American Journal of Engineering Research (AJER)
E-ISSN: 2320-0847 p-ISSN: 2320-0936
Volume-8, Issue-1, pp-218-225
www.ajer.org
Research Paper Open Access

Energy and Heat Transfer Analysis on "Sliding Tray" Type Clove Dryer with Installed Heater Pipes in the Drying Chamber

Susanto Johanes[1], Soeadgihardo Siswantoro[1], Kartika Wulandari[1], Retno Puspitasari[1], Setyawan Bekti Wibowo[1]
[1]*Mechanical Engineering, Vocational College, Universitas Gadjah Mada, Yogyakarta, Indonesia 55281*
Corresponding Author: Susanto Johanes

ABSTRACT: *The analyzed "Sliding Tray"-type clove dryer is a result of the redesigning of "Rotating Part of Tray" type dryer, with the objective of upgrading its performance. In the "Rotating Part of Tray" type of dryer, the heat from the combustion of fuel is immediately discharged through a pipe after heating the bottom plate, while in the type of "Sliding Tray", heat is still used as a sidewall heater and 35 pipes horizontally installed in the drying chamber, so that heat utilization is more optimal. Located 3 cm above each row of horizontal pipes, a tray is installed. The horizontal heating plate mounted on the stove is made of stainless steel, while the side wall heater is made of aluminum plate. This study discusses energy use and heat transfer in the "Sliding Tray" type dryer with no load. There are three conditions observed, namely (a) when the air blower and the induced draft fan of gas from the combustion are turned off, (b) when the fan is turned on but the blower is turned off and (c) when the fan and blower are turned on. During this no-load drying process, the setting of drying chamber temperature is carried out automatically using a solenoid valve and thermo-controller. The data obtained are the temperature of the dryer air, the outside air, the tray, the pipe, the combustion gases coming out of the machine, which all of them are recorded every 5 minute interval, using a digital thermometer. The results of this research indicate that the function of adding pipes as heat absorbent from gases from combustion is quite significant, especially at the lower to middle levels, while at the upper level less or even less useful, because the pipes actually absorb heat from the air in the drying chamber. There is a high temperature difference between the bottom (1st) and the top tray (7st), so other efforts are needed, for example by recirculating heating air and or increasing the fan capacity, so that the drying chamber temperature is more evenly distributed.*

KEYWORDS *clove dryer, sliding tray, seven levels, heating pipe, no load.*

Date of Submission: 11-01-2019 Date of acceptance: 26-01-2019

I. INTRODUCTION

Clove is a commodity of agricultural products with a high selling value, although is seasonal, they carry an important role in the culinary and non-culinary industries. Clove products are mostly used in the clove cigarette (*kretek)* industry, pharmaceutical ingredients, cosmetics and perfumes. Various cloves, i.e. White cloves, *Katak cloves*, and Zanzibar Cloves [1].

Post-clove harvest handling at the farm level is generally done traditionally. Threshing of the buds is done by hand, thus it takes a long time. Therefore the drying of the cloves is done immediately after harvesting, because the delay in drying will have a negative effect on the quality of the cloves [2]. In order to maintain the quality of the cloves, it is necessary to do the drying effort so that it is durable and provides added value.

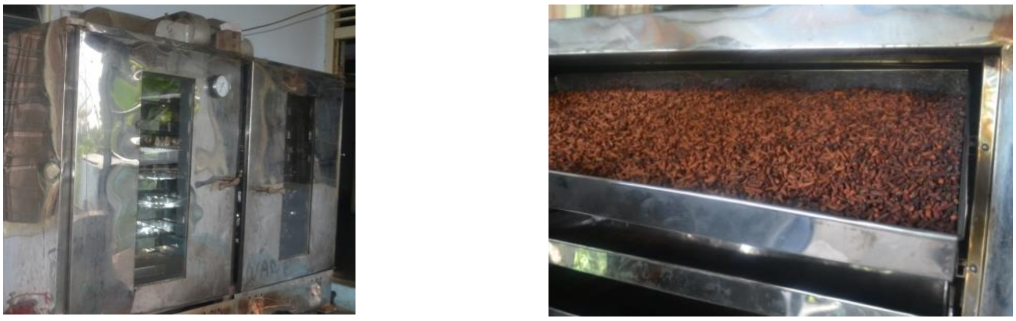
When the weather is good, and the sun shines brightly, drying the clove buds is done by natural way (sun-drying), to reach the level of dryness according to the market demands or the ratio of the weight of wet and dry cloves to 3: 1 [3], it takes approximately 3-4 days, but in the rainy season, it could be even longer. The irony is that the clove harvest is around July-September, which is in the rainy season [4], this is an apparent obstacle for farmers.

