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Alternative Drying Methods to Improve the Quality of Dried Cloves

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Abstract:
The main product of clove plants is clove buds, which are usually preserved in dry form. The drying process of clove buds is generally done under the sun. However, one of the disadvantages of this drying system is that if the weather is not right, such as during the rainy season and high humidity, it needs a large area of land, and if too long to be left in moisture air, it will be covered by mold. A literature search conducted to find out the most recent topics about drying agriculture and spice products that appropriate with clove. Clove drying has widely studied before, but there is still little research on the drying methods that affect the quality of dry clove, especially eugenol level in essential oil content. An artificial drying method suitable for a clove that can replace sun drying is oven drying. Several factors that can affect the quality of the clove are air temperature, space of the tray in the oven, and the thickness/layer of the clove that need to be observed. This research oven was designed with an indirect heating system, which was adjusted to the needs of clove farmers.

Keywords*: clove, essential oil, oven drying, space, temperature, thickness.*

INTRODUCTION:

Cloves in Latin namely Syzygiumaromaticum are a family of Myrtaceae. This species originates from certain volcanic islands in North Maluku (formerly known as the island of spices), in eastern Indonesia [1]. Cultivation of clove trees founded in islands and countries, namely the Comoros Islands, Tanzania islands, Sri Lanka, Madagascar, and Indonesia, but the leading producers are coming from Indonesia [2]. Originally part of the clove plant which is clove flower is used mainly as medicine, especially for nutritional health. The central part of the commercially valuable clove plant which is of interest that clove buds are mostly used in the tobacco industry as well as in food 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 in a simple way, mostly done by the farmers who have a relatively small area of a plantation. Usually, only a small number of them do semi-mechanical processing like what is done at a significant plantation level. The drying process of clove buds is generally done under the sun. During the dry season, the drying process of clove buds takes typically 5 to 7 days to dry and ready to be used or to be stored. However, the disadvantage of this drying system is that if the weather is not right, such as during the rainy season and high humidity, it needs a large area of land, and if too long to be left in moisture air, it will be covered by mold.

DRYING PROCESS

A. Review of Drying Process

Drying is an essential process in preserving materials and the processing industry of agricultural products[3]. Drying is the process of reducing the

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moisture content of materials to the extent that the growth of microorganisms and enzyme activities that can cause decay is inhibited and stopped. The more water content in a material, the faster the decay by microorganisms.[4], [5], [6]. Drying conditions such as time of drying, temperature, environment, and equipment can cause negative and positive effects on the drying process [7]. Many types of research have been conducted around the world to address drying process. From methods, dried material, mathematical models, and energy needed have been discussed for quite sometimes. This review has been classified into five categories (see Figure 1).

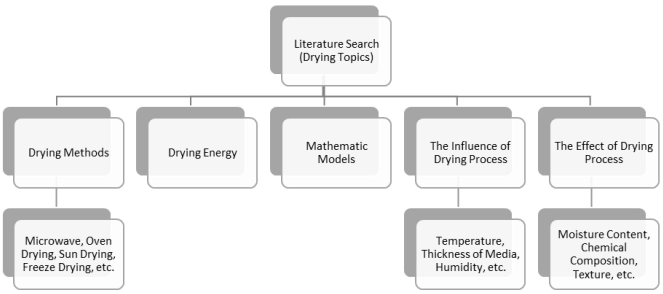

Figure 1. Literature Search for Drying Agriculture Products Topic

B. The Influence of Drying Process

The factors that influence drying consist of two elements, those which are related to drying air and factors that are associated with the nature of the dried material. Factors related to drying air consist of temperature, volumetric speed of drying air, and humidity. While factors related to the nature of the material consist of the shape or thickness of the material, initial moisture content, and partial pressure in the material, these factors can affect agricultural product composition during drying.

1. Air Temperature and Air Velocity

In almost all drying studies, temperature is very influential on the rate of drying. In this tomato drying study, an increase in air temperature will increase the rate of drying [8]. The drying kinetics of various horticultural products was influenced by the characteristic of air (temperature and velocity) and particle dimension [9]. It was found that drying kinetic is affected by air conditions and sample size. If the temperature increases, it can reduce water content of dried material. During the dehydration process, the most element that impact the kinetics of drying is air temperature. When the temperature rises, the equilibrium moisture content, drying constant, and moisture diffusivity will also increase [9]. In quince drying research, the characteristic of air (temperature and velocity) can affect the time of drying.[10].

