Chapter

Fresh Chili Agribusiness: Opportunities and Problems in Indonesia

Amos Lukas, Agustinus N. Kairupan, Agung Hendriadi, Arief Arianto, Lamhot Parulian Manalu, Lanjar Sumarno, Joni Munarso, Mulyana Hadipernata, Huda M. Elmatsani, Bonnie O. Benyamin, Akhmad Junaidi, Mochammad Jusuf Djafar, Roosganda Elizabeth, Sahlan, Nasruddin, Puji Astuti, Subandrio, Heryoki Yohanes, Ermi E. Koeslulat, Eko Bhakti Susetyo, Suharto Ngudiwaluyo, Abdul Halik, Wahyu Purwanto, Guntur Haryanto, Sitti Ramlah, Noverina Sjafrina, Agus Budiyanto, Sari Intan Kailaku, Rienoviar, Alvi Yani, Nenie Yustiningsih, Himawan Adinegoro, Henky Henanto, Payung Layuk, Meivie Lintang, Gabriel H. Joseph, Derek Polakitan, Heri Wahyudianto, Joko Saptohadi, Kusumawati Dewi Budiarti, Taufik Hidayat, Josep Ginting, Amsal Rasyid and August Polakitan

Abstract

The National Socioeconomic Survey (SUSENAS) conducted in Indonesia in September 2021 found that the average consumption of red chili per month was 0.15 kilograms (kg) per capita per month. The average consumption of fresh chili per month is 40.90 thousand tons, and the cumulative total reached 490.83 thousand tons in 2021. Uneven chili production across time and region makes prices fluctuate, which affects inflation by 0.01–0.07%. Another problem is the imbalance of supply and demand between time and region, which impacts farmers' welfare. Setting planting time and location and improving distribution can solve these problems. The application of technology that can extend the life of fresh chilies for one month is a solution for chili distribution from farmers to areas with high demand. One-wave roasting and drying technology can extend chilies' freshness for six months. By producing chilies that have a shelf life of more than three months, it is possible to store them in warehouses using the warehouse receipt system. The application of the warehouse receipt system to chili commodities is also an alternative to solving postharvest problems. The distribution and application of technology that can extend the life of chili can increase its economic value and make chili not a commodity that contributes to Indonesian inflation.

Keywords: chili consumption, opportunities, agribusiness, distribution, application of technology

1. Introduction

Fresh chili has been designated as one of the main commodities, so it has become one of the focuses of programs and activities in agricultural development. Policies and programs for the development of fresh chili have been carried out to increase production and require the problem of price fluctuations and increased availability [1]. One of the Horticultural Crops commodities that are continually needed by the community of Indonesia is red chili. Some areas in Indonesia use red chilies as one of the essential spices because chili has a hot taste [2]. The output must be raised using a variety of red chilies, and to meet the demand for red chilies, expenses must be decreased.

According to data from the Indonesian Central Bureau of Statistics (BPS), red chili is one of the top five vegetable crops in terms of production during the last five years, omitting shallots, potatoes, cabbage, and chilies. The national production of red chili reached 1.36 million tons in 2021. West Java, North Sumatra, and Central Java had the highest total of red chili production in 2021, with 343.07 thousand tons, 210.22 thousand tons, and 169.28 thousand tons, respectively. Household consumption of red chili increased by 9.94% in 2021, reaching 490.83 thousand tons. Furthermore, market operations hit 8.23% of red chili traders in 2021, while natural catastrophes impacted 50.85% of them the previous year.

Fresh red chili production tends to increase from year to year from 2012 to 2022. **Figure 1** shows fresh red chili production from 2012 to 2022.

