Experiment on Influent Parameters on Wood Vinegar Burning Process

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Abstract This research aims to develop a burning tank for making charcoal and experiment for the wood vinegar burning process using wood as raw material. To design, and operation of such a burning tank for making charcoal require a detailed understanding of parameters that affect the system performance. In the research, the device designed for testing and developing a burning system that can improve the distillation rate of wood vinegar. The developed system consists of two tanks, a burning tank for making charcoal, and a distillation tank for collecting wood vinegar. The burning tank for making charcoal made of steel with 400mm diameter and 600mm long for containing 15-20 kg of wood provides tight airflow and has two exhaust ducts attached to top and bottom of the tank side. The distillation tank for collecting wood vinegar has 24 copper pipes with a diameter of 12mm, and 400mm long, resulting in a condensing surface area of 0.36 m². The condensing pipes installed in 65 litres tank contains cool water with a temperature of 30 °C to 40 °C, used as media for removing the heat from those pipes surface. In the experiment, four influent parameters are investigated; two kinds of woods, three fire conditions of airflow rate, three moisture contents in woods are varied and two positions of exhaust duct are observed. The developed system tested by using 15 kg of Eucalyptus and River tamarind wood within 8 hours, producing 6.39L of yield wood vinegar. The experiment results show that the interaction between the new model designed and parameters significantly effect on the yield percent of wood vinegar collected. That is the effect of the prototype and those parameters can increase the wood vinegar 16 times compared to the conventional system.

1. Introduction
In a rural area, charcoal was made from wood by using an earthen kiln. The woods are often deadwood collected from the forest or sometimes bamboo is used. In addition, the charcoal then sells or use for cooking. Traditional kilns release very harmful smoke and pollution into the environment [1]. Recently, newer styles of the burning tank for making a charcoal have been studied to make a good quality charcoal and are suitable for adaption wood vinegar during a gasification process.

Wood vinegar is a liquid smoke, generated from the gas and combustion of fresh wood burning under airless condition. It is a dark liquid, contains more than 200 natural compounds primarily acetic acid, methanol, phenols, and formaldehyde [2]. Its principal components are acetic acid and methanol:
Acetic acid is used as a soil disinfectant, and methanol is used to increase crop yield utilizing less water, whereas phenols are known as a natural source for antioxidants [3]. Such attributes of its ingredients make it a better choice for sustainable farming thereby increasing the crop yield. Food and Fertilizer Technology Center [2] also shown that fruit trees produce increased amounts of fruit after applying wood vinegar in an orchard. It is also safe in the food chain living matters, especially insects that help pollinate plants. There are many researchers have been studied on types of wood vinegar. Most of the research has been taken in China and Japan. Wessapanet et al, [4] who investigated undertaken to develop a pyrolysis oven for the production of wood vinegar by using charcoal residual as fuel. The oven was designed with an inside chamber for the heat to be evenly distributed throughout the oven with a lid covered while Somsuk, et al. [5] who also investigated pyrolysis oven in wood vinegar production by developing a heat exchanger using copper tubes and uncondensable wood gas to reheat by passing to burning chamber. Yang, et al. [6] who studied influent of airflow rate and the moisture of fuel on biomass burning behaviors. The result from this research shows that primary air has a significant effect on the moisture evaporation, devolatilisation, and char burning. Increasing primary airflow initially increasing each of the process rates but it causes a decrease in the rates beyond a certain point (the critical airflow rate). Moreover, higher moisture in the fuel results in higher moisture evaporation rate. Shen et al, [7] who observed on the influent of oxygen supply and burning rate on emission factor as a result state that a fast burning or the burning with a low air supply amount could result in oxygen deficient atmosphere. In addition, increased air supply may cool the combustion temperature, both of which could lead to the change in the formation and emission of carbonaceous particulate matter. Chalermsan, et al. [1] who produced wood vinegar from a rural charcoal kiln and it used as plant protection. Jiang, et al. [8], also carried out an experiment of wood vinegar produced from pine nut shell continuous pyrolysis. Other researchers have focused on improving animal health by using a compound of wood vinegar mixing in animal food. Suzilawati [9] investigated the design and development of a pyrolysis system to produce wood vinegar by using rice husk as a raw material. Other researchers include Yamauchi; et al. [10] who investigated wood vinegar made of broadleaf tree bark carbonized has a testing effect on red mites by injection into their bodies. Now, this natural fertilizer is receiving much attention from researchers, organizations, and institutions in the region.

