International Journal of Physical Sciences and Engineering
Available online at www.sciencescholar.us
Vol. 7 No. 1 April 2023, pages: 1-10
e-ISSN : 2550-6943, p-ISSN : 2550-6951
https://doi.org/10.53730/ijpse.v7n1.13910

Performance Test of Single Heater Chili Dryer with Liquefied Petroleum Gas Fuel

I Gde Antha Kasmawan [a], Winardi Tjahjo Baskoro [b], I Made Satriya Wibawa [c]

Manuscript submitted: 27 November 2022, Manuscript revised: 18 December 2022, Accepted for publication: 09 January 2023

Corresponding Author [a]

Keywords

chili dryer;
dry chilies;
drying duration;
liquefied petroleum gas;
single heater;

Abstract

Chilli farmers in rice fields without electricity need help to make a simple chili dryer to process chilies when the chili harvest is abundant. To overcome this, it is necessary to design a dryer with a liquefied petroleum gas (LPG) fueled heater. The main objective of this research is to make and test the performance of the chili dryer. The building of the dryer is made of 95% metal and the remaining 5% non-metallic material (wood) with a length of 60 cm, a width of 50 cm, and a height of 120 cm in which there are 6 chili tray slots. Furthermore, the entire process of testing the performance of the tool is carried out using only freshly picked chilies until dry chilies are obtained (20% of initial weight). For the results of the first stage test (variation of drying temperature with an initial weight of chili set at 3 kg), it was found that the average drying time at each temperature of 70, 85 and 100°C was around 14.2; 9.3; and 6.5 hours. For the results of the second stage of the test (variation of the initial weight of chilies with a constant drying temperature of 85°C), it was obtained that the average drying time for each initial weight of chilies 1, 2, 3, 4, 5, and 6 kg was around 6.1; 8,6; 9.3; 9.3; 11.8; and 14.2 hours. The most effective and efficient chili dryer performance test was obtained from drying chilies with an initial chili weight of 4 kg (9.3-hour drying duration) by consuming about 0.82 kg of LPG.

Contents

[a] Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Denpasar, Indonesia
[b] Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Denpasar, Indonesia
[c] Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Denpasar, Indonesia

1 Introduction

Cayenne pepper or bird's eye chili is one of the most important seasoning ingredients in Indonesia, especially for traditional Balinese dishes. Its presence can be seen clearly in every Balinese dish along with onion, garlic, spices, and ingredients for spices from tubers such as galangal, ginger, and turmeric, with a portion of almost 15% of the total ingredients. Apart from being a flavoring ingredient, chili is also believed to be anti-bacterial. This was confirmed through research results that chili extract has been proven to be used as an inhibitor for bacterial growth (Koffi-Nevry et al., 2012).

On certain holidays, especially moments before religious ceremonies, the demand for chili tends to increase and affects increasing the price of this commodity. Chili commodity prices often fluctuate depending on their availability and market demand (Youn & Tonon, 2010; Zhang et al., 2022). The decline in chili prices is generally caused by simultaneous harvests in various regions with abundant yields and declining market demand under certain conditions, and conversely, chili prices soar when harvests fail and market demand is high, especially just before the holidays. Even though prices have been set for the local area, the price of chili on the market still fluctuates frequently (Sativa et al., 2017). On the other hand, chili is a horticultural commodity that is easily damaged and rotten, so it needs to be handled properly. These problems, especially during times of abundant harvests, urgently need to be addressed so that losses at the farm level can be avoided (Artnaseaw et al., 2010; Nimrotham et al., 2017).

The effort to prevent chili farmers from losses due to falling chili prices during abundant harvests is to extend the chili's shelf life. One of these efforts is by drying, namely processing freshly picked chilies into dry products using a chili dryer. The chili dryer can be made using appropriate technology. The heating source can use a heat source from the sun, gas or electricity. The drying process with a dryer with a solar heat source can generally take 3-5 days (Kamble et al., 2013; Pandey et al., 2015; Nimrothama et al., 2017). If the equipment is equipped with the installation of a fan, it can take up to 2 days at the fastest whereas if it is with ordinary drying it can last for 7-10 days (Hossain et al., 2015). The development of solar-source dryers can also be designed with a rotating device to make it easier for farmers to work so they don't experience fatigue (Alit & Susana, 2022). The drying process with a dryer with a source of liquefied gas (LPG) can generally last 6-10 hours or in an oven dryer in the range of 1 day (Gamuchirai et al., 2019). In general, increasing the drying temperature and drying air exchange rate will reduce the product drying duration (Charmongkolpradit et al., 2010). However, the research results show that the fastest drying process for red chilies is carried out at a temperature of 80°C, which is for 7-8 hours (Purbasari & Putri, 2021). The highest quality of drying and brightness of the color of dried chili products is at a temperature of 50°C (Getahun et al., 2021). In red chilies, the artificial drying process with a combination of rack systems, installation of fans, and drying in the sun can maintain the vitamin C content and overcome changes in the color of the products produced (Renate & Simbolon, 2022).

