Universal Journal of Public Health 13(2): 504-510, 2025 http://www.hrpub.org
DOI: 10.13189/ujph.2025.130222

# Harnessing Liquid Smoke: Quality Evaluation of Organic Waste Combustion in Smokeless Incinerators

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*Received September 17, 2024; Revised March 11, 2025; Accepted March 20, 2025*

***Cite This Paper in the Following Citation Styles***

***(a):*** *[1] Andi Rafika, Syamsuar, Hasnawati Amqam, Erniwati Ibrahim, Wahiduddin, Balqis , "Harnessing Liquid Smoke: Quality Evaluation of Organic Waste Combustion in Smokeless Incinerators," Universal Journal of Public Health, Vol. 13, No. 2, pp. 504 - 510, 2025. DOI: 10.13189/ujph.2025.130222.*

***(b):*** *Andi Rafika, Syamsuar, Hasnawati Amqam, Erniwati Ibrahim, Wahiduddin, Balqis (2025). Harnessing Liquid Smoke: Quality Evaluation of Organic Waste Combustion in Smokeless Incinerators. Universal Journal of Public Health, 13(2), 504 - 510. DOI: 10.13189/ujph.2025.130222.*



**Abstract** Waste Organic consists of food scraps, agricultural waste, and other natural materials that can be decomposed and returned to the environment. Incinerators are one of the best technologies for waste management. Liquid smoke is a distillation or condensation of vapor from indirect or direct combustion of materials that contain a lot of carbon and other compounds. This study aims to analyze the quality of liquid smoke produced by smokeless waste combustion devices using organic waste. This research is a quasi-experiment, analyzing the quality of liquid smoke produced from burning organic waste based on the duration of burning time. Based on the duration of burning time of 15 and 25 minutes the results of the analysis on the parameters of total acid, total phenol, N-Total, phosphorus, potassium, C-Organic, and pH in the samples of straw waste, coconut pulp waste and food waste have no effect or no significant difference in the quality of the parameters tested. This can be seen from the significant value (sig) which has a value> 0.05. The quality of liquid smoke produced using a smokeless waste combustion device has not met the standards of the Decree of the Indonesian Minister of Agriculture number 261/KPTS/SR.310/M/4/2019 concerning minimum technical requirements for organic fertilizers. Smokeless waste combustion devices can be used to process waste but the liquid smoke produced cannot be used as liquid organic fertilizer.

**Keywords** Garbage, Burning Equipment, Liquid Smoke

## 1. Introduction

Organic waste is one of the components of urban waste that has a large enough volume and is a serious problem for both the government and the community, because until now there has not been an appropriate solution to handle it [1]. The negative impacts caused by waste include environmental pollution (large amounts of waste can result in environmental pollution, land, air, and water environments), sources of disease (garbage that accumulates and disturbs results in unpleasant odors to the emergence of various diseases such as vomiting, diarrhea, digestive diseases etc). Waste is one of the polluting materials that becomes very dangerous for ecosystems and human health [2]. There are three types of technology that are currently widely applied for waste management, namely waste composting technology, waste incineration technology, and waste recycling technology [3]. Poorly managed waste can pollute groundwater, cause ecosystem damage, and disrupt wildlife [4].

The most effective way to deal with waste is by burning, but the results of combustion will cause pollution that can pollute the air and have an impact on the environment [5]. Smokeless Waste Combustion Tool is a tool used to change the shape of waste into a smaller size. Size changes can reach 50.0-90.0% of the previous volume [6]. The use of smokeless burning equipment is the most appropriate thing in overcoming problems related to waste handling, because with this tool it does not produce smoke that pollutes the environment [7].

The utilization of liquid smoke from the combustion of smokeless organic waste is an innovation that contributes to the reduction of environmental pollution and the improvement of the quality of the products produced. The quality of liquid smoke is greatly influenced by environmental factors and the combustion method used. Previous studies have shown that environmental factors, such as temperature and humidity, not only affect the pyrolysis process, but also determine the composition of compounds formed in liquid smoke, which may have implications for its safety and effectiveness in health applications and disease vector control [8]. Liquid smoke produced under non-optimal conditions has the potential to contain hazardous compounds that can pollute the air and impact the respiratory health of the surrounding community.