However, there is still a lack of detailed or no supporting documents on the experimental study of parameters for wood vinegar burning process and develop the distillation rate of wood vinegar using wood as raw material. The advantage of an experimental study can improve the distillation rate of wood vinegar and lies in its ability to reveal the detailed behavior of parameters in the burning process inside. The research investigates two kinds of woods, three fire conditions of airflow rate, three moisture contents in woods are varied and two positions of the exhaust duct. River tamarind and Eucalyptus wood are used as a raw material for the production process. This research aims to contribute a better understanding, controlling of wood vinegar burning process.

2. Methodology

2.1. Design concepts
Schematic of wood vinegar processing system shown in Figure 1. The system consists of five parts: (1) burning gate, (2) burning kiln, (3) pipe connecting between burning tank to distillation tank, (4) distillation tank, and (5) condensing tubes. The wood vinegar burning device designed to contain 15-20 kg of wood. It provides a gate for flowing the air into the tank for burning process. The burning tank uses Liquid Petroleum Gas (LPG) as fuel. The required temperature to heat the wood is about 120-430°C to give the good quality of wood vinegar under the amount of airless condition. The limit-air known as the incomplete combustion gases that are a mixture of volatile organic compounds pass through the connection pipe to the distillation tank. This has 24 copper pipes used as a condensing tube to be condensed into wood vinegar resulting in a condensing surface area of 0.362 m². The condensing pipes installed in a 65 liter-tank contains with cool water, which is used as media for removing the heat from those pipe surfaces.

2.2. Operation and structure design

The burning system consists of two main components: burning tank as shown in Figure 2 and distillation tank Figure 3. The burning tank has 400 mm diameter, 600 mm tall and 1.5 mm thickness. The sand residual is used as isolation to protect the heat loss from inside, shown in Figure 11. It is designed for wood burning under the airless condition and obtains the heat from the burning gate. The tank made of sheet metal. The kiln has a kiln hood at the outside tank used for LPG fuel heating as shown in Figure 12. The capacity of the tank is 0.075 m³ for wood. Two exhaust ducts with a 60 mm diameter and 150 mm long, attached to the tank side for more smooth ventilation and experiment investigated.
The distillation system used in the extraction process for raw wood vinegar collection. The burning tank designed for the concept; the experiment of parameters for a wood vinegar burning process using wood as raw material and thermal decomposition of organic substances harmful gases pass through the copper tube. Cool water used as a media for removing the heat from those pipe surfaces. The vapor condense to be wood vinegar Figure 15. The concept helps to increase performance and decrease the greenhouse effect.

3. Experiment

In this research, the experiment process has been analyzed based on factorial design. The seven replicating have been employed in order to study the influence parameters; two kinds of woods, three fire conditions of airflow rate, three moisture contents and two positions of exhaust duct. Testing conditions are set based on yield percent of obtained wood vinegar. In order to determine the optimal conditions for producing the wood vinegar. The influences of exhaust duct positions are investigated by testing two replicates, fire conditions of airflow rate are varied free air mass flow, 4.2L/s and 6.4L/s will test with 2 replicates, the moisture of woods inside are removed 0kg, 1kg, 2kg will test with 2 replicates and two kinds of woods are used to test with 2 replicates. River tamarind and Eucalyptus wood use to test in the experiment as raw materials. In each experiment, 15 kg of wood is used, within a duration 5 hours, and 0.5kg of LPG. Finally, the yield percent of wood vinegar production performed.