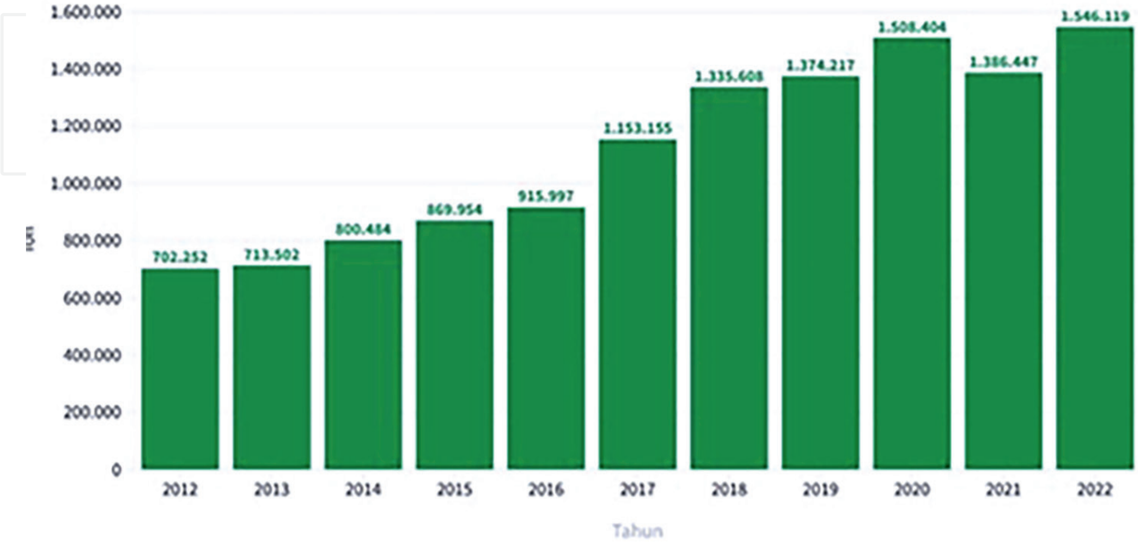


Figure 1.
Fresh red chili production 2012–2022 [3].

Based on **Figure 1**, production of fresh red chili in 2012 amounted to 702.25 thousand tonnes in 2012 increased to 713.5 thousand tonnes in 2013, 800.48 thousand tonnes in 2014, 869.95 thousand tonnes in 2015, and 916 thousand tons in year 2016. Fresh red chili production continued to increase beyond 1 million tons in 2017, 1.15 million tons increasing to 1.34 million tons in 2018, increasing to 1.37 million tons in 2019, and increasing again 1.51 million tons in year 2020.

Fresh red chili production experienced a decline in 2021 compared to 2020 to 1.39 million. The covid-19 epidemic is largely to blame for this. The decline in cayenne pepper production in 2021 is the first time in the last decade. From 2011 to 2020, it is known that cayenne pepper production has continued to increase every year.

The production of fresh red chilies has again increased to 1.55 million tons in 2022, exceeded the production of fresh red chilies in 2020. Compared to 2021, the production of fresh red chilies in 2022 has increased by 11.5% compared to 2021. The increase in fresh red chili production from year to year for the last 10 years shows that fresh red chili is a promising product in the future.

There is an adage that Indonesians cannot live without chili sauce. Various foods taste less delicious if not served with chili sauce. In fact, some people are willing to eat before the chili sauce is served. Due to people's love for chili sauce, the demand for cayenne pepper as one of the raw materials in Indonesia is quite high. It also encourages the large production of cayenne pepper in the country in last 10 years.

Seeing the trend, cayenne pepper production has tended to increase in the last decade. Indonesia's cayenne pepper production touched its highest level at 2022. Meanwhile, East Java is the province with the largest cayenne pepper production in Indonesia, 578,883 tons. This amount contributes 41.75% to the national cayenne pepper production. Central Java is second with cayenne pepper production of 179,287 tons or 1293%. Meanwhile, West Java produced 137,456 tons of cayenne pepper, or 9.91%. Some areas that are production centers of cayenne pepper in East Java province include Malang, Blitar, and Nganjuk districts [4, 5].

Red chili is one of the vegetable commodities most consumed by Indonesian people. This high level of consumption is inseparable from Indonesian culinary culture, which uses red chilies as a basic spice or food flavoring. The National Socioeconomic Survey (SUSENAS) conducted in Indonesia in September 2021 found that the average consumption of red chili per month was 0.15 kilograms (kg) per capita per month. **Figure 2** shows the consumption of red chilies for the last five years, from 2017 to 2021.