The drying process of cloves using a machine is to make use of hot air as a drying medium. One of the way is that the air is flowed in pipes which are heated by gas or biomass, then the hot air produced is flowed using a blower, heading into the clove oven chamber. This way reduces the water content of cloves to 8-14% and it takes about 2.5 hours [5]. In Indonesia, a lot of cloves are produced, so to overcome the obstacles the farmers need a good clove dryer for their production to produce quality clove products. The author has tried to design and make the dryer, one of the designs that has been made is the type of "Rotating Parts of Tray" dryer, however it still has several shortcomings.

The clove drying process using a "Rotating Parts of Tray”-type machine has been carried out with a clove drying capacity of 15 kg, from a dryness level of 73.18% to 26.78%, with a thermal efficiency of the drying process of 11.57% [6]. The results of the analysis show that there is still a need to repair the tool, in order to increase heat absorption from the combustion results.

The new design of the "Sliding Tray"-type clove dryer is an effort to improve the performance of the previous dryer, the "Rotating Part of Tray". In the "Rotating Part of Tray"-type dryer, after the heat from the combustion of fuel heating the bottom plate is immediately discharged into the air through the exhaust pipe, but the results of the analysis show that the calorific value is still high. Whereas in the "Sliding Tray"-type dryer, the heat is still used as a side wall heater and pipes in the drying chamber, so that heat utilization is more optimal.

This research is a test of the performance of clove dryers (or other agricultural products, especially those that have the same or almost the same size as cloves), and "Sliding Tray"-type when the machine is in no-load state. There are three conditions observed, namely, (a) when the air blower and induced draft fan of the combustion gas are turned off, (b) when the fan is turned on but the blower is turned off and (c) when the fan and blower are turned on. Installation of pipes in the drying chamber is intended to utilize the heat of the remaining gas from the combustion of LPG (Liquefied Petroleum Gas) fuel, previously the gas was used as side wall plate heaters. With this new design, the hope is to be able to make the most use of the heat of the remaining gas from the combustion of LPG fuel to improve the performance of the clove drying machine. How much the influence does the installation of these pipes have on the performance of this dryer. The Fig. 1 below is one example of a clove bud dryer machine on the market [4]. Fig. 2 is "Cabinet"-type clove dryer by one manufacturer in Yogyakarta.