In addition, in the context of environmental health, waste monitoring and management are essential to prevent various health risks. In addition, waste that is not managed properly can become a habitat for disease vectors, such as rats and ectoparasites, contributing to the spread of pathogens that cause leptospirosis and other zoonotic diseases [9]. Liquid smoke in this process is obtained by condensing the smoke produced through the pyrolysis reactor chimney. The process of condensing smoke into liquid smoke is very beneficial for the protection of air pollution caused by the process [1].

Consequently, researchers are interested in exploring the topic through a study titled "Harnessing Liquid Smoke: Quality Evaluation of Organic Waste Combustion in Smokeless Incinerators".

## 2. Material and Methods

This research is quasi-experimental research, namely this research analyzes the quality of liquid smoke produced from burning organic waste based on the duration of burning time.

The image in figure 1 illustrates a smokeless waste incinerator designed to mitigate the negative environmental impacts of waste disposal. This device is made up of several key components, including a combustion chamber, air ducts, and a filtration system. The combustion chamber operates at high temperatures, allowing it to efficiently break down waste materials and minimize the production of harmful gases. The air ducts facilitate the flow of air needed for optimal combustion, ensuring that the process occurs efficiently and safely.

**Figure 1.** Plan of a Smokeless Waste Incinerator

In addition, the advanced filter system plays a critical role in capturing smoke and other pollutants produced during the incineration process. This system effectively traps particulate matter and prevents harmful substances from being released into the atmosphere. As a result, the smokeless incinerator not only contributes to effective waste disposal but also significantly reduces air pollution, offering a sustainable and eco-friendly solution for managing solid waste.

Analysis of the quality of liquid smoke is testing the results of the output produced in the form of liquid smoke which is then each analyzed for chemical components, namely total acid, total phenol and macro nutrient analysis, namely total nitrogen, phosphorus, potassium, C-Organic, and pH. In this study, the combustion duration is set to evaluate two different burning times: 15 minutes and 25 minutes. The combustion process begins by burning straw waste, coconut pulp waste, and food waste individually for 15 minutes. After this initial phase, the burning continues with the same materials—straw waste, coconut pulp waste, and food waste—for an additional 25 minutes. The duration of burning time can affect the environmental impact, health, and efficiency of waste management itself. Although the duration of 25 minutes is better than 15 minutes in terms of burning efficiency and residue reduction, both durations still have significant positive impacts on the environment and health.

## 3. Results

The research was conducted from April to June 2024. Laboratory test analysis was carried out at the Biochemistry Laboratory of Hasanuddin University and Maros Agricultural Laboratory.

From the results of table 1, the highest temperature of burning waste at the 25th minute reached (190 ℃) with the type of straw waste sample. While the lowest temperature of burning waste in the 15th minute reached (87 ℃) with the type of food waste sample.

**Table 1.** Measurement Results of Temperature and Combustion Time Using Smokeless Waste Combustion Device

| Burning Time | Sample Type | Temperature |
|---|---|---|
| 15 Minutes | Straw Waste | 120 ℃ |
| | Coconut Pulp Waste | 91 ℃ |
| | Food Waste | 87 ℃ |
| 25 Minutes | Straw Waste | 190 ℃ |
| | Coconut Pulp Waste | 140 ℃ |
| | Food Waste | 104 ℃ |

The results of table 2 show that the highest total acid content at the 25th minute is (0.26%) in the type of sample, namely coconut pulp waste. While the lowest total acid level result is at the 15th minute (0.13%) in the type of food waste sample. The test results above show that the total acid level does not meet the requirements. The highest total phenol content was (0.5211%) at the 25th minute of the sample type, namely straw waste. While the lowest total phenol content result is (0.1996%) in the type of food waste sample.

The highest N-total level is at the combustion time of 25 minutes (0.11%) in the sample type, namely straw waste. While the results of the lowest N-total levels are at 15 minutes of burning time, namely (0.01%) in the sample types of straw waste, food waste and coconut pulp waste. The highest phosphorus level was (0.001%) at a combustion time of 25 minutes with sample types of straw waste, coconut pulp waste and food waste. While the lowest phosphorus level result is (0%) at the combustion time of 15 minutes with the type of all three types of samples. The highest potassium content was (0.002%) at a combustion time of 25 minutes and the sample types were straw waste, coconut pulp waste and food waste samples. While the lowest potassium content result is (0%) at a burning time of 15 minutes with the type of sample of food waste, coconut pulp waste and straw samples. The test results above show that potassium levels do not meet the requirements. The highest C-Organic content result is (0.05%) at a combustion time of 25 minutes with the type of sample that is straw waste. While the result of the lowest C-Organic content is (0.004%) at a burning time of 15 minutes the type of straw waste sample. The test results above show that C-Organic levels do not meet the requirements.

