# DEVELOPMENT OF CLOVE BUDS DRYING PROCESS FOR SMALL TO MEDIUM ENTERPRISES

BY

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# ABSTRACT

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, so some farmers use the oven drying method. The initial study found that the eugenol content after the drying process decreased by 17%–20%. Therefore, his study has four successive objectives to maintain high eugenol content in dry cloves. The first objective is to identify factors that are affecting the eugenol content of the clove buds during the drying process. The second is to propose a modification drying model by combining various parameters. Next, to design and develop a drying apparatus to keep eugenol levels in clove buds high. And the fourth objective is to fabricate the prototype drying apparatus on the lab scale. After the problem was identified, the problem was solved using two methods, first theoretically through a combination of existing formulas, second through the TRIZ method, and continued research for a new oven prototype. The theoretical method showed that the porosity in the clove pile can affect the drying process. Hence, in the theoretical method, a formula was found to determine the thickness of the clove pile. The theoretical method also found several parameters to be a reference in designing a new oven, namely the number of trays in the oven (4, 5, 7, and 10), clove thickness (1, 1.5, 2, and 2.5 cm), the space between the trays in the oven, and steam gap on the tray (1–3 cm). In addition, it can also determine the appropriate oven coating material (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 tray space (indirect heating), and without using a blower. Several parameters were adjusted in the experiment using a drying oven prototype according to the theoretical calculation results and the TRIZ method results. In researching the new prototype oven, five parameters were used to get optimal results. These five parameters were obtained from the solution using the TRIZ method, namely temperature, the thickness of the pile of cloves, steam gap, size of the mesh tray, and the distance between the trays. Optimization using Response Surface Methodology (RSM) was divided into two stages on three responses: drying rate, eugenol content, and energy. From the results of optimization and verification in the first stage, it was found that three factors; temperature (70 °C), thickness (1 cm), and steam gap (3 cm), gave appropriate results (error below 5%) for the three responses (drying rate, eugenol content, and energy). Then, from the results of optimization and verification in the second stage, it was found that three factors; temperature (74 °C), a mesh of tray (10 mesh), and space of tray (12 cm) also gave appropriate results (error below 5%) for the three responses (drying rate, eugenol content, and energy). In conclusion, the new oven design based on theoretical calculations and the results of the TRIZ method can produce dry cloves which have eugenol content above 70%.

# ملخص البحث


يحتوي زيت القرنفل الأساسي (EO) على نسبة عالية من الأوجينول. يحتاج القرنفل الطازج إلى الخضوع التجفيف وتقطير لإنتاج الزيوت الأساسية. ومع ذلك، لا يمكن التجفيف بالشمس على النحو الأمثل في موسم الأمطار، لذلك يستخدم بعض المزّارعين طريقة التجفيف في الفرن. في بداية الدراسة أن محتوى الأوجينول انخفض بعد عملية التجفيف إلى 17–20٪. لذلك، تهدف هذه الدراسة إلى أربعة أهداف متتالية الحفاظ على نسبة عالية من الأوجينول في القرنفل الجاف. الهدف الأول هو تحديد العوامل التي تؤثر على محتوى الأوجينول في براعم القرنفل أثناء عملية التجفيف، والثاني هو اقتراح التعديل نموذج التجفيف من خلال الجمع بين المعلمات المختلفة. ثم لتصميم وتطوير جهاز تجفيف للحفاظ على مستويات الأوجينول في براعم القرنفل لا تزال مرتفعة. والهدف الرابع هو تصنيع النموذج أولي لجهاز التجفيف على مقياس معمل. بعد تحديد المشكلة، يتم حل المشكلة باستخدام طريقتين ، الأولى من الناحية النظرية من خلال التجمع من الصيغ الموجودة، والثانية من خلال طريقة TRIZ، واستمرار البحث لاختبار النموذج الأولي لفرن الجديد. وجدت الطريقة النظرية أن المسامية في كومة القرنفل تؤثر على عملية التجفيف. لذلك في هذه الطريقة النظرية، تم العثور على صيغة لتحديد سمك كومة القرنفل. ووجدت الطريقة النظرية أيضًا عدة معاملات لتكون مرجعية في تصميم فرن جديد، وهي عدد الصواني في الفرن (4، 5، 7، 10)، سمك القرنفل (1، 1.5، 2، 2.5 سم) المسافة بين الصواني في الفرن وفجوة البخار على الصينية (1–3 سم). بالإضافة إلى ذلك، يمكنها أيضًا تحديد مادة طلاء الفرن المناسبة (الخشب الرقائقي، اللوح المجلفن، والهواء). وفي طريقة TRIZ، تم العثور على عدة حلول لتصميم فرن جديد. وتم تغيير ثمانية أشياء من فرن التجفيف الحالي، بما في ذلك؛ عدد الصواني في الفرن، فجوة بخار في كل صينية، حجم الشبكة المستخدمة لقاعدة الصينية، مادة فرن التجفيف، سمك القرنفل على الصينية، درجة الحرارة المستخدمة في عملية التجفيف، التركيب ترموستات للتحكم في درجة الحرارة في الفرن، انفصل غرفة الاحتراق عن مساحة الصينية (تسخين غير مباشر)، وبدون استخدام منفاخ. وتم تعديل العديد من المعلمات في التجربة باستخدام نموذج أولي لفرن التجفيف وفقًا لنتائج الحساب النظري ونتائج طريقة TRIZ. وفي البحث الذي يستخدم النموذج أولي جديد للفرن، يتم استخدام خمس معلمات للحصول على أفضل النتائج. وتم الحصول على هذه المعلمات الخمسة من المحلول باستخدام طريقة TRIZ، وهي درجة الحرارة، وسمك كومة القرنفل، وفجوة البخار، وحجم صينية