The drying process in principle aims to reduce the water content of the raw product. The decrease in water content in chili products can inhibit microbial activity so that the product's shelf life can be extended (Achanta & Okos, 2000). The drying process can also cause residues from certain types of pesticides in chilies to be removed up to 16-49% (Noh et al., 2015). The technique of drying raw chili products into dry products is of course hoped to be able to help farmers when harvests are abundant so that price stability in the market is more maintained. In addition, dried chili products and their preparations are now in great demand and can be found in conventional or modern markets so that chili farmers need not worry about marketing (Aishwarya et al., 2021; Raslavičius et al., 2014).

This research is aimed at facilitating farmers in making and using chili dryers in the field (in rice fields). More specifically, the first objective of this research is to realize a simple chili dryer without electricity using a single heater fueled by LPG. The second objective is to understand the performance test of the chili dryer which includes the effectiveness and efficiency of the appliance regarding the heating temperature, drying duration, the number of chilies dried, and the amount of LPG consumed (Hernández-Fernández et al., 2021).

2 Materials and Methods

The chili dryer was designed using a combination of a tray dryer and oven system in the shape of a box with a length of 60 cm, a width of 50 cm, and a height of 120 cm. The dryer is formed using frame, base, and walls of metal except for the tray frame using local wood. The heat source used comes from a single heater with LPG fuel. The design of the dryer is shown in Figure 1.

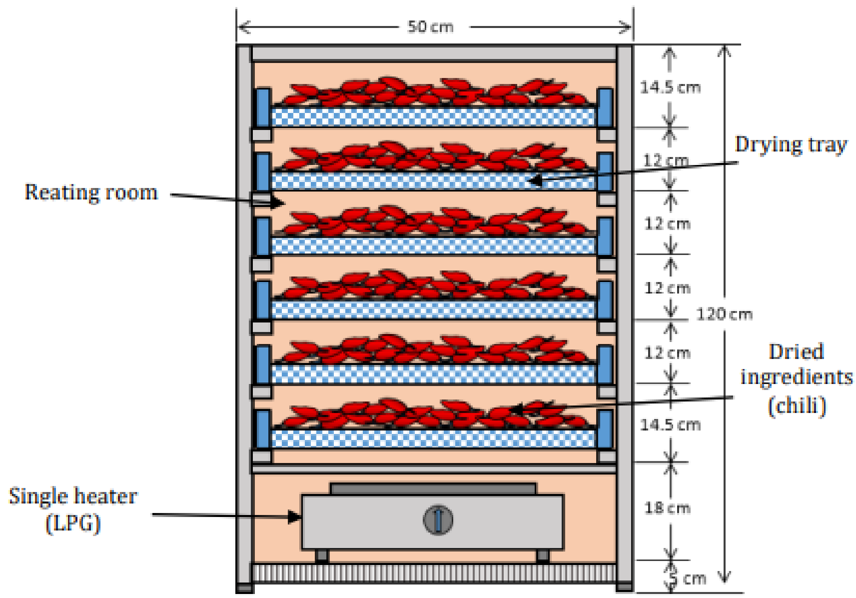

Figure 1. Design of a simple chili dryer

After the dryer was built, performance tests were carried out using experimental material in the form of fresh ripe cayenne pepper (a day after picking). The preparatory stages include the washing (cleaning) process, the process of weighing all the chilies to be dried, and the process of installing the dryer. The next step is to weigh the chilies per portion and arrange them evenly on a tray which is then inserted into each tray slot in the dryer. Next, the heater is turned on and adjusted in such a way that the desired drying chamber temperature is obtained. The operation of the dryer continues until dried chilies are obtained or a shrinkage of about 80% is obtained (marked by dry chilies that break easily). After the drying process is complete, all trays are removed and the dried chilies are collected which is then weighed (Sampathkumar & Senthilkumar, 2012; Aldabbagh et al., 2010).

