

Clove essential oil (EO) has a high eugenol content. Fresh cloves need to go through a drying and distillation process to produce essential oils. However, sun drying cannot be done optimally during the rainy season. Therefore, some farmers (SMEs) use the oven drying method. The initial study found that the eugenol content after the drying process decreased. Therefore, this study aimed to maintain high eugenol content in dry cloves. After identifying the problem, it is solved using the TRIZ method, and research is continued for a new oven prototype. Three issues are found in drying cloves based on field surveys and literature studies. First, the clove moisture content is not uniform after the drying process. The second problem was that the clove was too dry after the drying process and the eugenol content decreased. And the third problem is the oven that has been used so far is still fuel-wasting. The literature studies also found several parameters to be a reference in designing a new oven: the number of trays in the oven, clove thickness, the space between the trays in the oven, and the steam gap on the tray. In addition, the appropriate oven coating material can also be determined (plywood, galvanized plate, and air). In the TRIZ method, several solutions were found to design a new oven. Eight things have been changed from the existing drying oven, including the number of trays in the oven, a steam gap in each tray, the size of the mesh used for the tray base, material for the drying oven, the thickness of the cloves on the tray, the temperature used in the drying process, installation of a thermostat to control the temperature in the oven, separate combustion chamber from the tray space (indirect heating), and without using a blower.

Keywords: clove, essential oil, eugenol content, SMEs, oven drying, TRIZ method

APPLICATION OF TRIZ TO MODIFY OVEN DRYING FOR SMES TO MAINTAIN THE EUGENOL CONTENT IN DRIED CLOVES

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1. Introduction

After harvesting, the processing of clove flowers is generally done traditionally, mainly by farmers who do not have extensive planting land. After harvesting, farmers dry the cloves directly under the sun because not many farmers have clove dryers. However, sun drying has disadvantages, including being very dependent on weather, taking a long time (5 to 7 days), the temperature cannot be controlled, and being prone to product contamination.

Some drying technologies that have been studied and used are microwave drying, oven drying, spray drying, and freeze drying. Of the few technologies, oven drying seemed suitable for farmers' needs due to the affordable price of the equipment, easy operation, and low operational costs. However, the existing dryer is still focused on reducing the moisture content of the product, even though clove drying must pay attention to the levels of essential oils contained in it so that they do not evaporate.

Many factors can affect the amount of essential oil in cloves, some of which are drying time, drying temperature, and the thickness of the media. So far, many studies discuss the effect of temperature on product moisture content, but

very little is associated with essential oils such as eugenol levels in cloves. Temperatures that are too high in the drying process can cause many essential oils to evaporate. The next factor that may affect the moisture content and eugenol levels in cloves is the thickness of cloves.

Some scientists have studied the design of drying ovens, such as ovens for wheat [1] and tunnel dryer designs for food crops [2].

Therefore, studies are devoted to designing a drying oven, which aims not only to focus on reducing the moisture content but also to maintain the eugenol content in dry cloves. To obtain an oven design with a specific purpose (maintaining the eugenol content), the TRIZ method was used. That is a method that can provide solutions in terms of improving and worsening parameters.

2. Literature review and problem statement

Clove farmers in Indonesia are classified as small and medium enterprises (SMEs). A small enterprise is a productive

economic business that stands alone. With limited funds, high operational costs, and even the number of workers, these small and medium enterprises need help to solve various problems. Not only a matter of financial management, marketing, and improving product quality. For example, clove farmers are constantly faced with the quality of cloves after the drying process.

Drying is one of the common methods of plant preservation [3]. The purpose of drying is to inhibit enzymatic degradation and prevent the growth of microorganisms, which in turn could prolong the shelf life of the product [4]. Sun drying is the most popular and economical drying method among farmers, especially farmers who live in a tropical area [5], but it will be difficult to dry if cloves are harvested during the rainy season. However, drying under the sun is not practical since it relies heavily on the weather, takes longer times, and causes exposure of the product to environmental contamination. Drying conditions such as time of drying, temperature, environment, and equipment can cause negative and positive effects on the drying process [6]. The paper [7] presents research results that oven drying at 40 °C produces the largest percentage of essential oil yield compared to other methods. But the drying time is still longer than vacuum drying. Sun drying can cause substantial color and aroma degradation in many types of herbs [8]. Meanwhile, sun drying causes a decrease in essential oil content if compared to hot air and shade drying. This may be caused by the fact that the sun drying temperature is difficult to control, as well as the wind velocity factor.