2. Shape and Thickness of Sample

Besides the drying air temperature, many other factors influence the drying results. One factor related to the material is the shape and thickness of a sample. Thickness and thinness of a sample can affect the process of evaporation of water in a dried material. The shape of the sliced banana and temperature of air can affect the drying kinetics [11]. Besides temperature and velocity of air, the dimension of sliced potatoes positively influenced the diffusion coefficient in drying kinetics [12]. To increase the rate of heat transfer, then it can slice the product or put it in thin layers [13]. Potato slices and thickness can influence the duration of the drying process [14]. In the tomato drying research, the best results are influenced by thickness [15].

3. Relative humidity

The increase in temperature in the drying process automatically causes a decrease in relative humidity. These two factors are very related and affect reducing the moisture content in the dried material. In drying coffee with solar greenhouse drying system, it was proving that the increase in temperature and decrease in humidity can affect the rate of drying and water content in coffee [16]. Low relative humidity combined with high temperatures has been showing to accelerate drying time in drying experiments conducted for seaweed [17]. Many factors can affect the process of mass transfer and

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heat transfer from a drying process, namely the temperature and humidity of the air [18]. In kenaf core drying research also uses variable temperature and relative humidity to determine the appropriate modeling. [19]. In the research on drying udon noodles, it was found that the effect of relative humidity on the drying process was almost the same as the effect of temperature [20].

C. The Effect of Drying Process

One method for preserving food and crop is the drying method [3]. With this method, both plants and food have a long shelf life by avoiding degraded enzymes and damage caused by microbes [21]. However, the drying process can change aromatic compounds, reduce the number of nutrients, and discoloration [3][22]. Drying conditions, such as the environment, time, equipment, and temperature, can have positive or negative effects [23]. The following are some of the impacts that will occur on drying process by using some drying method:

1. Color Darkening

Previous studies have shown that the oven dries above 40 °C causing dark colors. Hence, the length of the drying process and the increase in temperature can be a significant cause of leaf discoloration [3]. A lot of previous research on crop drying discusses the effect of the duration of heating temperature on the color quality of dried plants. Loss of color quality from the leaves of Kelussia o. also occurs in various drying methods [21]. One of the qualities considered in the results of the drying process is the color of the dried material. With an increase in drying temperature in the eggplant causes a decrease in color brightness [24]. But there are also studies of drying that do not have a bad effect on the color of the material, namely the drying process of blackcurrant [25]

2. The Yield of Essential Oil

The amount of essential oil in a dried material can be influenced by various factors, one of which is the drying method. The most obtained oil yield in the shade drying method then followed by the oven drying method for drying *Origanum V.* and *Origanum O.* plants [7]. With six different drying methods and several variations in air temperature showed a significant effect on the yield of essential oils in dried Kelussia[21]. The drying procedure also determines the yield of the essential oil. Drying with the oven at 60 °C is very influential on essential oils.The drying method with shade and oven 45°C had an appreciable EO yield[21]. Evaporation of aromatic compounds using low temperatures causes higher oil yields with the shade drying method than other methods.

High temperatures can reduce levels of essential oil in the material (*Mentha piperita*), this happens in all the drying methods studied [23]. The freeze drying method in drying coriander shows the highest yield of essential oils compared to other methods, this is related to the temperature and pressure of the process [26].

3. Essential Oil Composition

In the study of drying kelussia, there are several components of essential oils that increase when compared to the sample before drying [21]. The most powerful thing in the drying process is the temperature, which is also related to the type of drying method. So that in the study of drying landrace bacilli obtained the essential oil components in the shade method [27]. This is also proven in the coriander drying research, where the essential oil component depends on the technique and drying temperature [26]. For the research on cloves that are dried and stored, there is a reduction in the number of components in clove essential oil [28]. However, there are also some studies on drying that do not have a significant effect on the elements of essential oils such as drying anise hyssop using the oven and air method [3].

4. Characteristic aroma

Drying can eliminate or produce aromatic components in the dried material. In drying materials such as leaves and herbs, one must consider the product's aroma because it is one of the important

properties that must be maintained [29]. As in the drying of coconuts to produce copra, this process produces aromatic components that make copra to be of poor quality [30]. In the research of several drying methods, it was found that the aromatic component is not much lost in the microwave method [21]. Room temperature can be used as one of the drying methods that can produce a product that does not have much reduction in aromatic components [31]. So it can be concluded that the temperature and the technique of drying have a major influence on the aromatic component in a leaf and herbs [27].