الشبكة، والمسافة بين الصواني. وينقسم التحسين باستخدام منهجية سطح الاستجابة (RSM) إلى مرحلتين على ثلاث استجابات: معدل التجفيف، ومحتوى الأوجينول، والطاقة. ومن نتائج التحسين والتحقق في المرحلة الأولى، وجد أن ثلاثة عوامل؛ درجة الحرارة (70 درجة مئوية) والسماكة (1 سم) وفجوة البخار (3 سم) نتائج مناسبة (خطأ أقل من 5٪) للاستجابات الثلاثة (معدل التجفيف، محتوى الأوجينول، والطاقة). ثم من نتائج التحسين والتحقق في المرحلة الثانية، وجد أن ثلاثة عوامل؛ أعطت درجة الحرارة (74 درجة مئوية) وشبكة صينية (10 شبكة) ومساحة صينية (12 سم) نتائج مناسبة (خطأ أقل من 5٪) للاستجابات الثلاثة (معدل التجفيف ومحتوى الأوجينول والطاقة). في الختام، الفرن الجديد تصميم المبني على الحسابات النظرية ونتائج طريقة TRIZ فصوصًا جافة تحتوي على نسبة يوجينول أعلى من 70٪.

# APPROVAL PAGE

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# DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Beauty Suestining Diyah Dewanti

Signature ................................................ Date ................................................

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In the name of Allah, Most Gracious, Most Merciful and Praise be to Allah, the Cherisher and Creator of the worlds, for giving me the chance to complete this study.

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# LIST OF SYMBOLS

| | |
|---|---|
| % | Percentage |
| *t* | Drying time |
| *a, b, c, n* | Dimensionless constant for drying |
| $k$, $k_1$, $k_0$ | Drying velocity constant |
| *exp* | Experimental |
| *MR* | Moisture ratio |
| *L* | Thickness of the material |
| *dw* | Dry weight |
| $\phi$ | Porosity of a group material |
| $\varphi$ | Porosity of single material |
| *V* | *Volume;* $V_f$ volume of fluid; $V_{pm}$ volume of porous media; $V_w$ volume of water; $V_s$ volume of solid |
| *k* | *Thermal conductivity;* $k_{pm}$ thermal conductivity of porous media; $k_s$ thermal conductivity of solid; $k_f$ thermal conductivity of fluid; $k_p$ thermal conductivity of porosity single material; $k_w$ thermal conductivity of water |
| *A* | Area |
| *T* | *Temperature;* $T_s$ temperature of solid; $T_o$ temperature at y = 0; $T_a$ temperature of air; $T_i$ temperature at y = L |
| *c* | Spesific heat; $c_p$ spesific heat of porosity single material; $c_f$ spesific heat of fluid; $c_s$ spesific heat of solid; $c_{pm}$ spesific heat of porous media |
| *h* | Convection heat transfer coefficient |
| $\rho$ | Mass density; $\rho_f$ mass density of fluid; $\rho_{pm}$ mass density of porous media; $\rho_s$ mass density of solid; $\rho_p$ mass density of porosity single material |
| *m* | Mass; $m_f$ mass of fluid |
| $v_\varphi$ | Velocity of porosity |
| *t* | Time |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| CCD | Central Composite Design |
| DOE | Design of Experiment |
| EO | Essential Oil |
| GC-MS | Gas Chromatography-Mass Spectrometry |
| IUPAC | International Union of Pure and Applied Chemistry |
| LPG | Liquid Petroleum Gas |
| MHP | Mini Heat Pipes |
| RH | Relative Humidity |
| RSM | Response Surface Method |
| SME | Small to Medium Enterprises |
| SNI | Standard Nasional Indonesia (Indonesian National Standard) |
| TRIZ | *Teoriya Resheniya Izobretatelskikh Zadatch* |