According to **Figure 2**, red chili consumption has declined from 479.65 thousand tons in 2017 to 469.15 thousand tons in 2018. The consumption of red chilies fell again in 2019 to 406.77 thousand tons. Furthermore, red chili consumption climbed to 446.46 tons in 2020. However, red chili consumption in 2020 is still lower than the maximum level in 2017. Red chili consumption is expected to reach 490.83 tons in 2021.

The average consumption of fresh chili per month is 40.9025 thousand tons, and the cumulative total reached 490.83 thousand tons in 2021. This number increased by 9.94% from consumption in 2020 and is the highest consumption in the last five years. The province with the highest consumption of red chilies in 2021 is West Sumatra, which is 0.59 kg/capita/month. The food of the people in the Mining Realm almost all use red chilies as a flavor enhancer. The next largest consumption comes from Bengkulu, which is 0.58 kg/capita/month, Jambi 0.46 kg/capita/month, and Riau 0.37 kg/capita/month.

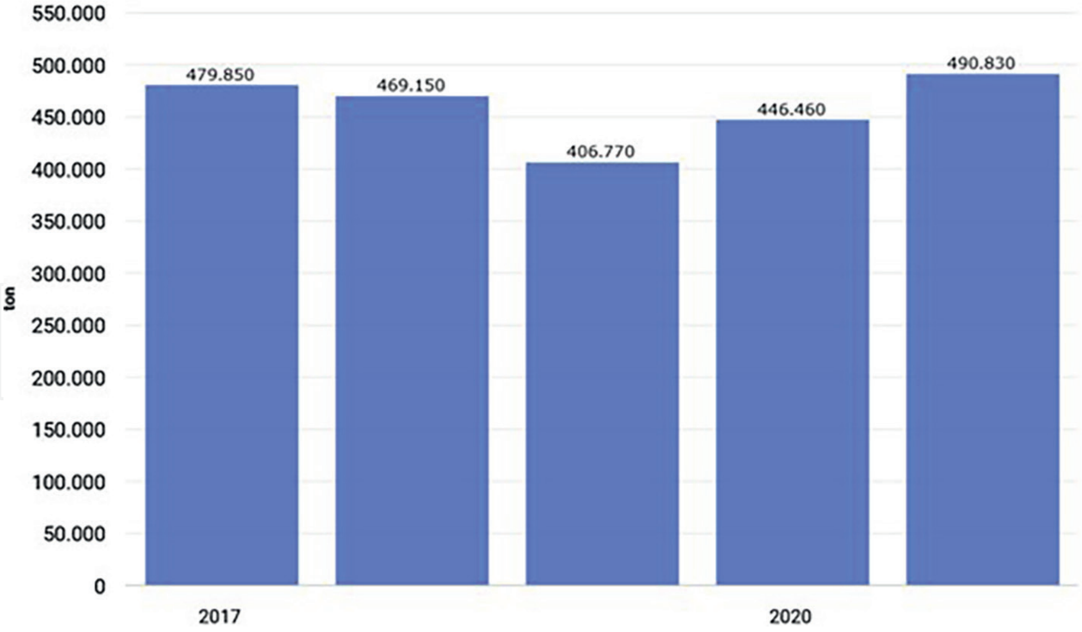


Figure 2.
Consumption of red chilies 2017–2021.

The volume of domestic demand makes chili a promising commodity. Chili request high demand for cooking spices, and the food and drug sector is profit potential. Not surprisingly, chili is a Horticultural commodity that experienced the largest price swings in Indonesia [6].

Fresh chili is a commodity that has the highest price fluctuation compared to other horticultural products. Sometimes the price of fresh red chili can be high at one time, then drop at a certain time. Uneven chili production across time and region makes prices fluctuate, which affects inflation by 0.01–0.07%.

Until now, the government has not succeeded in reducing the high fluctuations in chilies. Chili is a food that can only be stored for a short time. Thus, the condition of chili stocks is very influential on the weather and harvest season. Chili price fluctuations can be suppressed if there is a buffer stock for chili commodities. This means that some of the harvested chilies will be processed first and stored for a long time. However, the buffer stock strategy for chili is difficult to implement because Indonesians prefer to eat fresh chilies. In addition, storing chilies to keep them fresh is still very expensive. Thus, a stock solution for fresh chilies cannot be feasible now. For chili, it is more manageable to spread production, both between regions and between regions over time.