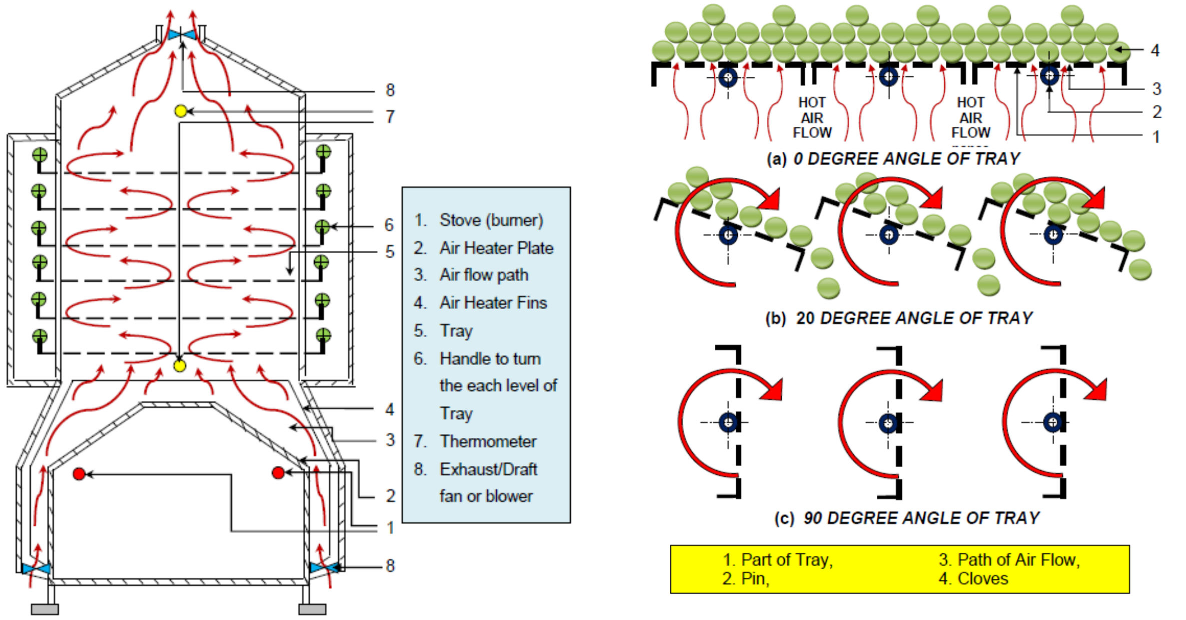


(a) (b)

Fig. 1. (a) Clove bud dryer, arranged as several levels of pan, (b) one of pan filled with clove buds.

Fig. 2. “Cabinet”-type Clove (or other agriculture produce) Dryer.

Susanto J., et al., [7], has made a type of “Rotating Parts of Tray” dryer, with five levels, using dual fuel (LPG or firewood), which still needs some improvement especially in terms of utilizing heat from the fuel combustion so that become more optimal. The test results of the machine for clove drying capacity of 15 kg (wet), were successfully dried to 8.04 kg, required LPG fuel as much as 3.79 kg, from the dryness level of approximately 73.18% to 26.78%, and required time for 4 hours 20 minutes, at an average temperature of the drying chamber of 49.71 °C, and produced thermal efficiency of 11.57% [6]. Sketch of the "Rotating Part of Tray" type of clove dryer, as shown in Fig. 3, while the dryer's product is shown in Fig. 4.



(a) (b)

Fig. 3. (a). Sketch of the "Rotating Part of Tray"-type of clove dryer, (b). Sketch of three kinds of Tray positions; slope 0, 20 & 90 degrees.

(a) (b) (c)

Fig. 4. (a). "Rotating Part of Tray"-type clove dryer, in processing, (b). Five-leveled "Rotating Part of Tray"-type clove dryer. (c). Five level trays are shown when the door is opened.

The final sketch of the design of the clove (or other agricultural produce) dryer, as shown in Fig. 5, initiates the design of the cabinet type with the addition of heating pipes installed in the drying chamber, which serves to utilize the heat of the remaining gas combustion.

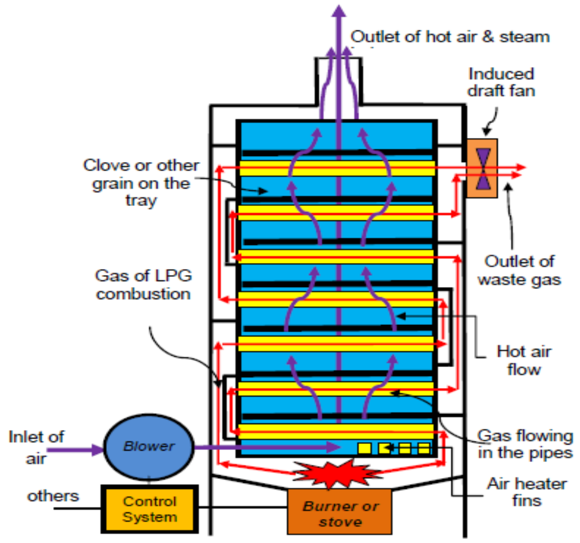


Fig. 5. Sketch of the air flow & gas from the combustion in Seven-leveled "Sliding Tray"-type clove (other agricultural produce) dryer.

In this dryer, heat transfer takes place by radiation and convection from the gas combustion of LPG gas fuel, received by the bottom heating plates made of stainless steel. Then a portion of the heat is transmitted by conduction to the side heating plates made of aluminum, then to the trays and the heating pipes installed in the drying chamber, which rests on the side heating plate. Besides being heated by conduction, the trays and heating pipes are heated also by convection by hot air. The hot air is produced by the blows from the blower, which is then heated by heating plates. The combination of heat transfer by convection of hot air produced and conduction heat from the tray, is used to heat cloves or other agricultural produce which are spread evenly over the tray.