# CHAPTER ONE

# INTRODUCTION

## 1.1 BACKGROUND OF THE STUDY

Clove (Syzygium aromaticum) belongs to the Myrtaceae family of the Myrtales order. It is a spice plant that originated in Maluku, Indonesia (Amelia et al., 2017). Cultivation of clove trees began in islands and countries including the Comoros Islands, Tanzania, Sri Lanka, Madagascar, and Indonesia, with Indonesia as the leading producer (Baietto, 2014). In Indonesia, the largest clove production comes from Java and Manado (Amelia et al., 2017). Originally, part of the clove plant, which is the clove flower, was used mainly as medicine, especially for nutritional health. Cloves are included in the plantation sector commodities which is an essential contributor to farmers' income.

Clove farmers in Indonesia are classified as micro and small enterprises. Micro and small enterprises, according to Law No. 20 of 2008, are productive businesses that are independently owned by an individual or a legal entity. With limited funds, large operational costs, and a small number of workers, these micro and small enterprises need help with various problems, including how to improve product quality. For example, the quality of cloves after the drying process.

The central part of the commercially valuable clove plant, which is the clove buds, is mostly used in the cigarette industry as well as in food industries. However, through innovation, other parts of the clove plant, namely leaves and flower stalks, have also been used as sources of clove oil used in pharmaceutical, cosmetics, and other industries. The main product of clove plants is clove buds, which are usually preserved in dry form. Processing of clove buds is generally carried out simply, mostly done by the farmers who have a relatively small area of the plantation. Usually, only a small number of them use semi-mechanical processing similar to what is being done at the significant plantation level. The drying process of clove buds is usually done under the sun. During the dry season, the drying process of clove buds takes typically 5 to 7 days to dry before it is ready to be used or to be stored. However, the disadvantage of this drying system is that if the weather is not conducive, such as during the rainy season and high humidity, a large area of land is needed. If left too long in moist air, it will be covered by mould. The advantage of this natural heat process is that the drying results are reasonably good because clove buds would not be exposed to extreme heat and the cost is reasonably cheap because they do not require energy for heating.

Drying is one of the common methods of plant preservation (Sourestani, Malekzadeh & Tava 2014). The purpose of drying is to inhibit enzymatic degradation and prevent the growth of the microorganism which in turn could prolong the shelf life of the product (Ebadi et al., 2015; Alma et al., 2007; Xie et al., 2015). Sun-drying is the most popular and economical drying method among farmers, especially farmers who live in tropical areas (Hastuti et al., 2017). However, drying under the sun is not practical since it relies heavily on the weather, takes a longer time, and causes exposure of the product to environmental contamination (Pirbalouti et al., 2013). Drying conditions such as time of drying, temperature, environment, and equipment can cause negative and positive effects on the drying process (Ozdemir et al., 2018).

Essential oils (EOs) are the main ingredients of many volatile medicinal plants such as cloves. There are many studies on the effects of different drying methods on EO results and medicinal plant composition  (Ozdemir et al., 2018; Murni et al., 2017; Ghasemi Pirbalouti et al., 2017a; Doymaz, 2012; Pirbalouti et al., 2013). 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 needs dried clove flowers, they have a minimum eugenol content standard of around 70% and 13–14% maximum moisture content. Thus, the introduction of the best drying methods for clove buds can be useful for increasing the yield and composition of their EO, especially Eugenol.