Red chili development policies and programs have been carried out so far, increasing production, underdelivering the problem of price fluctuations, and increasing around-the-clock availability. Generally, farmers in chili production areas and centers red are experienced and able to apply appropriate cultivation technology recommendations, even though business management still encounters obstacles, such as setting production patterns, setting planting schedules, and synchronizing production patterns production between regions and production centers. Aspects of the use of production technology may is said to have been successful. It is just that business actors still need to improve in handling postharvest and product processing, so the availability of red chili cannot always be fulfilled.

Most of the ages in large chili farming families are in the productive age. Productive age is support in family life related to welfare. The more productive family members, the more family members work to meet their needs in achieving a level of welfare. In chili agribusiness, many family members, and dependents have >5 family members/responsible [5].

In the context of chili prices, the situation involves many small-scale farmers with limited land and production capacity. These farmers depend on intermediaries or large traders to sell their chili harvests in the market. Because of this dependence, an imbalance in bargaining power arises, favoring the intermediaries, who control the supply of chili produce from numerous small-scale farmers and determine the selling price.

Due to their reliance on intermediaries and the lack of direct access to better markets, small-scale farmers often receive low selling prices for their chilies, leading to reduced profitability. In contrast, intermediaries take advantage of this situation to gain excessive profits by setting higher selling prices for end consumers compared to what they pay to farmers. This complex system poses challenges for small farmers, impacting their income and market opportunities, while intermediaries benefit significantly.

As a result, during the red chili harvest, the stock becomes abundant and causes the chili price to drop to its lowest point. However, after the harvest period is over, due to the short shelf life of fresh red chili products, the availability of fresh red chili products on the market becomes scarce. It ultimately causes the price of fresh red chili to soar.

The handling of red chili results is generally done at the farmer level, and is restricted to simple cleaning, sorting, drying, and packing of fresh chili; many do not even complete this stage at all, namely the result. Traders/middlemen sell the harvest immediately on the field and transport it to the truck. Furthermore, the method of handling during packaging and Transportation is still crude and less practical (heaped up, compacted, and without enough aeration). As a result, rate damage and yield losses (postharvest losses) are still significant and can even reach 50%. These issues and circumstances frequently arise during the primary harvest, resulting in a production buildup and a consequent drop in pricing. This harms farmers' and business operators' ability to secure production and revenues.

Stepping up the use of postharvest handling technology and processing of chili products, such as red cayenne pepper, which is done through excavation and the introduction of appropriate technology, guidance, and technology assistance, as well as the provision of postharvest facilities are one effort and strategy is made to address this problem. A small amount of study is still being done on handling and processing chili products after harvest. However, the focus is largely on areas of pure research (pure science and technology). Therefore, the field of applied research needs to be developed and highlighted for it to be applied.

Drying and roasting technology will reduce the red chili's volume and weight, extend its shelf life, and increase its economic value, facilitating transportation [7]. However, so far, research emphasizing the application of appropriate technology still needs to be improved. Therefore, a breakthrough in postharvest processing and technology research is called for further investigation. Chili can easily solve field problems and then disseminate them to farmers and business actors.

2. Indonesia in global chili pepper trade, production, and consumption

The year 2018, Indonesia was a major player in worldwide hot pepper trade, production, and consumption. As the world's second-largest chili producer, Indonesia contributed considerably to the entire chili peppers supply in the international market, producing 88,000 tons of chili peppers and demonstrating its solid position as a key global producer (**Figures 3–5**) [3].

Additionally, Indonesia actively participated in the hot pepper export sector, ranking 3rd globally in terms of hot pepper exports. With 36,000 tons of hot peppers exported (**Table 1**), the country demonstrated its crucial role in supplying hot peppers to other nations and contributing to the global hot pepper trade. The main export destinations of Indonesian chili in 2021 were Saudi Arabia, Nigeria, and Taiwan, contributing 37.20% (equivalent to USD 8.35 million), 14.16% (equivalent to USD 3.18 million), and 7.33% (equivalent to USD 1.65 million), respectively. This was followed by Malaysia at 5.48% (equivalent to USD 1.23 million). The combined contribution of these top five countries reached 69.03% of the total value of Indonesian chili exports.