Essential oils (EOs) are the main ingredients of many volatile medicinal plants like clove. There are many studies on the effects of different drying methods on EO results and medicinal plant composition. In [9], the temperature used in the oven drying process should not be too high. Therefore, in drying cloves, the temperature should not be too high as it can cause the loss of many volatile compounds. In [10], oven drying can increase volatile compounds but the yield of essential oils decreases. To date, there is limited research, if any, on the effect of drying on the EO content (eugenol) of clove buds. Even though the market or industry that needs dried clove flowers has a minimum standard of eugenol content of around 70 % while the maximum water content is 13–14 %. Thus, the introduction of the best drying methods for clove buds can be useful for increasing the yield and composition of EO, especially eugenol.

Typical clove trees can produce on average 20 to 30 kilograms of fresh clove once harvested depending on the size and age of the tree. Dry cloves ready for sale are often rare when the rainy season lasts. In the rainy season, the supply of dried cloves from farmers is declining and slow. Farmers have difficulty in drying their crop cloves. Cloves can be dried in the dry season with the help of sunlight for 5 to 7 days with an average drying time between 8 to 10 hours per day. The duration of the clove drying process increases to 6–10 days even more in the rainy season, depending on rain intensity during the clove drying process. After drying, cloves have a moisture content ranging from 12 to 14 % and are brownish-red in color. For every 3 kilograms of wet cloves, on average, it will be 1 kilogram of cloves after drying. The increase in the clove drying process during the rainy season results in a queue of land for the clove drying process. Farmers must first wait for the soil to dry after rain to carry out the clove drying process.

The drying of cloves relies on sunlight, so it can only be done during the daytime and is impossible to do at night. Clove drying with the sun drying method during the dry season can take place well for farmers who have relatively large land. The obstacle in the dry season is that farmers do not

have extensive dry land to dry the cloves of their crops. The queue of wet cloves that have not dried due to land factors and rain causes wet cloves to accumulate. This resulted in wet cloves being sold at a low price because it feared that they would not have a turn in the drying process until finally, the cloves were fermented and rot. A large number of wet cloves sold by farmers resulted in plummeting prices for wet cloves.

The main content of clove oil is eugenol, eugenol acetate, and caryophyllene. The highest yield ever obtained from high-quality clove flowers (20 % oil content) is 17 %. Sun drying of cloves can reduce eugenol levels because the temperature cannot be adjusted. Oven drying seems to be an alternative drying method with fast drying time, simple treatment, and more controlled drying conditions. Some farmers have used ovens to help solve the sun drying problem. However, the drying results have not met the set standards, one of which is the eugenol content in dry cloves. Hence, it is necessary to do a lot of research to get maximum results.

In the TRIZ method approach (Fig. 1), specific problems that have been identified are converted into more general problems according to TRIZ. Then several alternative solutions will be given according to the TRIZ method. Furthermore, it can be used as a more specific solution that is suitable for the purpose and can be applied.



Fig. 1. TRIZ solution approach [11]

TRIZ methods are used to find a new invention to solve the issues in drying cloves by conventional oven drying. TRIZ assures the design of a new, quick and precise solution of problems to avoid wasting time providing too many alternatives solutions [12]. Alternative solutions from TRIZ methods are used to base the design of the prototype dryer. At this stage, the desired criteria and the obstacles faced are identified. The next step is to detail the problem based on the requirements, namely the breakdown of the problem based on the previous drying method’s constraints. After the problem is detailed, problem identification is made based on Altshuller’s 39 Parameters [13]. Fig. 1 summarizes the ability of the TRIZ solution approach to convert a specific problem into a specific solution. However, no research has thoroughly discussed the oven design to maintain the eugenol content in dry cloves. Therefore, this study will identify and resolve these problems using the TRIZ method. The findings of this study will recommend a drying oven design that can be applied to SMEs with high-quality dried cloves.

