella sp. | MPN/4 gr | | | 3 |

* The value is greater than the minimum or smaller than the maximum

Table 2. The Chemical Composition in Functional Groups of Liquid Smoke and Their Contributions to Product Properties [21]

| **Functional groups** | **Examples** | **Contribution to product qualities** |
|---|---|---|
| Phenols | Phenol, guaiacol, syringol, flavonoid | Smoky odor and flavor, antioxidant, antimicrobial, acidity |
| Organics acids | Acetic acid, propionic acid | Acidity, tartness, coloring, antimicrobial, peel-ability, protein coagulation |
| Carbonyls | 1-hydroxy-2-butanone, hydroxy acetaldehyde | Colouring, burnt-sweet aroma, textural changes, antimicrobial |
| Furans and fulfurals | 2-furfural, benzofuran | Sweet, fruity, and grassy flavor |
| Miscellaneous | Pyrazine, 1,6-anhydroglucose, 2-propenyl-butanoate | Elevating the overall sensory properties |

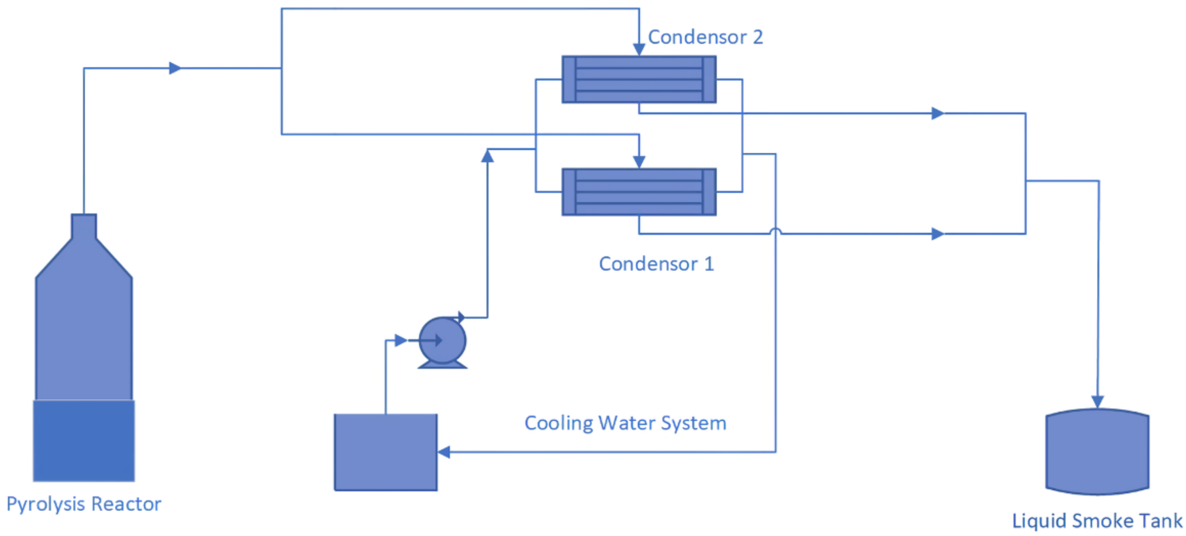


Figure 6. Flow diagram of pyrolysis at TPST Undip

The overall properties and makeup of biomass liquid smoke are affected by various elements, such as the conditions of pyrolysis (temperature, rate of heating, duration), the nature of the biomass, and the length of time it is stored [23], [24], [25]. The distillate obtained from the pyrolysis of Undip twig litter has a pH of 5. The pH values of this range do not meet the requirements set by the Japanese standard (See Table 3) for liquid smoke quality. The pH level is excessively high. For liquid smoke, a low pH value is optimal as the quality of the liquid smoke increases and the pH level decreases. Low-pH liquid smoke exhibits antibacterial and antioxidant properties. The resulting liquid smoke possesses a quite potent aroma. Concerning transparency, the resulting liquid smoke seems clear. According to

Japanese norms, only the clarity of liquid smoke complies. Currently, Indonesia has not established any regulations for liquid smoke derived from waste raw materials [26]. It is known that the Undip liquid smoke analyzed by GCMS contains carbonyl, acid, and phenolic components. Table 3 shows the composition in its entirety.