**Table 2.** Measurement Results of Chemical Components and Macronutrients in Liquid Smoke Output Results of Smokeless Waste Combustion Device

| Burning Time | Sample Type | Acid Amount | Phenol Amount | N-Amount | Phosphorus | Potassium | C-organik | pH |
|---|---|---|---|---|---|---|---|---|
| 15 minutes | Straw Waste | 0.13% | 0.0271% | 0.01 | 0 | 0 | 0.004 | 6.90 |
| | Coconut Pulp Waste | 0.13% | 0.0206% | 0.01 | 0 | 0 | 0.39 | 6.65 |
| | Food Waste | 0.13% | 0.0268% | 0.01 | 0 | 0 | 0.39 | 7.02 |
| 25 minutes | Straw Waste | 0.17% | 0.5211% | 0.11 | 0.001 | 0.002 | 0.05 | 4.05 |
| | Coconut Pulp Waste | 0.26% | 0.2209% | 0.07 | 0.001 | 0.002 | 0.03 | 6.27 |
| | Food Waste | 0.13% | 0.1996% | 0.08 | 0.001 | 0.002 | 0.02 | 7.06 |
| Quality standards | | **20-35%** | **25-40%** | **Minimum 0,5%** | **3-6%** | **3-6%** | **6%** | **4-9** |

* *Quality standards: SNI 8985:2021*

* *Quality standards: KMPRI 261/KPTS/SR.310/M/4/2019*

**Table 3.** Anova Test Calculation Results

| **Parameter** | **Result** | **Sum of Squares** | **df** | **Mean Square** | **f** | **Sig.** |
|---|---|---|---|---|---|---|
| **Total Acid** | Between Groups | 1865.333 | 2 | 932.667 | 0.084 | 0.921 |
| | Within Groups | 33257.566 | 3 | 11085.855 | | |
| | **Amount** | **35122.899** | **5** | | | |
| **N-Amount** | Between Groups | .004 | 2 | .002 | 0.120 | 0.891 |
| | Within Groups | .056 | 3 | .019 | | |
| | **Amount** | **.060** | **5** | | | |
| **Kalium** | Between Groups | .038 | 2 | .019 | 0.391 | 0.707 |
| | Within Groups | .145 | 3 | .048 | | |
| | **Amount** | **.183** | **5** | | | |
| **pH** | Between groups | 2.379 | 2 | 1.189 | 0.069 | 0.934 |
| | Within groups | 51.342 | 3 | 17.114 | | |
| | Amount | 53.721 | 5 | | | |

The results of table 3 show that the total acid, total phenol, N-Total, phosphorus, potassium, C-Organic, and pH in the straw waste, coconut pulp waste and food waste samples have no effect or no significant difference in the quality of the parameters tested. This can be seen from the significant value (sig) which has a value > 0.05.

# 4. Discussion

Testing of smokeless waste combustion equipment is carried out by including three types of organic waste samples, namely straw waste, coconut pulp waste and food waste as much as 375 grams using a comparison of burning times, namely 15 minutes and 25 minutes of combustion. Based on the combustion process that has been carried out by researchers, the highest temperature is in the type of straw waste 190 ℃ with a combustion time of 25 minutes. This is in line with research conducted by Overall that the combustion process using a smokeless waste combustion device carried out using 750 grams of dry organic waste material can be burned within 25 minutes with an average smoke particle yield of 28.312 Pt with a maximum temperature of 190 ℃. The effect of time applied can have a significant effect ($p>0.05$) on changes in pH value, density, total acid content and total phenol [10].

The duration of burning time can affect the environmental impact, health, and efficiency of waste management itself. Although the duration of 25 minutes is better than 15 minutes in terms of burning efficiency and residue reduction, both durations still have significant positive impacts on the environment and health. According to Putri et al. [11], the difference in time and temperature of each material is due to the different characteristics of each raw material seen from the amount of water content, density and particle size of the raw material. Smoke first comes out of the pyrolyzer after the pyrolysis process runs between 15 - 20 minutes and the pyrolyzer temperature is above 50 ℃. Liquid smoke first comes out after the pyrolysis process runs between 14 - 18 minutes and the pyrolyser temperature is above 80 ℃. The difference in time and temperature of each material is due to the different characteristics of each raw material seen from the amount of water content, density and particle size of the raw material.