3. The aim and objectives of the study

The aim of the study is to overcome the problem of clove farmers (SMEs) in maintaining the eugenol content in dried cloves.

To achieve the aim, the following objectives are accomplished:

- to identify the problems in clove farmers that affect the eugenol content of dried cloves during the drying process;

- to define the issues using the TRIZ method;
- to solve the problems using the TRIZ method;
- to design and develop a drying apparatus to keep eugenol levels in dried cloves high.

4. Materials and methods

The object of this research is to design an oven dryer that can maintain the eugenol content in dried cloves.

A hypothesis has been put forward that it is possible to increase the eugenol content in dry cloves using a new oven dryer design by considering the improving and worsening parameters of the TRIZ method.

The assumptions made are that the dimensions of cloves and the moisture content in fresh cloves are uniform. Natural air velocity, based on pressure differences (resulting from temperature differences). The surface area of the clove is in contact with hot air.

The first step is conducting some initial experiments to get some data for analysing the problem definition. After that, the problem is solved using the TRIZ method. TRIZ methods are used to find out a new invention to solve the problems in drying cloves by conventional oven drying. TRIZ assures the invention of a new, quick and precise solution of problems to avoid wasting time of providing too many alternative solutions. Alternative solutions from TRIZ methods are used to base the design of the prototype dryer.

Research studies are based on theory and experiment. The equipment is divided into theoretical research and experimental research equipment. There is research equipment, in theory, using a computer completed with software. And the equipment for experiments is an oven dryer direct heating system with a blower. The clove oven is made of plywood for the outer layer, galvanized plate for the inner layer with LPG (Liquid Petroleum Gas) as an energy source. The moisture content is analyzed using Shimadzu MOC-120H Moisture Balance. While the analysis of eugenol levels is made using Shimadzu QP-2010GC-MS (Gas Chromatography-Mass Spectrophotometer). Fresh and dried cloves must be extracted first so that GC-MS can analyze them. The materials used in this research are fresh cloves (*Syzygium aromaticum*) obtained from East Java, Indonesia.

5. Resultsof the research on the application of the TRIZ method to design an oven dryer to maintain the eugenol content

5. 1. Identification of clove farmer problems that affect the eugenol content of dry cloves during the drying process

Until now, clove farmers still use conventional methods to dry cloves. Fig. 2 shows sun drying carried out on the land around the farmer’s house. It appears that this drying method requires extensive land and can only be done with sunlight. The survey was carried out when the clove harvest was still in the rainy season so drying time was very limited. Also, the humidity of the surrounding air will increase, which will make the drying process longer.

Some farmers have simple oven dryers. An oven dryer can reduce the difficulties encountered in the sun drying process. Horizontal oven dryers with direct heating systems can be seen in Fig. 3. According to farmers, this horizontal type is fuel-wasting. The direct heating system makes the clove

charred and contaminated with substances from the gas of fuel (LPG) combustion.



Fig. 2. Sun drying method



Fig. 3. Oven drying (direct heating system with blower)

The next stage is to analyze the cloves. The clove sample was analyzed to determine moisture and eugenol contents. Three samples need to be analyzed: fresh cloves, cloves dried by the sun drying method, and cloves dried by the horizontal oven drying method. From the three samples, GCMS results indicate that the highest content of clove oil is eugenol. Then the data from the analysis of moisture and eugenol contents are presented in Table 1.

Table 1
Moisture and eugenol contents of cloves

Analysis	Fresh cloves	Cloves dried by sun drying	Cloves dried by oven drying
Moisture content	70.15 %	14 %	13 %
Eugenol content	75.95 %	54.66 %	58.17 %

The data in Table 1 show that the decrease in moisture content by sun drying and oven drying does not differ much and the two drying methods are still eligible with the moisture

content of dried cloves for industry requirements. In contrast to the results of eugenol content analysis, there was a decrease with both sun drying and oven drying.