DRYING METHOD FOR AGRICULTURE PRODUCTS

A. Research Drying Method for Agriculture Products

The drying behavior of agricultural products throughout the drying process depending on the initial condition product, dimension, first and final water content, bulk density, the thick pile of material, air temperature, humidity, the velocity of air, and pre-treatment [32]. Drying methods for agriculture products can divided into two, namely naturally and artificially methods (Figure 2), where each of these methods further divided into directly and indirectly technique. The natural drying is a drying that is not assisted by a tool that usually only uses the sun and wind to reduce the moisture content that is present in a material. The artificial method is a drying method that uses the help of mechanical and electrical equipment so that it is easy to control in operation, and the product has a uniform quality. Of the two methods (natural and artificial), the drying method further divided into two, namely direct and indirect.

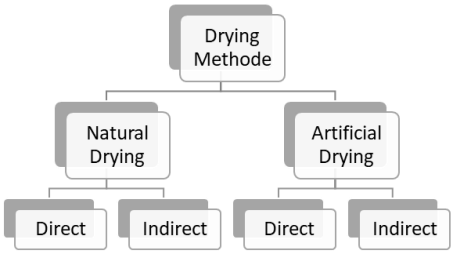

Figure 2. Classification Drying Method

Drying using sunlight is a natural drying method. Drying with sunlight is more popular and economical methods among farmers, especially farmers who live in a tropical area [33]. However, drying by the technique of sunlight also has many disadvantages, such as requiring a large area, which requires a long time because it can only be done in the morning and evening, and the product can be polluted by open conditions [27]. In increasing the shelf life of an agricultural product, various kinds of artificial drying developed. Most of these dryers, apart from their configurations, use expensive energy sources such as electricity, geothermal energy, microwave power, infrared, liquid oil gas, or a combination of solar energy and other forms of energy. Table 1 shows various kinds of drying methods for spice products. From several studies, the oven drying method showed the most suitable results for agriculture products.

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Table 1. Drying Methods Used to Agriculture Products

Product	Dryer Type	Reference
I. JEW'S MALLOW (*CORCHORUS OLITORIUS*) LEAVES	Oven	[34]
Curcuma longa L. leaves	Microwave, Oven, Freeze	[35]
Origanum vulgare L. *Origanumonites* L.	Oven, Shade, Sun	[7]
II. GREEN BELL PEPPER	Vacuum-assisted Microwave	[36]
Clove (*Syzygiumaromaticum*)	Oven	[28]
Clove (*Syzygiumaromaticum*)	Sun Drying	[33]
Stevia rebaudiana	Spray, Freeze, Oven	[37]
Walnut	Intermittent and Direct Oven, Sun Drying	[38]
Olive leaves	Convective Drying	[39]
Ginger	Sun, Oven, Vacuum Oven, Freeze	[40]
Olive pomace	Microwave Drying	[41]
LippiacitriodoraKunth	Shade, Freeze, Oven, Vacuum Drying	[4]
Kelussiaodoratissima	Sun, Shade, Oven, Microwave, Freeze	[21]
Ginger	Solar Cabinet Drying	[42]
Onion	Infrared Radiation System, Hot-air Convection System Combination Hot-air Convection&Infrared	[43]
Black pepper	Microwave oven	[44]
Lemon Balm	Hot-air Drying	[45]
Anise hyssop	Oven	[3]
Basil landraces	Sun, Shade, Oven, Microwave, Freeze	[27]
Basil (*Ocimumviride*) leaves	Microwave, oven, Hot air drying, Sun, Ambient Air	[46]
Legume leaves	Oven, Freeze	[47]

B. Drying Method For Cloves

The drying of cloves relies on sunlight, so it can only do during the daytime and impossible to do at night. Clove drying with sun drying method during the dry season can take place well for farmers who have relatively large land. The obstacle in the dry season that arises is when farmers do not have an extensive dry area to dry the cloves of their crops. The queue of moist cloves that have not dried due to land factors and rain causes wet cloves to

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accumulate. Spice products after harvesting tend to easily damage due to high water content so that it may cause the growth of almost all microorganisms [3], [27]. Drying spices undergo storage before being further processed into other products [28]. Spice products, such as cloves, will have a higher selling value in the dry form. Clove is one of the plants that have an aromatic component (Eugenia c. Or Syzygium a.), which is used as an ingredient for flavoring dishes [48].