Research on determining the temperature that affects the weight loss of chili 80% was carried out in the experimental room. The initial chili weight was kept the same at 3 kg for each temperature variation, namely 70, 85, and 90°C. For each first treatment, the first step was to prepare 1.0 kg of chili and put it in each of the three bottom trays, then preheat it for 30 minutes until a stable room temperature was reached. During heating, the chili was stirred every 30 minutes until 80% weight loss was obtained. After the experiment was completed, the duration of chili drying and the amount of LPG that had been used up were recorded for consideration in the next experiment. After the data was obtained and data analysis was carried out, the research continued to determine the initial chili weight to 80% chili weight loss. For this reason, experiments were made at a constant temperature (85°C) but the initial chili weight was varied, namely 1.0; 2.0; 3.0; 4.0; 5.0; and 6.0 kg and the implementation is similar to the temperature determination experiment. Each experiment was repeated three times. After all the data was collected, data analysis was carried out statistically to determine the parameters of temperature and initial weight of the material for the chili weight loss of 80%. Based on the data analysis, the effectiveness and efficiency of the chili dryer that has been made can be identified (Omojaro & Aldabbagh, 2010).

3 Results and Discussions

3.1 Chili dryer making

The chili dryer was made based on the design of the dryer that has been presented in the research method with several improvements. The chili dryer is presented in Fig. 2. The whole of the dryer, including the frame, top, walls, dryer base, and heating stand, are made of metal, except for the frame of the tray where the chilies are dried, which is made of wood for user safety and comfort. The inside of the tool contains six slots where the tray is placed. The outer dimensions of the dryer are 60 cm x 50 cm x 120 cm, which respectively indicates the length, width and height of the tool. Based on this size, the maximum capacity of the dryer is around 6 kg of raw chilies. As a source of heat, the dryer uses a single gas burner which is connected directly to an LPG cylinder via a gas hose equipped with a regulator.

(a) (b) (c)

Figure 2. A chili dryer that is ready to be used to obtain dry chili products ready to be ground with (a) external appearance, (b) internal appearance, and (c) ready-to-use appearance

In general, the specifications of the single-heating chili dryer (Fig. 2) are as follows:

- The frame of the dryer is made of metal (95%) except the frame of the tray is made of wood (5%)
- Dryer dimensions (size): 60 cm x 50 cm x 120 cm.
- Capacity: ± 6 kg of cayenne pepper.
- Fuel: LPG.
- Inside the dryer contains 6 slot trays and 1 gas heater (stove) which is connected to a cylinder filled with LPG via a regulator and gas hose.

3.2 Initial test of dryer performance

Testing of the dryer needs to be done after the dryer has been built. The initial performance test of the dryer for drying chilies and the subsequent implementation of the chili drying process is generally carried out in three stages, namely the preparatory stage, the drying process stage, and the final stage. An illustration of the three stages of the process is presented in Fig. 3.