5. 2. Problem definition using the TRIZ method

There are three problems found in drying cloves based on field surveys and literature studies. First, the clove moisture content is not uniform after the drying process. From literature studies and field surveys, this can be caused by the thickness of the pile of cloves. Also, this can be due to the uneven circulation of hot air in the oven, resulting in uneven drying. The second problem is that cloves after drying are too dry so the results of the analysis of moisture and eugenol contents do not follow the Indonesian National Standard (SNI). The third problem is that the oven that has been used so far is still fuel-wasting. In Table 2, the three issues are identified to determine improving parameters according to the TRIZ method.

Table 2

Identification of Altshuller’s 39 Parameter

No.	Cause of Bad Products	Improving Parameters (TRIZ)
1	Moisture content in cloves is not uniform after the drying process	Shape (12)
		Quantity of Substance (26)
2	Cloves are too dry after the drying process and the eugenol content decreased	Temperature (17)
		The extent of Automation (38)
		Shape (12)
3	Fuel wasting	Power (21)

There are 39 improving and worsening parameters available in the Matrix of Contradictions, which can be selected according to the problem. Of the three issues in Table 1, there are several parameters for improvement that can be done. For the first problem regarding the uneven moisture content, improvements were made to the oven shape (Shape – Improving Parameters No. 12) and dried material in each batch (Quantity of Substance – Improving Parameters No. 26).

The second problem is the condition of cloves that are too dry. The appropriate improvement parameter changes the drying process temperature (Temperature – Improving Parameter No. 17). Excessively high temperature causes too much evaporation from inside the cloves. The clove drying process is about reducing moisture and eugenol contents. Moisture and eugenol contents must comply with the Indonesian National Standard (SNI). In SNI, the maximum moisture content in dried cloves is 14 %, the eugenol content in clove essential oil is at least 78 %. Too much evaporation can cause the moisture content in dry cloves, and the eugenol

content in clove essential oil is not up to standard. Therefore, to set the process temperature, there is also a need for an automatic device that can control and maintain the desired temperature. That is following the Improving parameter No. 38 Extent of Automation. With the Automation that can control temperature, the increase or decrease in temperature during the drying process can be controlled automatically.

The third problem is fuel wasting. The previous oven used an LPG energy source and was assisted by a blower to speed up the drying process. However, if recalculate, the energy used is enormous from LPG and power for the blower. Therefore, to reduce energy wasting [14], the blower can be removed (Power – Improving Parameter No. 21).

5. 3. Problem solving with the TRIZ method

The next step in the analysis of the several improving parameters will have any adverse effects. And can be specified in the 39 worsening parameters in the contradiction matrix of the TRIZ method, which can be made in Table 2. For the improving parameter – the shape of the first problem can cause an impact on changes in Productivity (No. 39), such as product output per unit time. Then the second impact of changing shape is Easy to Manufacture (No. 32). And the third impact on Force (No. 10) in TRIZ is any interaction intended to change an object’s condition. As for the improving parameter – the quantity of Substance impacts the Weight of the Stationary Object (No. 2).

In the second problem, temperature impacts the duration of an activity (Loss of Time, No. 25). On the improving parameter – Extent Automation affects Manufacturing Precision (No. 29), the extent to which the system’s actual characteristics or object match the specified or required characteristics. Improving the shape will impact Device Complexity (No. 36), which is a more complicated oven shape than before. In the third problem, Improving Power can have an impact on speed (No. 9). Removing the blower in the oven will automatically reduce the drying rate.

The contradiction matrix is Improving vs. Worsening System Parameters, which provides suggestions in inventive principles to solve the contradiction. There are 40 Inventive Principles in the contradiction matrix that are written numbers in the boxes as in Table 3.

In Table 3, some numbers are inventive principles figures. There are 40 inventive principles offered by the TRIZ method, which is a solution to the contradiction between improving and worsening parameters.

For example, in the contradiction between Shape (improving parameter) and Force (worsening parameter), there are four inventive principle solutions; 35 (Parameter Change), 10 (Prior Action), 37 (Thermal Expansion), and 40 (Composite Materials).