Figure 7. Pyrolysis condition in TPST Undip

Table 3. Liquid smoke properties

| Type of analysis | Undip Liquid Smoke | Japanese standard |
|---|---|---|
| pH | 5 | 1.50 – 3.70 |
| Specific gravity | not analyzed | > 1.05 |
| Smell | Strong | - |
| Color | Brown | Yellow brownish |
| Transparency | Not murky | Not murky |

Table 4. The chemical composition of Undip liquid smoke

| Peak | Area | % Area | Composition | Description |
|---|---|---|---|---|
| 1 | 44.191 | 0.99 | 2-Furancarboxaldehyde (CAS) Furfural | Chemicals utilized as fuel and solvents |
| 2 | 38.624 | 0.87 | SORBIC ACID, TRIMETHYLSILYL | Often used as a preservative. |
| 3 | 615.925 | 13.86 | Phenol, 2-methoxy- (CAS) Guaiacol | Essential oils, have the potential to be Green Fuel precursors |
| 4 | 408.401 | 9.19 | 2-Methoxy-4-methyl phenol | This is a constituent of creosote. Compared to |

| Peak | Area | % Area | Composition | Description |
|---|---|---|---|---|
| | | | | phenol, creosol is a less hazardous disinfectant. |
| 5 | 81.144 | 1.83 | Phenol (CAS) Izal | as a precursor in the production of plastics and medications |
| 6 | 126.860 | 2.85 | Phenol, 2-methyl- (CAS) o-Cresol | Raw castoreum is used in food and fragrances |
| 7 | 289.371 | 6.51 | Phenol, 4-ethyl-2-methoxy- (CAS) p-Ethylguaiacol | utilized in the manufacturing of wine, beer, and biooil |
| 8 | 125.526 | 2.82 | Phenol, 2-ethyl- (CAS) o-Ethylphenol | widely employed in phenolic resins sold commercially |
| 9 | 72.119 | 1.62 | Phenol, 2,5-dimethyl- (CAS) 2,5-Xylenol | utilized in the production of antioxidants |
| 10 | 116.457 | 2.62 | Phenol, 2-methyl- (CAS) o-Cresol | Raw castoreum is used in food and fragrances |
| 11 | 39.378 | 0.89 | Benzene, 1-ethyl-4-methoxy- (CAS) p-Ethylanisole | For producing detergents, colors, and lubricants |
| 12 | 78.349 | 1.76 | Phenol, 4-ethyl- (CAS) p-Ethylphenol | Widely used in commercial phenolic resins, it provides aroma to wine |
| 13 | 54.009 | 1.22 | Phenol, 4-ethyl- (CAS) p-Ethylphenol | Widely used in commercial phenolic resins, it provides aroma to wine |
| 14 | 271.284 | 6.10 | Phenol, 2,6-dimethoxy- (CAS) 2,6-Dimethoxyphenol (syringol) | utilized in food as a flavoring agent |
| 15 | 94.454 | 2.12 | 1,2,4-Trimethoxybenzene | Ingredients for making medicine |
| 16 | 139.678 | 3.14 | Ethanone, 1-(2,6-dihydroxy-4-methoxyphenyl) - (CAS) 2,6-Dihydroxy- 4-methoxyacetophenone | Food additive testing uses naturally occurring phenolic chemicals from plants. |
| 17 | 446.075 | 10.04 | Hexadecanoic acid (CAS) Palmitic acid | Palmitic acid |
| 18 | 41.591 | 0.94 | 8-DODECENOIC ACID, 11-HYDROXY, METHYL ESTER | chemicals used to manufacture cosmetics and soap |
| 19 | 39.047 | 0.88 | 2-TRIMETHYLSILOXY-4-(METHYLMETHOXY ETHER) | utilized as a polymer modification, coupling |

| Peak | Area | % Area | Composition | Description |
|---|---|---|---|---|
| | | | | agent, and crosslinker in research |
| 20 | 54.513 | 1.23 | Octadecanoic acid (CAS) Stearic acid | extensively utilized in industry (lubricants, food additives, soaps) |
| 21 | 1.086.042 | 24.43 | OCTADEC-9-ENOIC ACID | Fatty acid, found in edible vegetable oils such as peanut oil |
| 22 | 96.495 | 2.17 | 4,4-Dimethoxy-1-methylcyclohexane | Cyclic olefin, utilized in the production of polymers |
| 23 | 85.499 | 1.92 | 9,12-Octadecadienoic acid (Z,Z)-(CAS) Linoleic | Used for paint or varnish oil |

The composition of chemicals in liquid smoke derived from Undip twig litter can be altered by the type of wood utilized, the storage method employed, and the presence of oxygen or air [27]. This phenomenon is presumably caused by the variance in the composition of lignin, cellulose, and hemicellulose among different types of wood. The twig litter found in Undip consists of a wide variety of wood types. To compare, the chemical composition of liquid smoke from Undip twig litter (a mixture of several species of wood) and teak wood differs.