As for the total heat used in the clove drying process, stated in Susanto J., et al. [7], concluding:

1. Calories used to heat cloves from atmospheric (environmental) temperatures to the desired temperature (drying chamber),
2. Sensible calorie used to heat water contained in cloves,
3. Calories used to evaporate (latent heat) water contained in cloves,
4. Heat loss through the wall of the dryer,
5. The calorie that comes out through the vent/ chimney exhaust, and
6. The loss of heat from the stove to the surrounding which is not absorbed by the dryer.

II. RESEARCH METHOD

Clove (or other agriculture produce) Dryer Machine observed as seen in **Fig. 6**, with specifications as listed in Table 1.

(a) (b)

Fig. 6. Seven-leveled "Sliding Tray"-type clove (or other agricultural produce) dryer.

Table 1. Seven-leveled "Sliding Tray"-type clove dryer machine specifications.

1. An indirect contact type,	9. Heating air flow using a blower 2",
2. Sliding Tray Type,	10. Without re-circulation air
3. LPG as fuel,	11. The combustion gas flow using a induced draft mini fan,
4. 7 tray-level,	12. The temperature setting of the drying chamber automatically uses thermo-controller mode: IL-80EN, source 110V/220V, range 0-200 ºC, couple CA (K) & solenoid valve, brand: Castel, type: 1020/2A6, ¼" flare, 220/230V, 50/60Hz.
5. Capacity of max 40 kg,	
6. The wide of each tray is 98 x 65 cm, from perforated steel plate materials.	
7. Number of heating pipes (¾") is 5 x 7, from copper materials	
8. Without fins	

There are three (3) targets in the study related to the performance of this seven-level sliding clove (other agricultural products) dryer, namely:

1. No-load drying/ heating process, when the fan and blower are turned off,
2. No-load drying/ heating process, when the fan is turned on, while the blower is turned off,
3. No-load drying/ heating process, when the fan and blower are turned on.

The weight measuring instrument used in this study is a digital scale, to determine the fuel consumption used and a temperature measuring device, in the form of a digital thermometer.

Before data collection is carried out, the installation of the necessary instruments is carried out, namely a temperature measuring device in the form of a digital thermometer. The thermocouple ends of a digital thermometer are installed in several positions on the dryer component; in the tray and the odd level pipe, namely 1, 3, 5 and 7, and on the way out of air, the outside gas exhaust, the heating air outlet. This clove dryer, tested without load, and uses LPG fuel. The temperature setting is done on the thermo control to produce a temperature of the drying chamber around 50 ºC. The process of no-load heating begins with turning on the stove (burner). Air circulation is produced by blower 2" at full speed (full throttle openings), so that the air absorbs heat from the bottom and the side heating plates of the dryer. The dryer is not equipped with the installation of heating fins, and no heating air re-circulation is carried out. Temperature measurements are carried out every five (5) minutes interval.

III. RESULTS AND DISCUSSION

The results of the no-load drying/ heating experiment when the fan & blower are turned off are shown in Fig. 7, when the fan is on while the blower is turned off the results are shown in Fig. 8, and when the fan & blower are turned on the results are shown in Fig. 9.