In the initial stage of this research, the content of eugenol in fresh clove essential oils and sun-dried cloves was analyzed first. The results of the analysis of fresh cloves obtained levels of eugenol by 75.95%, while the eugenol levels in cloves were dried in the sun 54.66%. From these results, it can be concluded that the content of eugenol in dry cloves by the sun-drying method is reduced to around 21%. Cloves consist of volatile and non-volatile components. The volatile component produces a variety of essential oils that are extracting from almost all parts of the clove tree. The main component with the most amount of total clove oil is eugenol [48]. Table 2 shows some previous researches in analyzing the number of chemical components in the essential oil of the clove. The higher of eugenol content, the better of quality, and the selling value [49].

Table 2. The Largest Component in Clove Oil After the Drying Process

Reference	Composition (%)		
	Eugenol	**Caryophyllene**	**Eugenyl Acetate**
[5]	87.00	3.56	8.01
[50]	78.30	10.80	7.97
[51]	81.13	3.45	11.60
[52]	81.20	3.92	12.43
[1]	74.64	12.79	8.7

CLOVE DRYER INNOVATION

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

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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. Temperatures that are too high in the drying process can cause many essential oils to evaporate. The next factor that was maybe affecting water content and eugenol levels in cloves is the thickness of cloves.

Table 3. Advantages and Weakness of Oven Drying

Author	Title	Advantages	Weakness
[53]	Influence of Drying Methods on Flour Quality and Cyanide Content of Cassava Root Tuber	• Lower cyanide content • Faster than tray drying	-
[7]	Effect of different drying methods on the essential oil yield, composition and antioxidant activity of Origanum vulgare L. and Origanumonites L.	• Highest oil yield • Highest antioxidant	-
[28]	Effect of oven drying and storage on essential oil composition of clove (Syzygiumaromaticum) from Toli-Toli	• At 50°C generally increase some compound • Increase spice nature such as essential oil	• Decrease the amount of ester &monoterpens
[26]	Effect of drying methods on qualitative and quantitative properties of essential oil from the aerial parts of coriander	• Increased volatile component	• Lowest essential oil yield
[4]	Influence of Different Drying Methods on Drying Period, Essential Oil Content and Composition of LippiacittriodoraKunth	• At 40°C is practice for medical plants • At 40°C can get maximal essential oil content	• Drying time longer than vacuum • Affect glandular trichome integrity
[54]	Different Drying Methods for Agriculture Products and Eatables – A Review	• The simplest way to dry food • No special equipment	• Small scale • Rotate the trays from top to bottom • Darkening

The literature search is done by selecting various research, article, and discussion related to oven drying for agriculture. An interview with some clove farmers will be conducted to collect their experience

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and difficulties with drying cloves. The analysis results of the literature review (table 1 and table 3), initial experiment, and farmers interview will be used as research guidance to design an oven drying setup method's novelty. Some farmers have simple horizontal oven dryers with direct heating systems. This oven dryer can reduce the difficulties encountered in the sun drying process. According to farmers, this horizontal type is wasteful of fuel. Then this direct heating system makes the clove charred and contaminated with substances from the gas from the combustion of fuel (LPG).

With these considerations, an oven design is made, as shown in Figure 2. The oven drying will be designed to be simple and cheap enough for a low cost. The oven drying used is made of plywood for the outer layer and aluminium plate for the inner layer. Energy sources : LPG (Liquid Petroleum Gas). This oven will be equipped with an automatic temperature regulator so that the temperature can be adjusted and will not exceed 60°C.

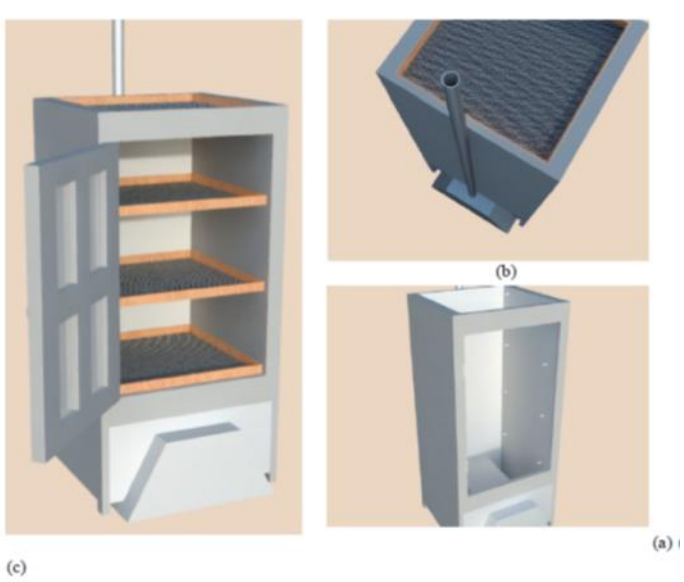

Figure 2. Design Oven Drying for Clove. (a) Overall view, (b) Top View, (c) Oven without trays