Moreover, Indonesia features among the top consuming countries, registering at 5th place in chili consumption. Indonesia is included in the group of countries with a consumption volume of 242,000 tons, highlighting the significant consumption of chilies.

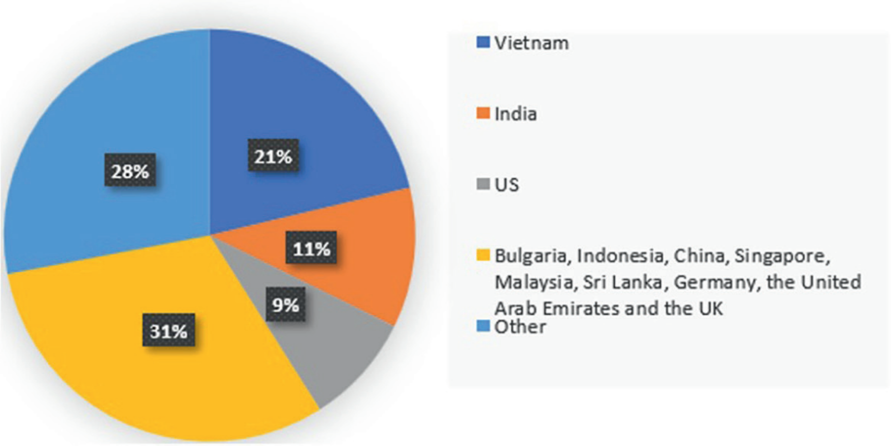


Figure 3.
World chili pepper consumption.

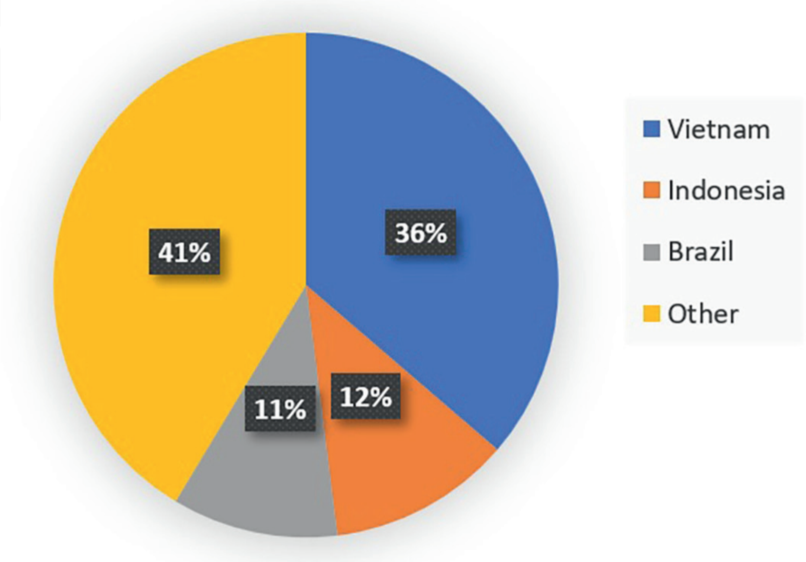


Figure 4.
World chili pepper production.