3.1 Factorial diagram design for the experiment

1. Experiment on exhaust duct positions: factorial diagram design for exhaust duct position experiments is revealed in Figure 4. The experiment is conducted by test on the top 500mm from bottom and bottom 100mm from the bottom positions of the exhaust duct. The position which can maximize the producing of wood is able to produce wood vinegar maximum will be selected to be the setup condition for two kinds of wood experiment.

![Figure 4](image-url)
2. Experiment on Eucalyptus and Revier tamarind wood: factorial diagram design for Eucalyptus and Revier tamarind wood experiments is displayed in Figure 5. The experiment is conducted by test on the kind of woods. The wood is able to produce wood vinegar maximum will be selected to be the setup conditions for wood moisture experiment in the next step.

![Factorial diagram experiment for kind of wood.](image)

Figure 5. Factorial diagram experiment for kind of wood.

3. Experiment on wood moistures: factorial diagram design for wood moistures experiments is shown in Figure 6. The experiment is conducted by test on three kinds of wood moisture in sense of moisture removed from wood, no-moisture removed, 1kg moisture-removed, and 2kg moisture-removed. The wood moisture weight can produce a maximum wood vinegar will be selected to be the test condition for the airflow rate experiment.
Figure 6. Factorial diagram experiment for air mass flow rate experiments

4. Experiment on air mass flow rate: factorial diagram design for wood airflow rate experiments as illustrated in Figure 7. The experiment is conducted by test on three kinds of airflow rate; free flow rate, 4.2L/s flow rate, 6.4 L/s flow rate. The wood moisture which can be produce the maximum wood vinegar will be point as the optimize condition as shown in Figure 22.
Figure 7. Factorial diagram experiment for airflow rate.
Figure 8. Factorial diagram designs for the testing.

3.2 The steps of the experiment:
1. Leave the fresh River tamarind wood for 25-30 days (depend on condition of moisture to be removed) before conducting an experiment step, (step 1).

Figure 9. Eucalyptus wood.

Figure 10. River tamarind wood.
2. Set up the device and fill wood river tamarind 15 kg to the burning tank, and set up LPG in the burning gate, (steps 2, 3 and 4).

3. Burn the LPG. Start to time, measure the temperature every 1 hour in the burning tank, (steps 4 and 5)

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**Figure 11.** Fill wood in the burning tank and set up the device.

**Figure 12.** Liquid petroleum gas set up and temperature measurement.
4. Notice the color of the wood vinegar product from the distillation tank. If the color turns to dark-brown liquid, which means it is becoming raw wood vinegar. Collection the vinegar drops from the wood vinegar drain (step 7).

5. If the color of wood vinegar turns to dark brown color, which means the moisture substance in those wood are all evaporated and the wood becomes good charcoals.
6. Stop to time after five hours. The period of timing since the beginning is the process time for producing wood vinegar. Leave the burning tank and the charcoal cool down for 6 hours.
7. Measure the amount of obtained charcoal, wood vinegar, and ash.
8. Repeat the step 1-7, with another replicating again.
9. Close the raw wood vinegar in the bottles or tanks for 3 months in order to separate light oil, sour vinegar, and tar. Remove the light oil, and tar out by using sourwood vinegar only.

4. **Result and discussion**

The result of the experiments influent parameters are investigated and different cases are discussed according to the behavior and characteristics of wood vinegar performance as following sections; two positions of exhaust ducts are varied, two kind of woods, three moisture contents in woods, and three fire condition of airflow rates. Those experiments were tested by using 15 kg of River tamarind and Eucalyptus wood within duration 5 hours. Amount 0.5kg LPG is used to burn for each cases. The result of the interaction between those parameters is significant to show the behaviour and effect on the yield percentage of obtained wood vinegar collected.
4.1 *Experiment results on Exhaust duct position*

The burning system constructed and tested its operation on positions of exhaust ducts by using River tamarind wood. The result from the operation tested is shown in (Table 1):

**Table 1.** Effect of exhaust duct position on amount of products.

| Testing             | Unit   | Exhaust Duct Positions | Percentage (%) |
|---------------------|--------|------------------------|----------------|
|                     |        | Bottom Position        | Top Position   |               |
| Wood                | kg     | 15                     | 15             | 0%            |
| Time                | h      | 5                      | 5              | 0%            |
| Fuel                | Kg     | 0.5                    | 0.5            | 0%            |
| Wood vinegar        | mL     | 3.392                  | 4.215          | 24%           |
| Charcoal            | kg     | 8.1                    | 6.2            | 31%           |
| Ash                 | kg     | 0.1                    | 0.2            | 50%           |

The average interval temperature in the burning tank process is 68-410°C that meets the desired temperature.