Table 5. Compositional differences between Undip liquid smoke and teak tree liquid smoke

| No | Undip Liquid Smoke | Teak Wood Liquid Smoke Components |
|---|---|---|
| 1 | 2-Furancarboxaldehyde (CAS) Furfural | Carbamic acid, phenyl ester |
| 2 | SORBIC ACID, TRIMETHLSILYL | Phenol, 2-methoxy- |
| 3 | Phenol, 2-methoxy- (CAS) Guaiacol | 2-Cyclopenten-1-one, 2-methyl- |
| 4 | 2-Methoxy-4-methylphenol | 2-Furanmethanol, tetrahydro- |
| 5 | Phenol (CAS) Izal | Phenol, 2-methyl- |
| 6 | Phenol, 2-methyl- (CAS) o-Cresol | 5-Hydroxy-2-heptanone |
| 7 | Phenol, 4-ethyl-2-methoxy- (CAS) p-Ethylguaiacol | Ethanone,1-(2-furanyl)- |
| 8 | Phenol, 2-ethyl- (CAS) o-Ethylphenol | 1-Acetoxy-2-propionoxyethane Phenol, 2-methyl-o-cresol |
| 9 | Phenol, 2,5-dimethyl- (CAS) 2,5-Xylenol | 2-Methoxy-4-methylphenol |
| 10 | Phenol, 2-methyl- (CAS) o-Cresol | 2-Cyclopenten-1-one, 3-methyl3-Meth |
| 11 | Benzene, 1-ethyl-4-methoxy- (CAS) p-Ethylanisole | Propanoic acid, 1-methylpropyl ester |
| 12 | Phenol, 4-ethyl- (CAS) p-Ethylphenol | 2,5-Dimethoxytoluene |
| 13 | Phenol, 4-ethyl- (CAS) p-Ethylphenol | 2-Furancarboxaldehyde, 5 Methyl |
| 14 | Phenol, 2,6-dimethoxy- (CAS) 2,6-Dimethoxyphenol (syringol) | 5-Hydroxy-2-Heptanone Phenol, 3,5-dimethyl- |

| No | Undip Liquid Smoke | Teak Wood Liquid Smoke Components |
|---|---|---|
| 15 | 1,2,4-Trimethoxybenzene | 2-Furanone, 2,5-dihydro |
| 16 | Ethanone, 1-(2,6-dihydroxy-4-methoxyphenyl) - (CAS) 2,6-Dihydroxy-4-methoxyacetophenone | 3,5dimethyl |
| 17 | Hexadecanoic acid (CAS) Palmitic acid | 2-Pentene, 3-ethyl-4,4dimethyl- |
| 18 | 8-DODECENOIC ACID, 11-HYDROXY, METHYL ESTER | |
| 19 | 2-TRIMETHYLSILOXY-4-(METHYLMETHOXY ETHER) | |
| 20 | Octadecanoic acid (CAS) Stearic acid | |
| 21 | OCTADEC-9-ENOIC ACID | |
| 22 | 4,4-Dimethoxy-1-methylcyclohexane | |
| 23 | 9,12-Octadecadienoic acid (Z,Z)- (CAS) Linoleic | |
| Ref: | Result of GCMS analysis | [28] |

In terms of composition, Undip liquid smoke is classified as liquid smoke grade 3. The classification of liquid smoke is as follows: Grade 3, it is not suitable to utilize liquid smoke as a food preservative due to its high concentration of carcinogenic tar. It is not employed for the purpose of preserving food; instead, it is utilized to eliminate odors from rubber and to enhance the resistance of wood preservatives against termites. Grade 2: liquid smoke that has been refined through redistillation. The objective of the redistillation method is to remove harmful substances such as benzo(a)pyrene. Formalin can be used as a replacement for preserving smoked meat, fish, or milkfish. The color is brownish, with a slightly acidic taste and a light smoky scent. Grade 1: Various distillation techniques yielded this liquid smoke. This variety of liquid smoke can be used as a taste enhancer and a preservation method for pre-prepared food products such as tofu, meatballs, and wet noodles. Grade 1 liquid smoke is the highest quality, characterized by its transparency, pale yellow color, somewhat sour taste, and lack of scent.

Converting leaf and twig litter into liquid smoke and compost could yield financial advantages. Currently, only U-Kompos products are available for sale. Before its sale, further development is required for liquid smoke, which is classified as grade 3. This concept is commonly known as a circular economy. The circular economy serves as a powerful concept to establish connections between resource utilization, waste, and emissions. It also aids in combining environmental policies (related to outputs) with economic policies (related to inputs).

## 4. Conclusion

Universities that adopt circular economy principles demonstrate their commitment to sustainability, an increasingly important value for students, faculty, and the broader community. A circular approach to managing tree litter waste aligns with the growing demand for environmentally responsible practices in higher education institutions. A sustainable waste management program that emphasizes the reuse of tree litter can also serve as a powerful tool for community engagement. Campus stakeholders—students, staff, faculty, and local-residents—can be involved in tree planting initiatives, composting workshops, and educational campaigns about the circular economy. These efforts not only promote environmental stewardship on campus but also extend the benefits of sustainability to the surrounding community. Undip is an educational institution dedicated to consistently applying the concepts of responsible waste management in line with SDGs 12: Responsible Consumption and Production. These endeavors are evident in handling leaf litter and twigs, which are transformed into compost and liquid smoke. Organic waste ceases to be a nuisance and instead becomes a profitable commodity through appropriate processing. This concept aligns with the principles of a circular economy, which emphasizes the utilization of garbage as a valuable economic resource.

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