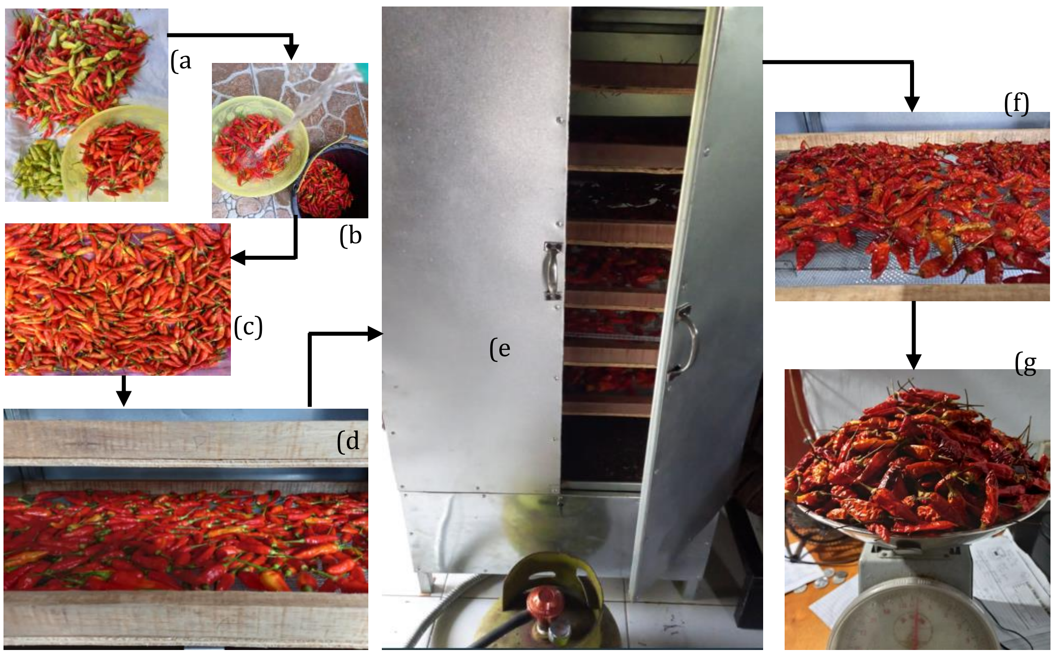

Figure 3. Chili drying process: (a) chili sorting, (b) washing, (c) chili ready to dry, (d) entering and arranging chilies in the dryer, (e) chili drying process, (f) removal of dried chilies from the dryer, and (g) chili weighing

Each of these stages can be described as follows:

- The initial stage is the preparatory stage which includes sorting the chilies by separating the ripe (red) chilies from the immature (green) chilies as well as cleaning leaves or other rubbish. After sorting, the next process is washing the red chilies until they are clean, followed by draining the water and drying it by airing it in an open area before finally placing it evenly on the drying tray.
- The drying process is carried out after each tray containing chilies is placed in each slot in the dryer. The next process is to turn on the stove after the supporting devices have been installed. Drying is carried out with several choices of heating fire settings whose monitoring can be seen on the thermometer that has been installed in the lowest slot. The drying process is carried out until the chilies become dry and ready to be ground which is characterized by the color of the skin of the bright red chilies and when the chilies are bent they break easily. To obtain uniform dryness of the chilies, during drying the trays are rotated, i.e. the bottom tray is placed in the top slot, the tray in the top slot is placed in the slot below it, and so on until the bottom slot is occupied by the tray that was previously placed in the slot above it. Each turning of the tray is accompanied by a process of stirring or turning the chilies. The process of turning the tray and turning the chilies is done every 30 minutes. The temperature of the drying chamber is continuously monitored using a thermometer reading. If there is

an increase or decrease in temperature, the action of setting the heater flame immediately takes place. After the chilies are dry evenly, the drying process is stopped by turning off the heating stove.

- The final stage is removing the tray along with the dried chilies from the dryer and proceeding with the process of weighing the chilies. The expected dry chilies are chilies that have experienced a shrinkage of 80% of the initial weight. The dried chilies are then immediately put in a closed package to keep them dry so that the purpose of the chili preservation process is achieved.

The success of the initial performance test of the dryer is used as the basis for further experiments, namely stage-1 and stage-2 trials according to the research method. In this initial experiment, it was discovered that there were difficulties in regulating the temperature of the drying chamber due to the limited setting of the heater flame. Based on this experience, the temperature setting was only carried out at three different temperatures, namely 70, 85 and 100°C.

3.3 Drying of chili stage-1 (fixed initial weight of chilli, temperature varies)

The results of the first experiment showed that for variations in temperature with a fixed initial weight of 3 kg, the average drying duration at temperatures of 70, 85, and 100°C were 14.2 ± 0.29; 9.3 ± 0.25; and 6.5 ± 0.25 hours. The results of the stage-1 experiment, diagrammatically, are shown in Fig. 4.

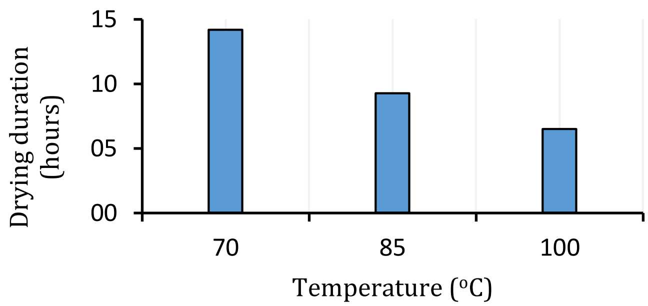

Figure 4. The results of the first stage experiment (the initial weight of the chili remained at 3 kg and the drying temperature varied)

When viewed from the drying duration, the experiment with a temperature of 70°C took too long (about 14 hours), for a temperature of 85°C the process was shorter (about 9 hours), while for a temperature of 100°C the process was the shortest (about 6-7 hours). However, based on the quality of the dried chilies produced, drying at 70°C and 85°C produces dry chilies with an even level of dryness, while drying at 100°C produces an uneven level of dryness (some of them even appear burnt). Based on these results, for the second stage of the experiment, drying was chosen at 85°C.