![Figure 14. The obtained charcoal.](image1)

![Figure 15. The obtained wood vinegar.](image2)

The average interval temperature in the burning tank process is about 68-410°C that meets the desired temperature. Exhaust duct on the yield of wood vinegar with respect to time collected, with two replicates. The experiment results are shown in (Table 2).
Table 2. Amount of wood vinegar with respect to time on each exhaust duct position.

| Time (h) | Burning tank (˚C) | Wood Vinegar (mL) |
|---------|-------------------|-------------------|
|         | Bottom Exp.1 Exp.2 | Top Exp.1 Exp.2 |
| 1       | 124 136           | 71 65            |
| 2       | 176 154           | 89 99            |
| 3       | 228 252           | 144 132          |
| 4       | 336 316           | 332 348          |
| 5       | 419 401           | 337 339          |

From Figure 16, the top exhaust duct position gives the bigger yield of raw wood vinegar for the production of wood vinegar by using the burning system. The distillation rates of wood vinegar of these two position are shown in Figure 15. At initial, the bottom position gives wood vinegar 10 mL in the first hour while the top position gives no condensed wood vinegar. It is seen that the bottom position started to evaporate moisture from the wood in the first stage. From second to third hour, the temperature of the bottom position and top position were increased rapidly, but the top position was able to produce wood vinegar much more than the bottom position. During the third to fourth hour, the temperature of the bottom position and top position reached to 326 ºC and 340 ºC respectively. In this stage, it is found that the wood was strongly self-burning which could produce wood vinegar maximum. The wood vinegar began slightly fall distillation. After the tank was cold down, the bottom position was fill with many wood vinegar stuck to the burning surface while the top position there was lesser. This is because the hot gas in the bottom zone was hard to flow out the exhaust duct. This leads to some of the wood vinegar condensed in the burning tank and remain the temperature increasingly. The top position allowed more smooth the gas flow at the exhaust duct to the distillation tank to condense into wood vinegar.

Figure 16. Comparison of product amount obtains from different position of exhaust ducts.

Figure 17. Wood vinegar distillation rate based on position of exhaust ducts.
4.2 Woods experiment result and discussion

The burning system has been tested on two kinds of woods; Eucalyptus, and River tamarind wood, to find the yield percentage of obtained wood vinegar. The results from the experiment are shown in (Table 3).

Table 3. Kind of wood with respect to amount of obtained wood vinegar.

| Testing          | Unit | Eucalyptus | River tamarind | Percentage (%) |
|------------------|------|------------|----------------|----------------|
| Wood vinegar     | mL   | 4,505      | 4,215          | 6.44%          |
| Charcoal         | kg   | 6          | 6.2            | 3%             |
| Ash              | kg   | 0.2        | 0.2            | 0%             |

The average interval of the measured temperature at the burning tank is 64-445°C that meets the desired temperature. Results from the effect of kind of woods with two replicates shown in (Table 4).