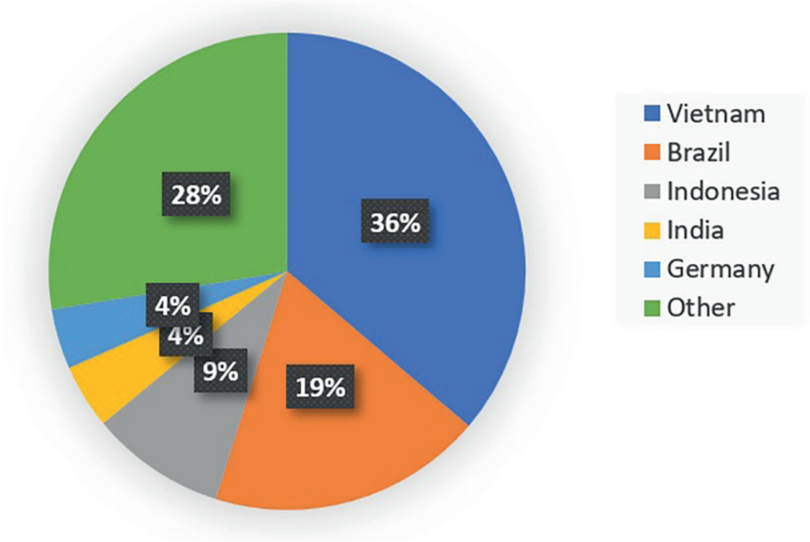


Figure 5.
World chili pepper export.

Export	Production	Consumption
• Vietnam (142,000)	• Vietnam (273,000)	• Vietnam (166,000)
• Brazil (73,000)	• Indonesia (88,000)	• India (86,000)
• Indonesia (36,000)	• Brazil (80,000)	• U.S. (68,000)
• India (17,000)		• Bulgaria, Indonesia, China, Singapore, Malaysia, Sri Lanka, Germany, the United Arab Emirates, and the UK (242,000)
• Germany (16,000)		

Table 1.
World chili pepper export, production, and consumption in 2018, tons.

3. Framework and formulation of the problem

The data demonstrate that growers and producers of chili have a strong production or cultivation technical foundation. Just a few people are still adept at using postharvest handling techniques to lengthen the shelf life of chili products. This practice results in many damaged and rotten chilies that cannot be stored for an extended period. As a result, farmers gain little profit and additional value, and their products are usually less competitive. Another reality is that there are irregularities in the production and supply of chili, including high demand for fresh chili among customers and an abundance of production during specific seasons (particularly the dry season). This circumstance results in extreme price changes, which ultimately produce inflation.

Field observations and preliminary research revealed that despite the government's provision of numerous facilities and assistance (postharvest wards, harvest baskets, blowers, dryers, flour, packaging machines, etc.), some aspects of handling postharvest still need to be improved. This problem was significantly linked to policy, planning, practice capital, yield marketing management, and institutional help, as well as farmers' low/lack of knowledge and technology.

Implementing handling technologies postharvest to create dry chilies and continue the processing into chili powder or other goods is an effort that needs to be made to increase chili's added value and competitiveness. Technology for postharvest handling and Chile processing currently exists and has even been extensively produced. However, the reality is that the use of suggested technology and postharvest technology in chilies at the farmer level is still limited, and the creation of norms and SOPs has yet to be discovered and put into practice there. There needs to be a match between the reality of how technology is being applied in the field and the conclusions, guidelines, and recommendations of technology research.

Make the application and dissemination among farmers and commercial actors easier, appropriate technology (applicative technology) for handling chili after harvest must be developed. The method of drying this chili still requires a lot of time, despite the fact that numerous applied studies have been conducted to look for technology that makes handling and processing chili goods easier (fruit splitting, balancing process, filtering, grinding, etc. According to Bahar [8], it takes 28–38 h to bake food to a moisture content of 9.47%, while drying it takes 33–77 h, depending on the quantity and weather. The efficiency of chili drying by farmers is still too high low, which is about 10% (because they do not follow the SOP, while the research results are carried out by Bahar [8] ranged from 29 to 21%. Therefore, it is necessary to look for technology to speed up the drying process.

In addition to using red chili drying technique to extend the life of red chili product, roasting technique using Far-Infrared Radiation are also carried out. IR radiation is energy in the form of electromagnetic wave and lies in the wavelength range between 0.78 and 1000 μm. It is more rapid in heat transfer than convection and conduction mechanism. IR radiation has received considerable attention lately because of its advantages in shortening drying time, high energy transfer rate, energy saving, and superior product quality compare to conventional heated air drying FIR wavelength lies in the wavelength range between 4 and 1000 μm and the FIR heat application can be classified into four major categories as baking, drying, thawing, and pasteurization [9].

Based on the above framework, the problem can be formulated as follows:

1. Fresh red cayenne pepper does not have a limited shelf life, there will be a lot of unsold chilies that will ultimately rot or incorrect postharvest treatment, which will be negative for farmers and destabilize prices if there is an excessive output.