## 1.2 STATEMENT OF THE PROBLEM

Typical clove trees on average can produce 20 to 30 kilograms of fresh clove once harvested, depending on the size and age of the tree. Ready for sale dry cloves are often rare when the rainy season. During the rainy season, the supply of dried cloves from farmers declines because they have difficulty drying their crop cloves. Cloves can be dried during the dry season with the help of sunlight for 5 to 7 days with an average drying time of between 8 to 10 hours per day. The duration of the clove drying process increases to 6 to 10 days even more in the rainy season, depending on the intensity of the rain during the clove drying process. After drying, cloves have a moisture content ranging from 12 to 14 % and are brownish red. For every 3 kilograms of wet cloves, on average, it will end up as 1 kilogram after drying. The increase in the clove drying process during the rainy season results in a scramble over the land needed for the drying process. Farmers must wait for dry land first from the humidity from the rain. Figure 4.1 shows the current (traditional) drying processes with the sun drying method.

The drying of cloves relies on sunlight which can only be done during the daytime and is impossible to do at night. Clove drying using the sun drying method during the dry season is effective for farmers who have relatively large lands. The obstacle in the dry season arises when farmers do not have extensive dry lands to dry the cloves. The number of wet cloves that have not dried due to land factors and rain causes wet cloves would 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 become fermented and rotten. A large amount of wet cloves leads to plummeting prices.

Clove flowers contain about 10–20% oil, clove stalks 5–10%, and clove leaves 1–4% (Nanan Nurdjannah, 2004). 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%. If cloves are dried in the sun, the process can reduce eugenol levels because the temperature cannot be adjusted. Oven drying seems to be an alternative drying method that offers 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. Therefore, further research is needed to investigate drying methods that could produce the high eugenol content in dry cloves.

## 1.3 RESEARCH PHILOSOPHY

Cloves are widely used for various purposes, namely as ingredients for medicines and enhancers of races and aroma of food and drinks as well as raw materials for clove cigarettes and cosmetics. The use of cloves has evolved to include raw materials for antiseptics, fungicides, bactericides, insecticides, and anaesthetic drugs for animals. The extent of the use of cloves is due to the component of essential oils contained in the flowers, stems, and clove leaves. The main component of clove essential oil is eugenol, which is the active ingredient in medicines.

Processing of clove flowers after harvesting is generally still done traditionally, mostly done by farmers who do have not extensive planting land. After harvesting, the farmers dry the cloves directly under the sun because not many farmers have clove dryers. Sun-drying has many disadvantages, including being very dependent on the weather, taking a long time (5 to 7 days), having no temperature control, and being prone to product contamination. Often, a dryer is needed to overcome these problems.

Some drying technologies that have been studied include microwave-drying, oven-drying, spray-drying, and freeze-drying. Of the few technologies, oven-drying seemed suitable for farmers' needs because the price of the equipment is still affordable, the operation is easy, and the operational costs are cheap. However, the existing dryer is still focused on reducing the moisture content of the product even though clove drying must pay attention to the level of essential oils contained and ensure that it does 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 levels of essential oils such as eugenol levels in cloves. High temperatures during the drying process can cause many essential oils to evaporate. The next factor that was maybe affecting moisture content and eugenol levels in cloves is the thickness of cloves.

Initial experiments have been carried out to obtain variations in temperature and thickness of the media to set the activity using the oven drying. At the same time, a combination and simulation were carried out in several journals and books on formulas relating to heat transfer, thermodynamics, and mechanical fluid.

The literature search was done by selecting various research, article, and discussion related to oven drying for agriculture. Related research has been traced through published work in the last two years via Scopus, Google Scholar, and Research Gate, producing more than 16.000 literature under the keywords “oven drying for agriculture.” Interviews with clove farmers were conducted to collect their information and uncover difficulties with drying cloves. The analysis results of the literature review, initial experiment, and farmers' interviews were used as research guidance to design a novel oven drying setup method.