Table 4. Amount of wood vinegar with respect to time based on kind of wood experiments.

| Time (h) | Burning tank (°C) | Wood Vinegar (mL) |
|----------|------------------|------------------|
|          | Eucalyptus | River tamarind | Eucalyptus | River tamarind |
| Exp.1 | Exp.2 | Exp.1 | Exp.2 | Exp.1 | Exp.2 | Exp.1 | Exp.2 |
| 1          | 61  | 67  | 71  | 65  | 755  | 683  | 321  | 349  |
| 2          | 219 | 231 | 89  | 99  | 1,248 | 1,272 | 1,242 | 1,198 |
| 3          | 359 | 381 | 144 | 132 | 1,331 | 1,309 | 1,409 | 1,431 |
| 4          | 398 | 418 | 332 | 348 | 1,218 | 1,200 | 1,273 | 1,207 |
| 5          | 439 | 451 | 337 | 339 |        |       |       |       |

Figure 18 shows the comparison of product amount between Eucalyptus and River tamarind woods. The by-production got from this experiment are charcoal and ash. The amount of charcoal and ash obtain from both wood experiments are quite similar. Nevertheless, the observation on the results in (Table 4) revealed that the interaction of temperature between the Eucalyptus and River tamarind woods, in which the temperature in the burning tank of Eucalyptus case is higher than the River tamarind case in every hour. This is mean that the Eucalyptus wood has high heating power than the River tamarind wood. The heating power increase the temperature in the burning tank meets the temperature of wood vinegar desired (120-430°C) faster. In this case, the wet smokes happen in the burning tank are flow into the distillation
tank. The smokes go up through condensing tube and then condense to be wood vinegar. In the second hour, 721 mL of wood vinegar was distillated from this wood. This obtained amount is higher than the use of River tamarind. However, in the fourth hour, the amount of wood vinegar condense turns to slightly drop down even the temperature in the burning tank of the wood was remain increasing. On this condition, It cause from the number of liquid substances in those woods are slightly evaporated. The temperature of River tamarind wood is 68-340°C, which is lower than the temperature of Eucalyptus case. In initial time, the wood produced wood vinegar is slower than the Eucalyptus wood case. Until the third-fourth hour, the temperature in the burning tank rises up and meets the temperature of wood vinegar desired. The wood vinegar distillation rate trend to produce faster and higher than Eucalyptus wood case. That it may cause from the number of liquid substances in those woods remain evaporating higher than the Eucalyptus wood case. Within 5 hours, the amounts of wood vinegar obtained from both of the wood were different. That is the Eucalyptus wood was able to produce wood vinegar more than River tamarind wood about 6.44% see the (Table 3). The experiment shows the type of wood is significantly affect the yield percentage of raw wood vinegar. That is, the Eucalyptus wood case can increase the wood vinegar about 6.44 % compared to the River tamarind wood case.

4.3 Wood moistures experiment result and discussion
In this research, the affect of wood moisture contents on distillation rate have been tested based on the conditions; freed moisture, 1kg and 2kg removed moisture respectively. The experiment results shown in (Table 5).

| Testing          | Unit | Moistures       | Percentage (%) |
|------------------|------|-----------------|----------------|
|                  |      | 0kg Removed-moisture | 1kg Removed-moisture | 2kg Removed-moisture |
| Wood vinegar     | mL   | 4,215           | 3,178           | 2,915           | 44.6%          |
| Charcoal         | kg   | 6.2             | 6               | 5.4             | 13%            |
| Ash              | kg   | 0.15            | 0.2             | 0.3             | 50%            |