Table 3

Contradiction matrix for solving technical contradictions

Improving parameters	Worsening parameters	Weight of Stationary Object	Speed	Force (Intensity)	Loss of Time	Manufacturing Precision	Easy Manufacture	Device Complexity	Productivity
		2	9	10	25	29	32	36	39
12	Shape	15 10 26 3	35 15 34 18	35 10 37 40	14 10 34 17	32 30 40	17 32 128	16 29 1 28	17 26 34 10
17	Temperature	22 35 32	22836 30	35 10321	35 28 21 18	24	2627	21716	15 28 35
21	Power	19 26 17 27	15352	262 36 35	35 20 106	322	2610 34	20 19 30 34	28 35 34
26	Quantity of Substance/the Matter	27 26 18 35	35 29 34 28	35 143	35 38 18 16	33 30	29 135 27	31 327 10	1329327
38	Extent of Automation	28 26 35 10	2810	235	24 28 35 30	28 26 18 23	12613	15 24 10	51235 26

All four solutions can be selected or only a few according to the objectives to be achieved. But it is also permissible to choose what is appropriate. So, Table 4 describes the inventive and sub-principle solutions and the suitable applications if applied.

Table 4 describes in more detail the inventive principles that have been selected accordingly and can be applied in designing clove drying ovens. Some sub-principles explain in more detail the inventive principles so that more specific and appropriate solutions are obtained. Then some of these solutions are used to create a new drying oven design.

5. 4. Design of the drying oven from the TRIZ method solution

From the solution given by the TRIZ method in Table 4, there are nine applications to the new oven design, namely:

1. Multi Tray. Drying ovens are designed with multiple trays to maximize energy from hot air not to be wasted. In Fig. 4, there are three variations in the number of trays

based on the distance between the trays. The number of trays is related to the thickness of the material to be dried, which also impacts productivity. In the experiment, it can be seen at what distance of trays the results of drying the cloves have an even moisture content.

2. Steam Gap on Tray. Each tray needs to be made with a gap to help the hot airflow up to the next tray. It aims to even out the heat in each tray so that each tray’s cloves get evenly heated. Slits in the tray are designed on the sides and in the middle, as shown in Fig. 5. This gap also helps the hot air flow easily distributed upward, as this oven design eliminates the blower to save energy. Without a blower, hot air can still flow upwards due to the temperature difference in the oven.

3. Mesh of Tray. The mesh size of the tray allows hot air to flow into the clove pile. The smaller the mesh on the tray, the easier it is for hot air to flow through the gaps into the cloves pile. In Fig. 6, the design for the top tray shows holes with a specific mesh size.

Table 4

Contradiction matrix and inventive principle of the TRIZ method

No.	Improving Parameters	Worsening Parameters	Inventive Principles	Sub Principles	Application
1	Shape (12)	Productivity (39)	Another Dimension (17)	Go single storey or layer to multi-storey or multi-layered	Multi Tray
				Move into an additional dimension – from one to two – from two to three	Steam Gap on Tray
		Easy Manufacture (32)	Another Dimension (17)	Move into an additional dimension – from one to two – from two to three	Mesh of Tray
		Force (Intensity) (10)	Thermal Expansion (37)	Use multiple materials with different coefficients of thermal expansion	Material of Oven Wall
2	Quantity of Substance (26)	Weight of Stationary Object (2)	Parameter Change (35)	Change other parameters	Thickness of Cloves
3	Temperature (17)	Loss of Time (25)	Parameter Change (35)	Change the temperature	Temperature
4	Extent of Automation (38)	Manufacturing Precision (29)	Feedback (23)	Introduce feedback to improve a process or action	Thermostat
5	Shape (12)	Device Complexity (36)	Segmenting (1)	Divide an object into independent parts	Indirect Heating
6	Power (21)	Speed (9)	Taking Out (2)	Extract the disturbing part or property from an object	Without Blower