## 1.4 RESEARCH OBJECTIVES

The study aimed to achieve the following objectives:

1. To identify factors that are affecting the eugenol content of the clove buds during the drying process.
2. To propose a modification drying model by combining various parameters.
3. To design and develop a drying apparatus to keep eugenol levels in clove buds remain high.
4. To fabricate the prototype drying apparatus on the lab scale.

## 1.5 RESEARCH METHODOLOGY

The main effort of the present investigation was to develop drying equipment (oven drying) based on problem definition and manufacturing prototype. The research methodology was divided into four research objectives to make it easier to conduct and structure as shown in Figure 1.1. The first was to identify factors that are affecting the eugenol content of the clove buds during the drying process. Then a field survey was done to find out the problems faced by farmers in the clove drying process. After that, a study of the literature on drying agro-industrial products from various sources was performed to get a suitable solution.

Secondly, existing formulas from journals and books about heat transfer, thermodynamics, mechanical fluids, and so on were combined. Then simulation of the existing formulas was done to develop a new formula.

The third step was conducting some initial experiments to get some data for analysing the problem definition, and then using the TRIZ methods to solve the problem. TRIZ methods were used to find out an invention to solve the problems in drying cloves by conventional oven drying. TRIZ assured the invention of a new, quick, and precise solution that could resolve the problems to avoid wasting the time by providing too many alternative solutions. Alternative solutions from TRIZ methods were used to base the design of the prototype dryer.

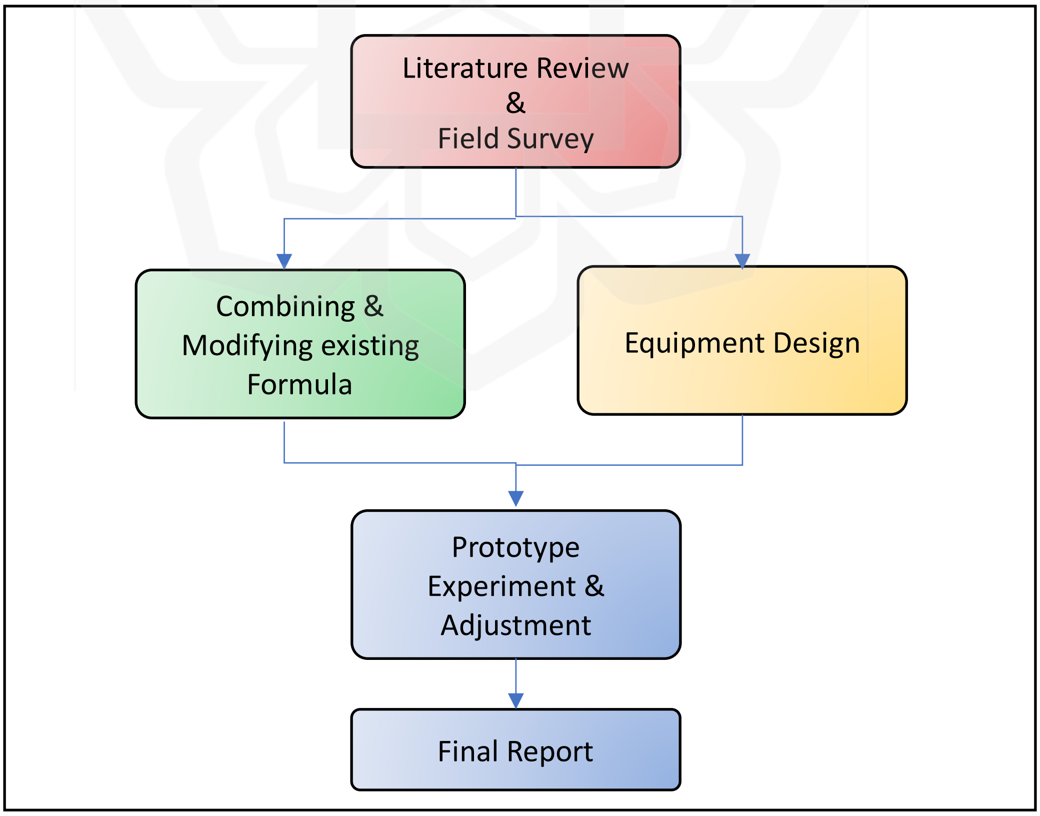


Figure 1.1 Simple Flow Chart of Research Methodology