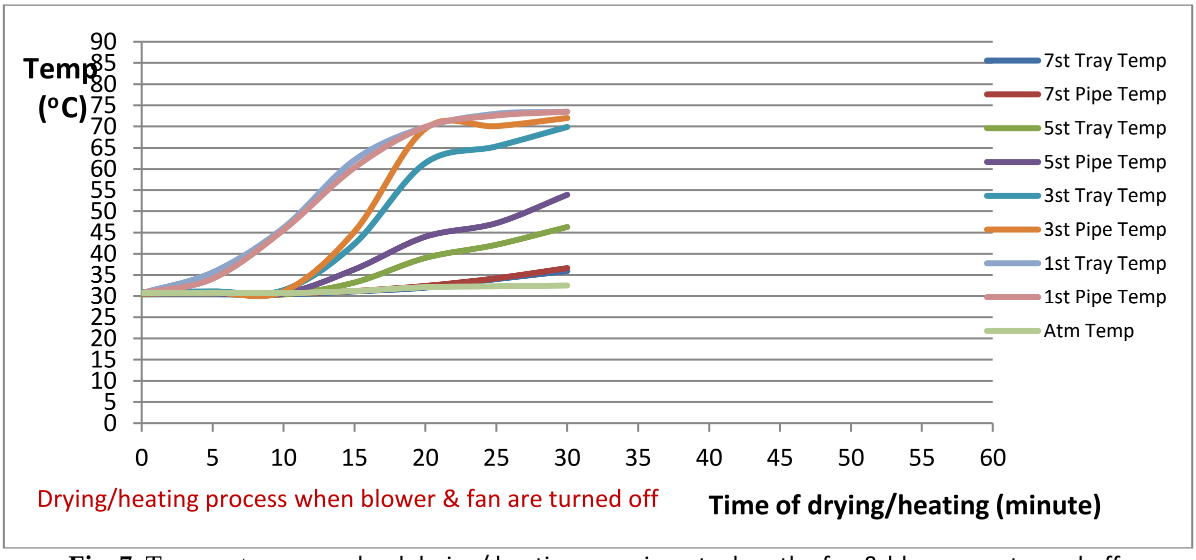


Fig. 7. Temperature on no-load drying/ heating experiment when the fan & blower are turned off.

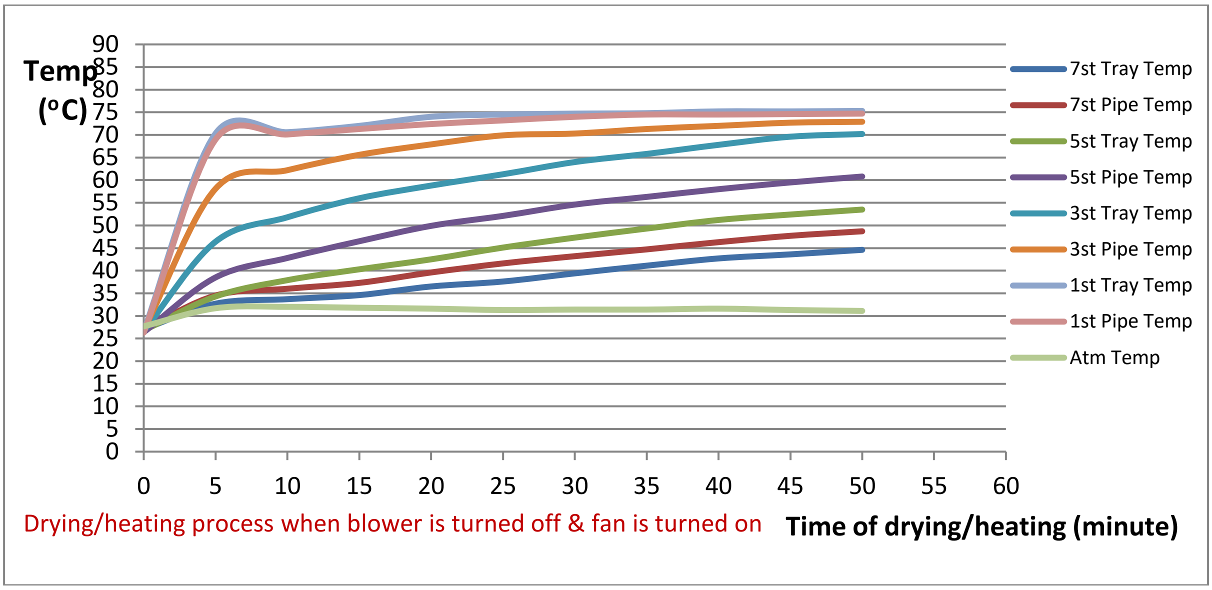


Fig. 8. Temperature on no-load drying/ heating experiment when the fan is turned on while the blower is turned off.