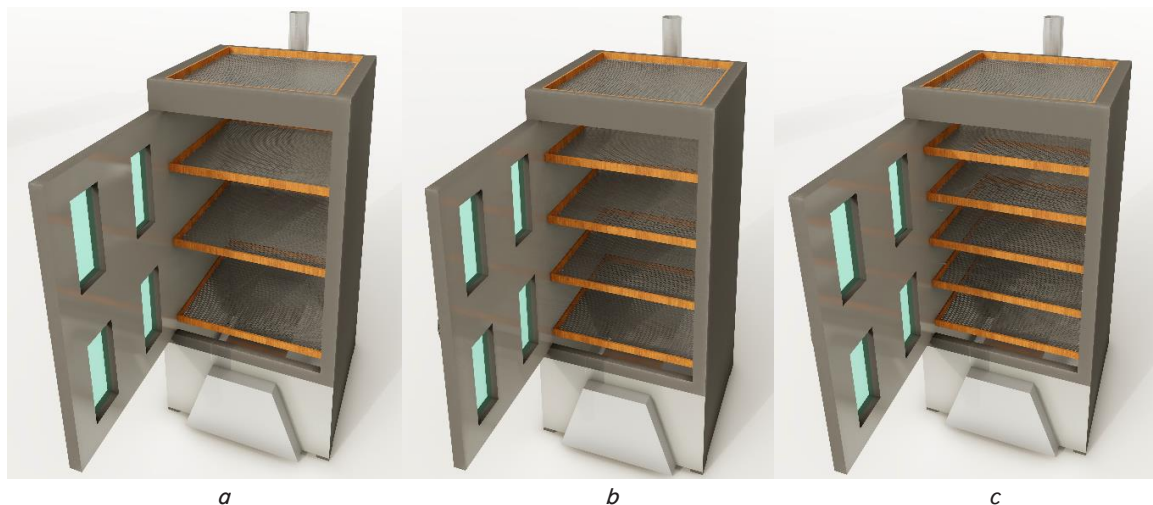


Fig. 4. Multi-tray oven design: a – 4 trays; b – 5 trays; c – 6 trays

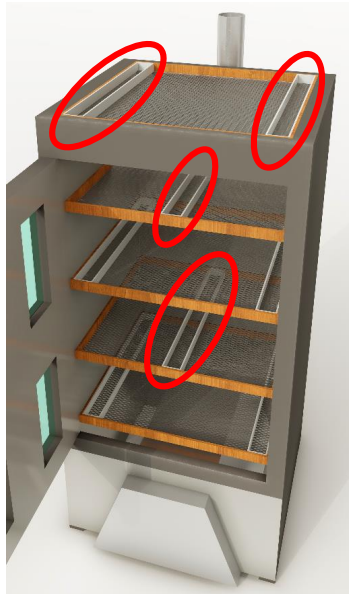


Fig. 5. Steam gap on the tray

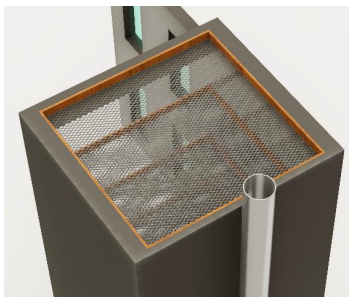


Fig. 6. Mesh of the tray

4. Oven Wall Material. The materials used in the manufacture of oven walls are plywood and galvanized plates. The choice of these two materials is based on low prices. Besides, it is necessary to choose suitable materials for the oven wall insulator so that not much heat from the oven comes out. Therefore, the selected insulator is air because it has no cost and has a small heat conductivity value of $0.024 \text{ W/m}^2\cdot\text{K}$. The layer of the oven wall uses a galvanized plate, then is fixed to plywood and space is given for air [15], and the outermost layer of the oven is made of plywood as in Fig. 7.