The uneven dryness of chili for a drying temperature of 100°C was caused by the stove fire being too big which was not followed by a quick reversal process. Meanwhile, in this experiment, the reversal process was made every 30 minutes. Thus, for drying at 100°C, it is necessary to have a hot air circulation system that is evenly distributed in the drying chamber. This can be done by installing a device to distribute the hot air in the drying chamber, for example by adding a fan.

3.4 Drying of chili stage-2 (initial weight of chilli varies, fixed temperature)

The results of the second experiment, the temperature of the drying room were kept constant at 85°C with variations in initial chili weight of 1, 2, 3, 4, 5, and 6 kg. The average drying duration obtained for these weight variations was 6.1 ± 0.14; 8.6 ± 0.14; 9.3 ± 0.25; 9.3 ± 0.25; 11.8 ± 0.25; and 14.2 ± 0.29 hours, as shown in Fig. 5. Meanwhile, the average amount of LPG consumed was 0.56 ± 0.01, 0.75 ± 0.03, 0.80 ± 0.01, 0.82 ± 0.03, 1.19 ± 0.02, 1.40 ± 0.02 kg, respectively, as shown in Fig. 6.

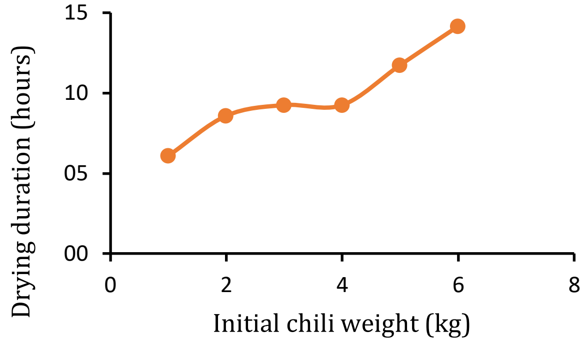

Figure 5. Results of the second stage of the experiment (the initial weight of the chilies varies, namely 1, 2, 3, 4, 5, and 6 kg with a constant temperature of 85°C)

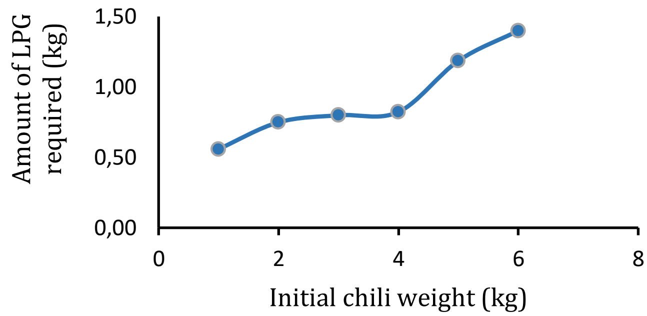

Figure 6. The amount of LPG required for the initial weight of chili varies, namely 1, 2, 3, 4, 5, and 6 kg with a constant temperature of 85°C

Based on these two graphs (Figures 5 and 6), the most effective and efficient use of a chili dryer to dry chilies at a constant temperature of 85°C is drying with an initial chili weight of 4 kg with a drying duration of about 9 hours. During this duration, the amount of gas consumed is around 0.82 kg. If cash, the costs incurred are around IDR 5,000.00 assuming the price of 3 kg LPG in the local market is around IDR 18,000.00. When compared to conventional dryers (using a solar heat source without installing a fan), which can take up to 3-5 days to dry [3,4,5], the use of an LPG-fired dryer is more effective and efficient (Carbo-Mendoza et al., 2022).