With the change in the oven system, this oven will overcome the shortcomings of the previous ovens, namely clove charred and contaminated. This oven uses an indirect heating system so that the vapor from the combustion does not directly come into contact with cloves, and this can avoid contamination. The tray is made of mesh wire so that cloves can catch steam from cloves that are still rich in essential oil in the upper tray. So that not much essential oil is lost due to evaporation. Then the tray is given an air gap in the middle, and on the side, this can make the hot air coming from below evenly distributed up to the top tray.

The mechanism airflow in the oven shows in figure 3.

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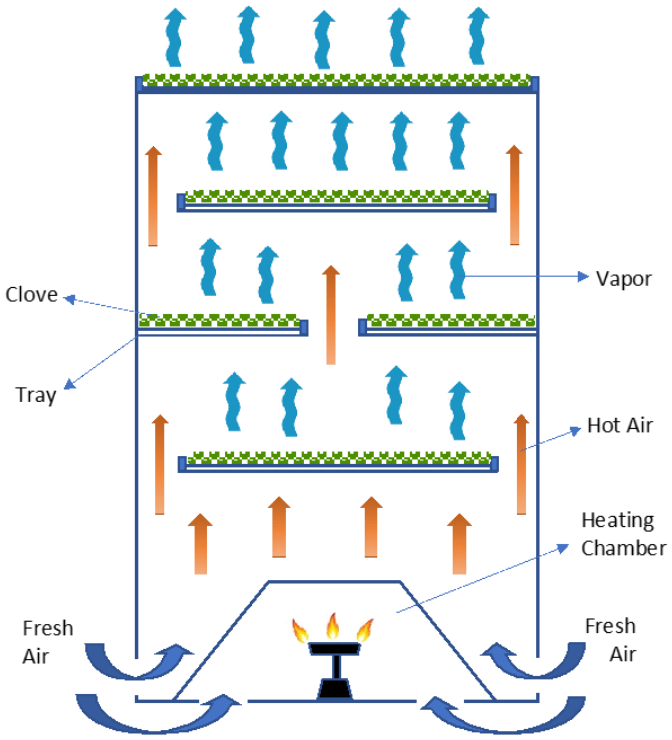

Figure 3. A sketch of the air flow in the oven

CONCLUSION:

This study aims to resolve the clove drying problems faced by clove farmers. High technology can solve these problems, but not in accordance with the conditions of farmers. Therefore, this study designs oven drying by modifying existing ovens that are adapted to the needs and abilities of farmers and can also improve the quality of dry cloves. This modified oven uses an indirect heating system to avoid contamination. Oven equipped with an automatic temperature regulator to adjust the temperature, and the tray is made from mesh wire. With this oven modification, the essential oil levels, especially eugenol, can higher than using sun drying methods.

REFERENCES

1. B. Amelia, E. Saepudin, A. H. Cahyana, D. U. Rahayu, A. S. Sulistyoningrum, and J. Haib, "GC-MS analysis of clove (Syzygium aromaticum) bud essential oil from Java and Manado," *AIP Conf. Proc.*, vol. 1862, no. July, 2017.
2. M. Baietto, "Bud Fall Induction in Clove (Syzygium Aromaticum)," *Acad. Res. Int.*, vol. 5, no. July, pp. 23–29, 2014.
3. M. M. Sourestani, M. Malekzadeh, and A. Tava, "Influence of drying, storage and distillation times on essential oil yield and composition of anise hyssop [Agastache foeniculum (Pursh.) Kuntze]," *J. Essent. Oil Res.*, vol. 26, no. 3, pp. 177–184, 2014.
4. M. T. Ebadi, M. Azizi, F. Sefidkon, and N. Ahmadi, "Influence of different drying methods on drying period, essential oil content and composition of Lippia citriodora Kunth," *J. Appl. Res. Med. Aromat. Plants*, vol. 2, no. 4, pp. 182–187, 2015.
5. M. H. Alma, M. Ertaş, S. Nitz, and H. Kollmannsberger, "Chemical composition and content of essential oil from the bud of cultivated Turkish clove (Syzygium aromaticum L.)," *BioResources*, vol. 2, no. 2, pp. 265–269, 2007.
6. Y. Xie, Z. Yang, D. Cao, F. Rong, H. Ding, and D. Zhang, "Antitermitic and antifungal activities of eugenol and its congeners from the flower buds of Syzgium aromaticum (clove)," *Ind. Crops Prod.*, vol. 77, pp. 780–786, 2015.
7. N. Ozdemir, Y. Ozgen, M. Kiralan, A. Bayrak, N. Arslan, and M. F. Ramadan, "Effect of different drying methods on the essential oil yield, composition and antioxidant activity of Origanum vulgare L. and Origanum onites L.," *J.*