In this study, the furnace construction material used is an iron drum with a capacity of 100 liters, tool height 52 cm, tool diameter 58 cm with an iron plate thickness of 0.9 mm. While in research [10] the material used as a pyrolysis reactor is a copper tank with a furnace wall thickness of steel around 8 mm, dimensions 120 cm high, 80 cm in diameter, with a non-permanent cover so that it can enter the material and take the remaining material easily. Inside the pyrolysis reactor, a furnace made of iron is installed at the same height as the reactor with a diameter of 40 cm which is given a small hole, which functions to deliver heat to all materials, and does not need a smoldering fire for the combustion process of the material [12]. The comparison of the combustion temperatures produced is also different due to the construction materials and the thickness of the material used as a furnace. Combustion temperature has a direct influence on the thickness of the furnace material [13].

Temperature is a parameter that affects the speed of chemical reactions, biological decomposition processes, and oxygen solubility in wastewater. Temperature is an important parameter in the operation of waste treatment units because it affects biological and physical processes. In addition, waste that has a high-water content causes a low combustion chamber temperature, because most of the heat energy is used to evaporate water. This causes an incomplete combustion reaction [12].

The test results show that the highest total acid content of liquid smoke is (0.26%) in coconut pulp waste. This is in line with research by Diatmika [14] that the highest average total acid is seen in pyrolysis at 200 ℃. This is because at 200 ℃ is the phase of decomposition of hemicellulose components that can form acidic compounds such as acetic acid compounds. Burning coconut pulp waste also produces acidic compounds such as acetic acid, formic acid, and others. The total acid content in these combustion products varies depending on the combustion conditions, the type of coconut pulp, and the analytical method used.

The highest total phenol content was found in liquid smoke from straw waste (0.5211%) with a combustion time of 25 minutes and a combustion temperature of 120 ℃. The amount of smoke produced is highly dependent on the characteristics of the raw materials used and the temperature reached during the process. This is in accordance with the opinion of Djatmiko et al. (1985) in Haji [1] which suggests the presence of chemical compounds in liquid smoke is influenced by the chemical content of the raw materials used and the temperature reached in the pyrolysis process. Rice straw contains 37.71% cellulose, 21.99% hemicellulose, and 16.62% lignin [15]. Phenol in liquid smoke is responsible for flavor formation in smoking products and also has antioxidant activity that affects shelf life [16].

Nitrogen is the main nutrient for plant growth, which is generally needed for the formation or growth of vegetating parts of plants, such as leaves, stems and roots. Based on the results of the analysis of macro nutrients for the highest N-Total content, the straw waste sample is 0.11%, with a burning time of 25 minutes. This research is in line with the results of research conducted [17], namely the Nitrogen content is 0.5%, based on these requirements it can be seen that all POC treatments in this study meet the N nutrient standards in POC, where N nutrients in the first POC were around 0.50-5.93%.

Based on the results of the analysis of macro nutrients for phosphorus levels, the highest result is at a combustion temperature of 25 minutes with the sample type of straw, coconut pulp and food waste samples, which is 0.001%.

The results of this study are in line with research conducted by Arinih [12] based on the results of reading the organic waste sample A P content is 0.55 mg/l and organic waste B is 7.80 mg/l. The test results show that the Phosphorus content of organic waste A and organic waste B does not meet the quality standards of liquid fertilizer. This is because the raw materials used and the formation of phosphorus in liquid organic fertilizer are influenced by various factors, including the type and source of raw materials, fermentation process, chemical and physical conditions during fermentation, and extraction methods. Phosphorus-rich raw materials, optimal fermentation, and proper environmental conditions all contribute to the high phosphorus content in liquid organic fertilizer.

Based on the results of the analysis of macro nutrients for potassium levels, the highest results were obtained with a combustion time of 25 minutes, namely in the straw, coconut pulp and food waste samples of 0.002%. Potassium is used to increase plant resistance to pests and diseases that plants need. In fruit waste there are organic materials such as Potassium (K) which can function to help the formation of proteins and carbohydrates, and strengthen the plant body so that leaves, flowers, and fruits do not fall easily. Potassium cannot be directly absorbed by plants, because it is still in the form of compounds that need to be broken down into K ions that are easily absorbed [18].