4 Conclusion

A simple chili dryer using LPG fuel with a single heater has been successfully made with dimensions of 60 cm x 50 cm x 120 cm. The entire tool is made of 95% metal and the remaining 5% is made of non-metal (wood). After testing the performance of the dryer in stages, it was found that the most effective and efficient use of a chili dryer to dry chilies at a constant temperature of 85°C is drying with an initial chili weight of 4 kg with a drying duration of about 9 hours with a total consumption of around 0.8 kg of LPG.

Acknowledgements

We are grateful to LPPM of Udayana University Bali has funded the 2022 Study Program Leading Research. We also thank all respondents and anyone who has participated in the research.

References

Achanta, S., & Okos, D. M. (2000). Drying Technology in Agriculture and Food Science: Quality Changes During Drying of Food Polymers. *Akses Tanggal*, *31*.

Aishwarya, K., Nirmala, R., & Navamathavan, R. (2021). Recent advancements in liquefied petroleum gas sensors: A topical review. *Sensors International*, *2*, 100091. https://doi.org/10.1016/j.sintl.2021.100091

Aldabbagh, L. B. Y., Egelioglu, F., & İlkan, M. (2010). Single and double pass solar air heaters with wire mesh as packing bed. *Energy*, *35*(9), 3783-3787. https://doi.org/10.1016/j.energy.2010.05.028

Alit, I. B., & Susana I. G. B. (2022). Rotary dryer in a study based on participatory principles for smallholder scale drying. *Global Journal of Engineering and Technology Advances, 12*(02), 072–077.

Artnaseaw, A., Theerakulpisut, S., & Benjapiyaporn, C. (2010). Drying characteristics of Shiitake mushroom and Jinda chili during vacuum heat pump drying. *Food and Bioproducts Processing*, *88*(2-3), 105-114. https://doi.org/10.1016/j.fbp.2009.09.006

Carbo-Mendoza, M. A., Cabrera-González, L. F., Ponce-Reyes, I. F., & Bazurto-Briones, L. A. (2022). Design of a photovoltaic system to cover the energy demand of a home in the Rocafuerte Canton, Manabí Province. *International Journal of Physical Sciences and Engineering*, *6*(2), 68–81. https://doi.org/10.53730/ijpse.v6n2.9286

Charmongkolpradit, S., Triratanasirichai, K., & Srihajong, N. (2010). Drying characteristics of chili using continuous fluidized-bed dryer. *American Journal of Applied Sciences*, *7*(10), 1300-1304.

Gamuchirai, L., Muusha, A. B., & Mashingaidze, L. M. (2019). Effect of drying techniques and storage conditions on quality and incidence of aflatoxins in dried chillies (Capsicum frutescens) in Zimbabwe. *Acta Sci Agric*, *3*(7), 21-25.

Getahun, E., Delele, M. A., Gabbiye, N., Fanta, S. W., & Vanierschot, M. (2021). Studying the drying characteristics and quality attributes of chili pepper at different maturity stages: experimental and mechanistic model. *Case Studies in Thermal Engineering*, *26*, 101052. https://doi.org/10.1016/j.csite.2021.101052

Hernández-Fernández, J., Lopez-Martinez, J., & Barceló, D. (2021). Development and validation of a methodology for quantifying parts-per-billion levels of arsine and phosphine in nitrogen, hydrogen and liquefied petroleum gas using a variable pressure sampler coupled to gas chromatography-mass spectrometry. *Journal of Chromatography A*, *1637*, 461833. https://doi.org/10.1016/j.chroma.2020.461833

Hossain, M. Z., Hossain, M. A., Awal, M. A., Alam, M. M., & Rabbani, A. H. M. M. (2015). Design and development of solar dryer for chilli drying. *International Journal of Research*, *2*(1), 63-78.

Kamble, A. K., Pardeshi, I. L., Singh, P. L., & Ade, G. S. (2013). Drying of chilli using solar cabinet dryer coupled with gravel bed heat storage system. *J Food Res Technol*, *1*(2), 87-94.

Koffi-Nevry, R., Kouassi, K. C., Nanga, Z. Y., Koussémon, M., & Loukou, G. Y. (2012). Antibacterial activity of two bell pepper extracts: Capsicum annuum L. and Capsicum frutescens. *International journal of food properties*, *15*(5), 961-971.