May- June2020
ISSN: 0193-4120 Page No. 6928 - 6939

Food Meas. Charact., vol. 12, no. 2, pp. 820–825, 2018.

8. E. E. Abano, H. Ma, and W. Qu, "Influence of Air Temperature on the Drying Kinetics and Quality of Tomato Slices," *J. Food Process. Technol.*, vol. 02, no. 05, 2011.
9. M. K. Krokida, V. T. Karathanos, Z. B. Maroulis, and D. Marinos-Kouris, "Drying kinetics of some vegetables," *J. Food Eng.*, vol. 59, no. 4, pp. 391–403, 2003.
10. D. A. Tzempelikos, A. P. Vouros, A. V. Bardakas, A. E. Filios, and D. P. Margaris, "Case studies on the effect of the air drying conditions on the convective drying of quinces," *Case Stud. Therm. Eng.*, vol. 3, no. July, pp. 79–85, 2014.
11. S. V. Borges, M. C. Mancini, J. L. G. Corrêa, and J. B. Leite, "Drying kinetics of bananas by natural convection: Influence of temperature, shape, blanching and cultivar," *Ciência e Agrotecnologia*, vol. 35, no. 2, pp. 368–376, 2011.
12. S. B. Bakal, G. P. Sharma, S. P. Sonawane, and R. C. Verma, "Kinetics of potato drying using fluidized bed dryer," *J. Food Sci. Technol.*, vol. 49, no. 5, pp. 608–613, 2012.
13. S. S. Onimisi and A. N. Sule, "Investigation of Drying Quality of Yam (A Staple Food) From Developed Multipurpose Food Dryer," *Int. J. Eng. Technol.*, vol. 6, no. 6, pp. 191–196, 2016.
14. S. Naderinezhad, N. Etesami, A. P. Najafabady, and M. G. Falavarjani, "Mathematical modeling of drying of potato slices in a forced convective dryer based on important parameters," *Food Sci. Nutr.*, vol. 4, no. 1, pp. 110–118, 2016.
15. A. F. K. Correia, A. C. Loro, S. Zanatta, M. H. F. Spoto, and T. M. F. S. Vieira, "Effect of temperature, time, and material thickness on the dehydration process of tomato," *Int. J. Food Sci.*, vol. 2015, 2015.
16. E. Menya and A. J. Komakech, "Investigating the effect of different loading densities on selected properties of dried coffee using a GHE dryer," *Agric. Eng. Int. CIGR J.*, vol. 15, no. 3, pp. 231–237, 2013.
17. A. Fudholi, M. Y. Othman, M. H. Ruslan, M. Yahya, A. Zaharim, and K. Sopian, "The effects of drying air temperature and humidity on the drying kinetics of seaweed," *Proc. 4th WSEAS Int. Conf. EMESEG'11, 2nd Int. Conf. WORLD-GEO'11, 5th Int. Conf. EDEB'11*, no. July, pp. 129–133, 2011.
18. T. Marnoto, "Drying of Rosella (Hibiscus sabdariffa) Flower Petals using Solar Dryer with Double Glass Cover Collector," *Int. J. Sci. Eng.*, vol. 7, no. 2, pp. 150–154, 2014.
19. S. Misha, A. S. Mat, M. H. Ruslan, K. Sopian, and E. Salleh, "The Effect of Drying Air Temperature and Humidity on the Drying Kinetic of Kenaf Core," *Appl. Mech. Mater.*, vol. 315, pp. 710–714, 2013.
20. T. Inazu, K. I. Iwasaki, and T. Furuta, "Effect of temperature and relative humidity on drying kinetics of fresh Japanese noodle (udon)," *LWT - Food Sci. Technol.*, vol. 35, no. 8, pp. 649–655, 2002.
21. F. Mirhosseini, M. Rahimmalek, A. G. Pirbalouti, and M. Taghipoor, "Effect of different drying treatments on essential oil yield, composition and color characteristics of Kelussia odoratissima Mozaff," *J. Essent. Oil Res.*, vol. 27, no. 3, pp. 204–211, 2015.
22. B. K. Bala and M. A. Hossain, *Solar drying of fishery products*. 2012.
23. H. Ayyobi, G.-A. Peyvast, and J.-A. Olfati, "Effect of drying methods on essential oil yield, total phenol content and antioxidant capacity of peppermint and dill," *Ratar. i Povrt.*, vol. 51, no. 1, pp. 18–22, 2014.
24. G. B. Urun, Ü. R. Yaman, and E. Kose, "Determination of drying characteristics and quality properties of eggplant in different drying conditions," *Ital. J. Food Sci.*, vol. 27, no. 4, pp. 459–467, 2015.
25. A. Michalska, A. Wojdyło, K. Lech, G. P. Łysiak, and A. Figiel, "Effect of different drying techniques on physical properties, total polyphenols and antioxidant capacity of blackcurrant pomace powders," *LWT - Food Sci. Technol.*, vol. 78, pp. 114–121, May 2017.
26. A. Ghasemi Pirbalouti, S. Salehi, and L. Craker, "Effect of drying methods on qualitative and quantitative properties of essential oil from the aerial parts of coriander," *J. Appl. Res. Med. Aromat. Plants*, vol. 4, 2017.
27. A. G. Pirbalouti, E. Mahdad, and L. Craker, "Effects of drying methods on qualitative and