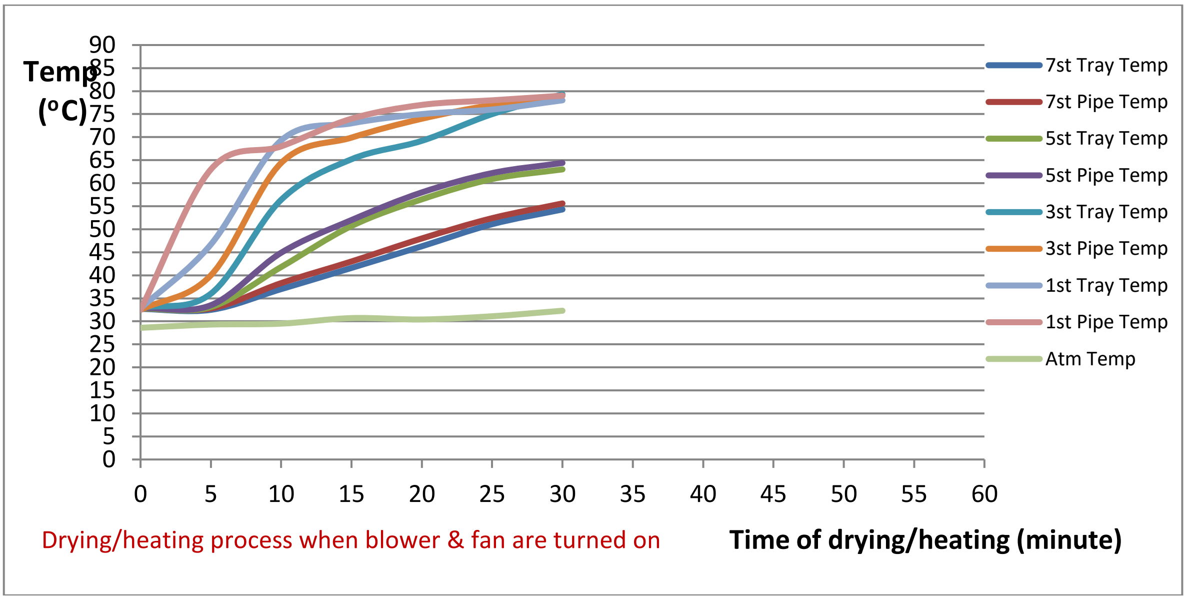


Fig. 9. Temperature on no-load drying/ heating experiment when the fan & blower are turned on

From the graph of Fig. 7, it can be seen that when relying on natural convection heat transfer, the gas flow resulting from combustion is quite slow. This results in absorption of heat by the tray and heating pipes, especially those at the top, become small, this due to the heat that reaches the tray and the pipe is mainly conduction mode. Because the vertical plate is quite thin, the temperature gradient is in a large vertical direction, thus the rate of temperature rise in that section is very low. While the temperature of the pipes and trays close to the bottom heating plate, to reach a temperature that can be said to be stable takes around 20-30 minutes. This includes a relatively long time because the heat transfer mode is mainly only radiation by the bottom heating plate, which needs time to enter the internal energy of the plate.

When compared between the graph in Fig. 7 and the graph in Fig. 8, it can be seen that the use of a mini fan that functions as an induce draft fan is quite helpful in an effort to produce gas flow from the fuel combustion, to move and flow upward, the gas is between guide plate and insulator or between the guide plate and the side wall. Due to the warmth of the steering plate and sidewall by the gas, finally the heat transfer to the pipes and trays, both by conduction and convection. This is seen in the rate of increase in temperature of the pipes and the tray is greater when only the fan is turned on while the blower remains in a dead state. However, because the mini fan is used, the ability to produce the air flow rate (volume flow rate) is small, so the rate of increase in temperature is very small, not as expected, especially for the tray & top-level pipes. Sketch of the flow of gas from combustion, as seen in Fig. 4, shows that the gas flowing to the left experiences a flow with an angle of 90^o as much as eight (8) times, whereas the flowing to the right experiences a flow of angle of 90^o six times. This of course results in considerable flow losses (losses), which contribute to the decrease in the flow rate of the combustion gas.

The temperature difference between the pipe and tray for the same level is quite large, this is seen very clearly in pipes and trays from one level to the middle level. This is due to the location of the pipe which is lower than the tray, but this is also due to the absorption of heat from the combustion gases by the pipes, and moreover because the thermal conductivity value of the pipe is better than the thermal conductivity of the tray.

The graph in Fig. 9 shows that there is a decrease in the rate of increase in temperature of the tray and pipe compared to the graph in Fig. 7. After the blower is turned on, the emission of radiation from the bottom plate towards the pipe and tray is reduced, this is due to a decrease in the internal rise of the lower plate energy. The internal energy stored in the bottom plate partially disappears by convection as a result of changes in the magnitude of the increase in air flow rate above the bottom heating plate.