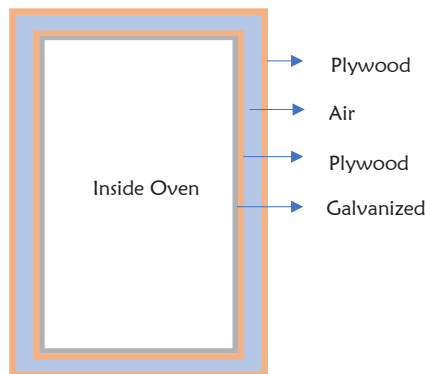


Fig. 7. Oven wall material

4. Clove Thickness. The thickness of the pile of cloves on the tray significantly affects the clove drying process, as shown in Fig. 8. The thicker the pile of cloves on the tray,

the dry part will be uneven. The hot airflow from the heat source will hit the cloves at the bottom layer then the water evaporates from inside the cloves. If the pile is too thick, it will be difficult for the cloves in the middle and top layers to contact the hot air because too many cloves are blocked. Therefore, the thickness of the pile of cloves on the tray needs to be considered.

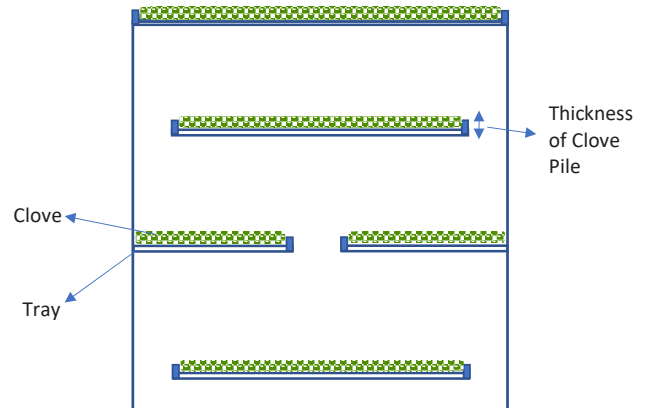


Fig. 8. Thickness of the clove pile on the tray

5. Temperature. A thermometer is installed in each tray and the combustion chamber to monitor and control the oven's heat. The drying temperature was controlled with this temperature measuring device. The recommended drying temperature of cloves from several previous studies is around $40\text{--}60 \text{ }^\circ\text{C}$. If it is less than $40 \text{ }^\circ\text{C}$, the evaporation process of water from inside the cloves is not optimal and takes a long time, but if it exceeds $60 \text{ }^\circ\text{C}$ it will cause the cloves to dry too much and the eugenol content will decrease. So, this thermometer is very helpful for drying oven users to monitor the drying temperature.

6. Thermostat. The thermostat is a device that can disconnect and connect an electric current when it detects changes in temperature in the surrounding environment according to the specified temperature settings. In general, today's thermostats can be divided into two main types, namely mechanical and electronic. Mechanical thermostats are a type of contact temperature sensor that uses electro-mechanical principles, while electronic thermostats use electronic components to detect temperature changes.

This thermostat uses a thermocouple as the sensor. The thermocouple is a type of temperature sensor used to detect or measure temperature by means of two different metal conductors joined at the ends to give a «thermo-electric» effect. Thermocouples are one of the most popular temperature sensors and are often used in various electric and electronic circuits or temperature-related equipment. Some of the advantages of the thermocouple that make it popular are fast response to temperature changes and wide operating temperature range from $-200 \text{ }^\circ\text{C}$ to $2,000 \text{ }^\circ\text{C}$. Apart from fast response and wide temperature range, the thermocouple is also resistant to shock or vibration and easy to use.

7. Indirect Heating. There are two types of heating systems in the drying process, direct heating and indirect heating. In the field survey, it was found that the oven used was a direct heating oven. The problem is that drying is too intense, which can be caused by the direct heating system. And this causes the drying temperature to be too high in the oven chamber. As shown in Fig. 9, this drying oven design uses an indirect heating system to overcome the temperature rise.

In addition, it can also reduce clove contamination by combustion gases.