May- June2020
ISSN: 0193-4120 Page No. 6928 - 6939

quantitative properties of essential oil of two basil landraces," *Food Chem.*, vol. 141, no. 3, pp. 2440–2449, 2013.

28. V. W. Murni, E. Saepudin, A. H. Cahyana, D. U. C. Rahayu, L. T. Hastuti, and J. Haib, "Effect of oven drying and storage on essential oil composition of clove (Syzygium aromaticum) from Toli-Toli," in *AIP Conference Proceedings*, 2017, vol. 1862, no. July.
29. M. R. Parmar, R. L. Rajput, M. T. Kumpavat, and V. B. Bhalodiya, "Retention of active ingradients in hot air tray drying," *Int. J. Eng. Res. Dev.*, vol. 14, no. 3, pp. 28–36, 2018.
30. L. D. B. Pestaño and W. I. Jose, "Engineering an Improved Coconut Processing System in the Philippines at the Farm-Level," *J. Adv. Agric. Technol.*, vol. 3, no. 1, pp. 58–62, 2019.
31. M. C. Díaz-Maroto, M. Soledad Pérez-Coello, M. A. González Viñas, and M. Dolores Cabezudo, "Influence of drying on the flavor quality of spearmint (Mentha spicata L.)," *J. Agric. Food Chem.*, vol. 51, no. 5, pp. 1265–1269, 2003.
32. A. Tiwari, "A Review on Solar Drying of Agricultural Produce," *J. Food Process. Technol.*, vol. 7, no. 9, 2016.
33. L. T. Hastuti, E. Saepudin, A. H. Cahyana, D. U. C. Rahayu, V. W. Murni, and J. Haib, "The influence of sun drying process and prolonged storage on composition of essential oil from clove buds (Syzygium aromaticum)," in *AIP Conference Proceedings*, 2017, vol. 1862.
34. A. O. Omolola, P. F. Kapila, and H. M. Silungwe, "Mathematical modeling of drying characteristics of Jew's mallow (Corchorus olitorius) leaves," *Inf. Process. Agric.*, vol. 6, no. 1, pp. 109–115, 2019.
35. M. C. Braga, E. C. S. Vieira, and T. F. de Oliveira, "Curcuma longa L. leaves: Characterization (bioactive and antinutritional compounds) for use in human food in Brazil," *Food Chem.*, vol. 265, no. January, pp. 308–315, 2018.
36. V. Kumar and S. L. Shrivastava, "Vacuum-assisted microwave drying characteristics of green bell pepper," *Int. J. Food Stud.*, vol. 6, no. 1, pp. 67–81, 2017.
37. C. Chranioti, S. Chanioti, and C. Tzia, "Comparison of spray, freeze and oven drying as a means of reducing bitter aftertaste of steviol glycosides (derived from Stevia rebaudiana Bertoni plant) - Evaluation of the final products," *Food Chem.*, vol. 190, pp. 1151–1158, 2016.
38. Q. Qu *et al.*, "Effects of three conventional drying methods on the lipid oxidation, fatty acids composition, and antioxidant activities of walnut (Juglans regia L.)," *Dry. Technol.*, vol. 34, no. 7, pp. 822–829, 2016.
39. Ö. F. Gamli, Ö. Süfer, and T. Eker, "Convective Drying Kinetics and Phenolic Contents of Olive Leaves," vol. 28, pp. 14–20, 2016.