The data obtained shows that the installation of heating pipes, especially those located at the lower to medium levels, is quite helpful in an effort to absorb heat from the combustion gases. But the installation of heating pipes at a higher level (top), the heat absorption function is no longer effective, even the opposite happens, namely a pipe that absorbs heat from the air in the drying chamber. This can be seen in Fig. 9 which shows that the temperature of the gases from combustion in the exit position is actually lower than the temperature of the air coming out of the dryer.

The use of a mini fan that has too little capacity causes too little pull or gas flow rate resulting from combustion, so that the heat exchange between the combustion gases and the surrounding area occurs mostly in the wall components of the bottom side of the dryer and uneven, resulting in more gas temperatures lower than the temperature of the air coming out of this dryer. This indication is felt when touching the wall, so if it is concluded qualitatively it shows that the temperature is quite high in certain areas and low in other areas.

From the graph, it can be seen that there is a high temperature difference between the bottom (1st) and the top tray (7st), so if you keep the design with as many trays as possible, it is worth another effort to overcome this, so that the drying chamber temperature is more evenly distributed, so that the heat transfer to agricultural products dried using this tool is more evenly distributed. One effort to overcome this is for example by heating air re-circulation.

IV. CONCLUSION

The conclusions obtained from the results of this research are as follows.

a. Using a mini fan helps draw gas from combustion of fuel, so the rate of increase in temperature of pipes and trays is greater,
b. The installation of heating pipes, which are located at the lower to medium level, is sufficient to help increase the temperature of the drying chamber, but is no longer effective,
c. The used fan capacity is too small, resulting in lower gas temperatures than the temperature of the air coming out of this dryer.
d. From the data obtained there appears to be a high temperature difference between the bottom (1st) and the top tray (7st), so a method for even distribution is needed.

The following things need attention and consideration, in order to improve the performance of this dryer.

a. Change the mini fan with a larger capacity fan,
b. Thicken the side heating plate so that heat transfer is better, so that the temperature is even more distributed
c. Installing fin on the bottom of the heating plate, so that the absorption of heat convection by air supply is greater,
d. Using the heating water re-circulation method, so that the heat is not much poured out and the temperature distribution of the drying chamber is more evenly distributed.

REFERENCES

[1]. Gita Adi Saputra, *Ciri-ciri, Jenis dan Manfaat Cengkeh (Characteristics, Types, and Benefits of Cloves)*, http://www.satwa.net/870/ciri-ciri-jenis-dan-manfaat-cengkeh.html, January 4 2014.
[2]. Ishak, 2013, *Model Pengeringan Lapisan Tipis Cengkeh* (*Syzigium Aromaticum*) *(Thin Layered Clove (Syzigium Aromaticum) Drying Models)*, Thesis, Agricultural Engineering Study Program, Department of Agricultural Technology, Faculty of Agriculture, Universitas Hasanuddin, Makassar.
[3]. Aksi Agraris Kanisius, 1973, *How to Cultivate Cloves*, Cultivation Series, Kanisius Publisher, Yogyakarta (Indonesian).
[4]. BPTP Administrator, *Innovation on Clove Harvesting on Rainy Season*, http://malut.litbang.pertanian.go.id/ind/index., September 30 2013 (Indonesian).
[5]. Rumah MesinPusat Mesin Usaha Anda, *Clove Dryer Machine*, http://rumahmesin.com/mesin-pengering-cengkeh/, April 16 2015 (Indonesian)..

[6]. Susanto J. & Winarto, 2016, *Thermal Efficiency Study on Clove Drying Process with Five-leveled Dryer*, Final Research Report, Vocational School UGM (Indonesian).

[7]. Susanto J., Soeadgihardo S., Greg Sukartono, 2014, *Practical and Economical Redesign for Cacao Seed Dryer Machine, for Tani Ngudi Mulyo Farmers Association in Banjaran Kalibawang*, Final Report Utilization of Research Results and Application of Applied Technology (Indonesian).

Susanto Johanes" Energy and Heat Transfer Analysis on “Sliding Tray” Type Clove Dryer with Installed Heater Pipes in the Drying Chamber" American Journal of Engineering Research (AJER), vol.8, no.01, 2019, pp.218-225