Nimrotham, C., Songprakorp, R., Thepa, S., & Monyakul, V. (2017). Experimental research of drying red chili by two methods: solar drying and low-temperature system drying. *Energy Procedia*, *138*, 512-517. https://doi.org/10.1016/j.egypro.2017.10.237

Nimrotham, C., Songprakorp, R., Thepa, S., & Monyakul, V. (2017). Experimental research of drying red chili by two methods: solar drying and low-temperature system drying. *Energy Procedia*, *138*, 512-517. https://doi.org/10.1016/j.egypro.2017.10.237

Noh, H. H., Kim, D. K., Lee, E. Y., Chang, M. I., Im, M. H., Lee, Y. D., & Kyung, K. S. (2015). Effects of oven drying on pesticide residues in field-grown chili peppers. *Journal of the Korean Society for Applied Biological Chemistry*, *58*, 97-104.

Omojaro, A. P., & Aldabbagh, L. B. Y. (2010). Experimental performance of single and double pass solar air heater with fins and steel wire mesh as absorber. *Applied energy*, *87*(12), 3759-3765. https://doi.org/10.1016/j.apenergy.2010.06.020

Pandey, M., Acharya, S. K., & Mishra, I. (2015). Drying of Chili Using Solar Cabinet Dryer & Analysis with Results of Various Parameters. *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, *3*, 280-286.

Purbasari, D., & Putri, R. R. E. (2021). Physical Quality of Red Chili Powder (Capsicum Annum L.) Result. *Protech Biosystems Journal*, *1*(1), 25-37.

Raslavičius, L., Keršys, A., Mockus, S., Keršienė, N., & Starevičius, M. (2014). Liquefied petroleum gas (LPG) as a medium-term option in the transition to sustainable fuels and transport. *Renewable and Sustainable Energy Reviews*, *32*, 513-525. https://doi.org/10.1016/j.rser.2014.01.052

Renate, D., & Simbolon, W. (2022). The Application of an Artificial Dryer and Sun-Drying to Enhance the Quality of Red Chili Flakes Simplicia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1097, No. 1, p. 012022). IOP Publishing.

Sampathkumar, K., & Senthilkumar, P. (2012). Utilization of solar water heater in a single basin solar still—an experimental study. *Desalination*, *297*, 8-19. https://doi.org/10.1016/j.desal.2012.04.012

Sativa, M., Harianto, H., & Suryana, A. (2017). Impact of red chilli reference price policy in Indonesia. *International Journal of Agriculture System*, *5*(2), 120-139.

Youn, H., & Tonon, F. (2010). Effect of air-drying duration on the engineering properties of four clay-bearing rocks in Texas. *Engineering Geology*, *115*(1-2), 58-67. https://doi.org/10.1016/j.enggeo.2010.06.012

Zhang, Z., Wang, D., & Li, M. (2022). Soil respiration, aggregate stability and nutrient availability affected by drying duration and drying-rewetting frequency. *Geoderma*, *413*, 115743. https://doi.org/10.1016/j.geoderma.2022.115743

Biography of Authors

Dr. I Gde Antha Kasmawan, S.Si., M.Si.
Obtained his bachelor's degree in Physics, Faculty of Mathematics and Natural Sciences, Airlangga University, Surabaya-Indonesia in 1993, obtained a master's degree in Physics at the Bandung Institute of Technology, Bandung-Indonesia in 2000, and obtained a doctorate in Ecotechnology at the Faculty of Agriculture, Udayana University, Denpasar-Bali in 2020. Since 1994 he has been a lecturer at the Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Bali-Indonesia.
Email: anthakas@unud.ac.id

Dr. Ir. Winardi Tjahjo Baskoro, M.T.
Obtained his bachelor's degree in Materials Physics at the Sepuluh Nopember Institute of Technology, Surabaya-Indonesia in 1989, obtained a master's degree in Optical Physics at the Indonesia University, Jakarta-Indonesia in 1998, and obtained a doctorate in Geophysics at the Sepuluh Nopember Institute of Technology, Surabaya-Indonesia in 2021. Since 1991 he has been a lecturer at the Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Bali-Indonesia.
Email: winardi@unud.ac.id

Drs. I Made Satriya Wibawa, M.Si.
Obtained his bachelor's degree in Physics, Faculty of Mathematics and Natural Sciences, Gajahmada University, Jogyakarta-Indonesia in 1991, obtained a master's degree in Physics at the Bandung Institute of Technology, Bandung-Indonesia in 1998. Since 1992 he has been a lecturer at the Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Bali-Indonesia.
Email: satriya_wibawa@unud.ac.id