40. Ö. A. Gümüşay, A. A. Borazan, N. Ercal, and O. Demirkol, "Drying effects on the antioxidant properties of tomatoes and ginger," *Food Chem.*, vol. 173, pp. 156–162, 2015.
41. T. Sadi and S. Meziane, "Mathematical modelling, moisture diffusion and specific energy consumption of thin layer microwave drying of olive pomace," *Int. Food Res. J.*, vol. 22, no. 2, pp. 494–501, 2015.
42. A. W. Deshmukh, M. N. Varma, C. K. Yoo, and K. L. Wasewar, " Investigation of Solar Drying of Ginger (Zingiber officinale): Emprical Modelling, Drying Characteristics, and Quality Study ," *Chinese J. Eng.*, vol. 2014, pp. 1–7, 2014.
43. H. S. El-mesery and G. Mwithiga, "Journal of Applied Science and Agriculture Specific Energy Consumption of Onion Slices During Hot-air Convection , Infrared Radiation and Combined Infrared-Convection Drying," *J. Appl. Sci. Agric.*, vol. 9, no. 20, pp. 13–22, 2014.
44. G. B. Radhika and S. M. Shyma, "Estimation of Mass Transfer Parameters and Drying Characteristics of Black Pepper using Microwave Energy," *Int. J. Innov. Res. Adv. Eng.*, vol. 1, no. 7, pp. 228–234, 2014.
45. D. Argyropoulos and J. Müller, "Kinetics of change in colour and rosmarinic acid equivalents during convective drying of lemon balm (Melissa officinalis L.)," *J. Appl. Res. Med. Aromat. Plants*, vol. 1, no. 1, pp. e15–e22, 2014.
46. E. Danso-Boateng, "Effect of drying methods on nutrient quality of basil (ocimum viride) leaves cultivated in Ghana," *Int. Food Res. J.*, vol. 20, no. 4, pp. 1569–1573, 2013.
47. S. Y. Sang, F. Jamharee, K. N. Prasad, A. Azlan,

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and N. Maliki, "Influence of drying treatments on antioxidant capacity of forage legume leaves," *J. Food Sci. Technol.*, 2011.

48. P. Milind and K. Deepa, "Clove: A Champion Spice," *Int. J. Res. Ayurveda Pharm.*, vol. 2, no. 1, pp. 47–54, 2011.
49. J. Towaha, "The benefits of cloves eugenol in various industries in Indonesia," *J. Perspekt.*, vol. 11, no. 2, pp. 79–90, 2012.
50. N. Nurdjannah and N. Bermawie, *Handbook of Herbs and Spices: Second Edition*. 2012.
51. H. Julianus Sohilait, "Chemical Composition of the Essential Oils in *Eugenia caryophylata*, Thunb from Amboina Island," *Sci. J. Chem.*, vol. 3, no. 6, p. 95, 2016.
52. H. Prianto, R. Retnowati, and U. P. Juswono, "Isolasi dan Karakterisasi dari Minyak Bunga Cengkeh (Syzygium aromaticum) Kering Hasil Destilasi Uap," *Kim. Student J.*, vol. 1, no. 2, pp. 269–275, 2013.
53. T. Kasaye Atlaw, "Influence of Drying Methods on Flour Quality and Cyanide Content of Cassava Root Tuber," *Int. J. Nutr. Food Sci.*, vol. 7, no. 4, p. 142, 2019.
54. M. Veerakumar, K. C. K. Vijayakumar, and P. Navaneethakrishnan, "Different Drying Methods for Agriculture Products and Eatables – A Review," no. 2, 2014.