The average interval of the measured temperature at the burning tank is around 64-452°C that meets the desired temperature. Results from the study the influence on wood moistures on the yield percent of wood vinegar collected vs. time, with two replicates. The experiment result is shown in (Table 6).
From Figure 20, it is found that the lesser moisture removed, the higher wood vinegar condensed. The by-product got from this experiment is charcoal and ash. The charcoal obtained from none removed-moisture condition. The result in the (Table 6) shown that the temperature of none removed-moisture is lower than the temperature of high removed-moisture condition. It is also found that the wood with none removed-moisture is not good for making higher temperature and its effect on the charcoal quality. However, the temperature of the wood meets the temperature of wood vinegar desired (120-430°C). Thus, the moisture substance in those woods started to evaporate to the liquid smoke and then pass through to condense tank to condense into raw wood vinegar in the third-fifth hour see (Table 6). At the fourth-fifth hour, the amount of wood vinegar just started to fall slightly condense. This cause from the number of liquid substances in those woods is still evaporating. Moreover, the distillation rate of wood vinegar is increased when the temperature of the burning tank reach to the temperature of wood vinegar need. But in the period of last third hour the distillation rate of wood vinegar was drop down quickly even the wet smoke temperature in the burning tank remain increasing. This is because the moisture content inside those woods is mostly diffused out as wet smoke. As a result, amount of wood vinegar from burning process, it is necessary to use the raw wood with more moisture content. However, the most moisture content it reduces of wood vinegar quality.
Besides, the moisture content in the wood is also prevent the combustion turn to completed combustion. The complete combustion condition is not good for the wood vinegar as well as the charcoal production process. As ending of experiment it is found that the charcoal obtained from the wood with non-removed moisture content are almost completed. The quality of the wood vinegar is pH=3.6. While the charcoal obtained from the wood with higher moisture content, the charcoal produce from the process are also perfect charcoals as well. The quality of the wood vinegar is pH=3.1. In the experiment, it is seen that the moisture content in the woods is strongly effects to the amount of raw wood vinegar and wood vinegar quality obtained from the distillation process.

4.4 Airflow rate result and discussion

As previous mentioned the airflow rate is one of important parameter that effect to the wood vinegar burning process. In this research, the experiments on airflow rate are on free airflow rate, 4.2L/s of airflow rate and 6.4L/s airflow rate. Results from the experiment shown in the following (Table 7):

**Table 7. Productions from testing.**

| Testing          | Unit | Airflow rate | Percentage (%) |
|------------------|------|--------------|----------------|
|                  |      | Free airflow rate | 4.2L/s | 6.4L/s | |
| Wood vinegar     | mL   | 4.235        | 4.215 | 4.175 | 1.42% |
| Charcoal         | kg   | 4.7          | 6.2   | 6.3   | 24.2% |
| Ash              | kg   | 0.4          | 0.2   | 0.2   | 50%   |

During perform experiment, the temperature of wet smoke inside the burning tank is varies within the range 68-430°C in order to meet the desired condition of temperature with two replicates. The experiment results are shown in (Table 8):

![Wood Moisture Experiment](image)
Table 8. Amount of distillated wood vinegar with respect to airflow rate.

| Time (h) | Freed airflow 4.2L/s | Freed airflow 6.4L/s |
|---------|-----------------------|----------------------|
|         | Exp.1 | Exp.2 | Exp.1 | Exp.2 | Exp.1 | Exp.2 | Exp.1 | Exp.2 |
| 1       | 69    | 71    | 71    | 65    | 72    | 80    | 192   | 268   |
| 2       | 268   | 280   | 89    | 99    | 98    | 106   | 1026  | 974   |
| 3       | 374   | 354   | 144   | 132   | 132   | 120   | 1345  | 1335  |
| 4       | 380   | 412   | 332   | 348   | 305   | 329   | 918   | 932   |
| 5       | 422   | 438   | 337   | 339   | 324   | 332   | 722   | 758   |

Figure 22 shows that all tested conditions of airflow rate give the quite similar amount of wood vinegar. The products obtained from the experiment are remarkable. The charcoal and ash from a freed airflow rate experiment are higher than the other rest cases. Based on the (Table 8), the temperature of freed airflow rate experiment is higher than the other rest cases. It is seen that with freed airflow rate condition, the burning tank is able to remain the temperature increase rapidly. The temperature in the burning tank meets the temperature of wood vinegar desired. Thus, the evaporation of the liquid smoke happen in the burning tank and flow to the distillation tank bypass through the condensing tube. The temperature of those tubes which surrounded by cool water is too low compared to the temperature of the vapor. That causes the temperature of the wet smoke drop down and distillated as liquid in early hour of the experiment see the Figure 23. The temperature keeps remaining at the third-fifth hour, but the amount of wood vinegar start to drop down. This is because the moisture content of those woods are almost diffused out. Therefore, the airflow rate into burning process is significant effect to increase the heat transfer between wet smoke and condensing tube. It helps to push the wet smoke from inside burning tank to the distillation. Furthermore, this can avoid the condensed smoke within the burning tank during the process. However, the heat in the burning tank will transferred out the wet smoke flow through distillation tank.
Therefore, the temperature of airflow obtained from experiments is lower than the freed-airflow condition. That is the temperature did not match with the desired temperature of the wood vinegar. Thus, the amount of distillated wood vinegar in this period is less as well see (Table 8). As ending of the experiment, it is seen that the freed airflow experiment give a lot of wood vinegar distillate on the wall of the burning tank than other cases. The more woods closed to the fire the more charcoals and ashes become. From this experiment, in order to increase the yield of raw wood vinegar and to obtain a good charcoal, the airflow should be supplied when the temperature in the burning tank meet the wood vinegar desired temperature (120-430°C).