Based on the results of research conducted by Rani [19] on the use of rice straw waste, vegetable waste and sawdust as compost, the percentage of C-organic content of all treatments decreased between 2.64% and 6.73%. This indicates that microorganisms have eaten carbon as an energy source for their growth so that the amount of carbon decreases. The C-Organic nutrient content shows that the highest concentration is found in the type of liquid smoke with the type of straw waste sample, which is 0.005%. This is because the straw sample contains complete nutrients in the form of both macro and micro nutrients. The C-Organic nutrient content using three types of organic waste samples did not meet the quality standards of liquid organic fertilizer. The low C-Organic content is also influenced by the time and temperature used when burning organic waste samples.

The results of measurements made by Ichsanti [10] show that the pH value of coconut pulp waste is 3.2 - 4.1, indicating that the pH produced is acidic. However, the longer the time of the liquid smoke making process, the pH value of the resulting liquid smoke tends to decrease [10]. A low pH value affects the durability and shelf life of sapa products or their organoleptic properties because at a low pH microbes or bacteria as disturbers in the preservation process tend not to be able to live and multiply properly. A good pH value for organic fertilizer is around 6.5 - 7.5 (neutral). However, in research Aldian [20], the change in the pH value of compost starts from a slightly acidic pH due to the formation of simple organic acids, then increases in further incubation due to the breakdown of proteins and the release of ammonia.

Based on the analysis of nutrient content parameters, N-Total, phosphorus, potassium and pH using three types of organic waste samples, it shows that the three types of organic waste samples used that meet the standards are only pH quality as an ingredient in making liquid organic fertilizer. The provision of liquid fertilizers in the form of liquid smoke and organic fertilizers provides additional nutritional intake to plants and is one of the steps to minimize soil damage and prevent land degradation caused by the use of chemicals because liquid fertilizers contain small amounts of nutrients that plants can use directly as they come from organic materials.

Handling waste problems should not be burdened with government parties alone, but it is necessary to hold socialization related waste to foster public awareness and concern that waste problems can be reduced starting from the smallest environment, namely the household. Liquid smoke is the result of distillation or condensation of vapor from indirect or direct combustion of materials that contain a lot of carbon and other compounds [21].

Research on environmental health risk factors has also shown that poor environmental quality, including inadequate sanitation and water pollution, can increase the risk of infectious diseases such as schistosomiasis, which remains a public health problem in some parts of Indonesia [22]. Therefore, the application of environmentally friendly waste combustion technologies, such as smokeless incinerators, can be a solution to reducing disease vector populations and inhibiting the spread of environmentally-based infectious diseases. Furthermore, the use of technology-based information systems in environmental health monitoring has been shown to increase effectiveness in identifying and addressing risk factors contributing to various environment-based diseases [23].

### 4.1. Limitation

1. The efficiency of the smokeless combustion device may vary depending on the type and moisture content of the organic waste used.
2. The quality and composition of the organic waste used as input may differ significantly, affecting the consistency and quality of the liquid smoke produced.
3. The accuracy and precision of chemical analysis methods (e.g., gas chromatography or spectrometry) used to assess the liquid smoke’s composition might affect the reliability of the results.
4. External environmental conditions, such as humidity, temperature, and air pressure, can influence the combustion process and the quality of liquid smoke produced.

# 5. Conclusions

1. The highest temperature of burning waste at the 25 minute reached (190°C) with the type of straw waste sample. While the lowest temperature of burning waste in the 15 minute reached (87°C) with the type of food waste sample.
2. The results of chemical components on total acid and total phenol levels obtained from burning organic waste, namely total acid levels and total phenol levels, do not meet the standards.
3. The macro nutrient components, namely N, P, K, C-organic, and pH, were analyzed in liquid smoke from the three types of organic waste, namely straw, coconut pulp, and food waste. Among the combustion vapor results of the five macro nutrient components, only the pH component meets the requirements as raw material for making organic fertilizer.
4. The results are based on the combustion of waste carried out with different durations of time, namely 15 and 25 minutes on the parameters of total acid, total phenol, N-Total, phosphorus, potassium, C-Organic, and pH in straw waste samples, coconut pulp waste and food waste have no effect or no significant difference in the quality of the parameters tested. This can be seen from the significant value (sig) which has a value> 0.05.
5. This research is experimental, so there are still many obstacles in its implementation, both in making tools and when testing in the laboratory. Therefore, the results obtained have not met the standards, and the liquid smoke produced is not yet suitable for use as liquid organic fertilizer.

# Acknowledgements

The author would like to thank the Department of Environmental Health and the Research Ethics Commission of Hasanuddin University for processing documents and obtaining research permits.

# Conflicts of Interest

The authors declare no conflict of interest.

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