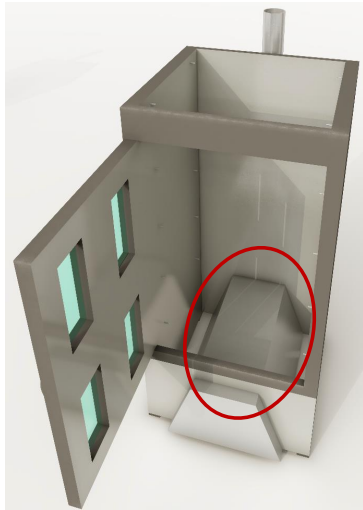


Fig. 9. Indirect heating system[16]

8. Oven Without Blower. The oven dryer design does not use a blower to reduce the energy loss caused by using a blower in an oven dryer previously owned by farmers. In the study, an anemometer was used to measure the velocity of air flowing out of the oven dryer into the free air through the chimney or the top tray.

The drying oven will be designed simple and cheap enough, as shown in Fig. 10. The drying oven used is made of plywood for the outer layer, galvanized plate for the inner layer and uses air as an isolator. Then LPG (Liquid Petroleum Gas) is used as an energy source. This oven will be equipped with a thermostat so that the temperature can be controlled.



Fig. 10. Design of the drying oven for clove

With the oven system change, this oven will overcome the shortcomings of the previous ovens, namely charred and contaminated clove. This oven uses an indirect heating system so that the combustion vapor does not directly contact cloves, which can avoid contamination. The trays use wire mesh so that hot air can flow through the wire mesh holes. Then the tray is given the air gap in the middle and on the side to help the hot air flow in each tray so that

the hot airflow can be evenly distributed, and this can make the hot air coming from below evenly distributed up to the top tray.

6. Discussion of the new design of drying oven using the TRIZ method to maintain the eugenol content in dried cloves

The results showed that three problems have been identified (Table 2): the clove moisture content is not uniform after the drying process, clove drying is too intense so that the results of the analysis of moisture and eugenol contents do not meet the Indonesian National Standard (SNI) (Table 1), and the oven that has been used so far is still fuel-wasting. There are 40 inventive principles solutions provided by the TRIZ method so that it can be selected according to the research objectives. Of the three problems, using the TRIZ method, several inventive principles solutions were obtained, namely (1) segmenting, (2) taking out, (17) another dimension, (23) feedback, (37) thermal expansion, and (35) parameter change. Then in Table 4, these inventive principles solutions are described in more detail into sub-principles so that it is easier to determine the right solution if applied in real terms. Several solutions from the TRIZ method were applied to the initial design of the clove drying oven. There are eight things that have been changed from the existing drying oven.

This drying oven design prioritizes clove products, which have moisture content and eugenol content according to the standards required by the industry. Because the previous oven did not emphasize the eugenol content, the design was different, not only to reduce the moisture content but to maintain the high eugenol content. Hence many details are paid attention to compared to the ovens that have been used before. In this oven, there is a steam gap in each tray (Fig. 4), afterward hot air can flow from the bottom to the top tray without a blower. And the size of the mesh tray (Fig. 5) is also considered because it relates to the flow of hot air that can enter the clove pile. So that the surface area of the dried cloves is larger. Separation of the combustion chamber (Fig. 8) is also not present in the previous oven, which aims to avoid product contamination with combustion gases. Removing this oven blower aims to save fuel, because the blower can cause the hot air velocity to increase so that the hot air in the oven is wasted faster.

The limitations of this study are that currently the design of the oven is only devoted to drying cloves to maintain their eugenol content. This oven capacity is also designed for clove farmers with a capacity of about 8–12 kg. The disadvantage of this study is that this oven is still limited to drying cloves and has a limited capacity. Therefore, it is necessary to make a prototype to test the feasibility of this oven design. Further studies are needed to increase capacity.

7. Conclusions

1. By identifying the problem of drying cloves, it is known that the eugenol content after the drying process has decreased.

2. The first step in designing a clove drying oven is to use the TRIZ method to determine the improving parameters of the three problems that have been identified.

3. With the Contradiction Matrix and Inventive Principle of the TRIZ method, suitable applications to new oven designs are obtained.

4. The new drying oven design according to the TRIZ method is an oven with an indirect heating system, without a blower and with a different tray design (using a steam gap and mesh size).

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