4.5 Overall Result and discussion
The burning system has been constructed and tested its operation on hold experiment. The tests are performed with various moisture contents, airflow supplied as the temperature in the burning tank meet the wood vinegar desired temperature. The experiment has been investigate on 15 kg of River tamarind wood and the position of exhaust duct has been tested. The duration of this experiment is about 8 hours. The average interval measured temperature of the burning tank is varied within the range of 65-419°C that meets the desired temperature. Results from the experiment based on the amount of distillate wood vinegar collected are shown in (Tables 9, and 10).

| Table 9. Conditions and output of the test based on hold experiment condition. |
|---------------------------------------------|--------|--------|
| Wood (kg) | 15    | Time (h) | 8      |
| Fuel (kg) | 0.5   | Wood vinegar (mL) | 6,390 |
| Charcoal(kg) | 3.3 | Ash (kg) | 0.4   |

| Table 10. Amount of wood vinegar with respect to time based on hold experiment. |
|---------------------------------------------|--------|------------------|
| Time (h) | Burning Tank Temperature (°C) | Distillate Wood Vinegar (mL) |
| 1       | 65      | 181              |
| 2       | 293     | 1,163            |
| 3       | 326     | 1,244            |
| 4       | 420     | 1,085            |
| 5       | 426     | 744              |
| 6       | 432     | 715              |
| 7       | 426     | 665              |
| 8       | 419     | 593              |

The proposed model design is able to produce wood vinegar 6.39 liters with the quality of pH=3.4. The measured temperature at burning tank while the wood vinegar burning process is about 65-452°C that meets the desired temperature. If the temperature below about 120°C the wood vinegar will consist mainly of water. In the other hand, if the temperature is above 400°C, it will consist mainly of tar. The product of the designed burning tank is wood vinegar and the by-products are charcoals as shown in Figure 15 and Figure 14, respectively. The wood vinegar is very valuable for agriculture. The charcoal can be used as solid fuel for cooking or can be sold. The first investment of the burning tank is about 5000 Baht. It is a simple burning tank structure, low investment but makes a high gain.

5 Conclusion
In this research, experiment has been investigated on parameters for wood vinegar burning process. The applicability of the proposed system in replacing the conventional system for wood vinegar production is determined. The experiment based on four parameters studies as explained in the case study overview have been examined. The effect of the parameters as following conclusion can be drawn:
(a) The interaction between the positions of the exhaust duct significantly affects the yield of the obtained wood vinegar. The results shown that the top position of exhaust duct can increase the wood vinegar 24% compared to the bottom position.

(b) The type of wood significantly affects the yield of the obtained wood vinegar. From experiment, the Eucalyptus wood can increase the wood vinegar about 6.44% more than the River tamarind wood.

(c) The moisture content in the woods is strongly affect on the yield of obtained wood vinegar. The wood with moisture content is able to produce wood vinegar much more than the 2kg removed-moisture 44.6%.

(d) The rate of airflow rate affects the amount of obtained wood vinegar when the burning tank meets the desired temperature within the range of 120-430°C.

Finally, the proposed methodology of the experiment is suitable for wood vinegar production. To eliminate or minimize the total wet smoke lost caused by a burning tank. The developed design new model can be used in wood vinegar production.

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