2. After the harvest period, especially during the rainy season, there is a scarcity of red cayenne pepper on the market due to low production or difficulty in distribution and low availability of red chili, so the price of chili increases high and is detrimental to consumers.

3. One of the keys to handling this problem is the application of technology postharvest and product processing through drying and roasting techniques of fresh red chili products, but knowledge, discovery, and application of efficient, appropriate technology for postharvest handling and processing of fresh red chilies into dried chilies and powdered chilies are still limited.

4. Overview of fresh chili

The red chili plant (*Capsicum annum L.*) is a shrub that develops and is a member of the Solanaceae family of plants. Red chili containing annual or short-lived plants hails from the American continent to be precise Peru, then spreads to the Americas, Europe, and Asia including Indonesia [2].

Various chilies, which are generally red chilies (*Capsicum annum L.*) and red cayenne pepper (*Capsicum frutescens*), are the main horticultural commodities which is a herbaceous plant with a spicy fruit taste because of the capsaicin content. Chili includes the active chemicals capsaicin and dihydrocapsaicin, which give it a distinct spicy flavors. Other content contained in chili is carotenoids, fats, proteins, and vitamins A and C. Chilies will ripen physiologically at 70–75 HST and in the highlands after 4–5 months old. The feature is that some of the fruit is red. The first harvest of chili is determined by several factors' environment, varieties, and cultivation methods. Harvesting can be done by picking, with a frequency of once every 3–4 days, and can be harvested up to 7–8 months old.

Chili comprises numerous types, and the most generally recognized is chili big red, curly chilies, red cayenne peppers, and green chilies. Red chili consists of big chili and curled chili. Chili has a value high economy and is much needed by all levels of society as flavoring and food seasoning. Red chilies can be marketed in numerous forms, such as young/green chilies, old fruit, fresh fruit, industrial materials (milled, dried, flour), processed, and industrial products. Fresh chiles spoil quickly; they can only be stored for 2–3 days at room temperature; after that, they will decline in quality and wilting. If the postharvest management process is conducted, the good ones will last more than five days. The postharvest handling technique for fresh chili begins with the right harvesting (picking) process, sorting and processing grading, and good storage methods [10].

5. Harvest and postharvest chili

Implementing Good Postharvest Handling (Good Handling Practices = GHP) will produce quality products ready to enter the modern market, reduce yield loss, maintain quality, extend life storage, and produce safe products for consumption. The application of GHP has become imperative to meet consumer demand for quality and safe product consumption and production in an environmentally friendly manner. Permentan Guidelines for Harvesting, Post harvesting, and Management of Horticultural Postharvest Wards No 73/Permentan/OT.140/7/2013, (Good Horticulture Packing House Management) provides detailed implementation of the good postharvest application mandated by Law No. 13 of 2010 concerning Horticulture.

Several initiatives are being implemented in Indonesia to promote value-added product processing in the chili sector. These initiatives include research and development to investigate novel processing technologies, infrastructure development to support processing facilities, and capacity building for farmers and processors through training programs. Market promotion, government incentives, and public-private partnerships are also being utilized to encourage investment and innovation in the chili processing business. To boost the value and marketability of Indonesian chili goods, various drying and processing procedures such as sun drying, air drying, freeze-drying, and processing into chili powder, flakes, sauces, and pastes are being investigated. Implementing quality and safety standards is also critical to ensuring the competitiveness and customer acceptance of value-added chili products on a national and international scale.

One of the keys to successful production is the postharvest management of chilies by farming or business actors, which increases added value and product competitiveness. After-harvest processing of chili includes (1) sorting and grading/classifying, (2) curing, specifically by spreading the harvest in a shaded area or chamber, (3) packing to preserve wounds, facilitate shipping, stop water loss, facilitate special treatment, and provide esthetic value, (4) cold storage at 8–12°C with 90–95% humidity will extend the freshness of chili for up to 8 days and (5) to prevent damage or rot, Transportation to trucks, preferably with a refrigerated box car.

According to Asgar et al. [11], the potential for chili yield loss before reaching customers is very large (20–30%) because chili is a commodity that is readily damaged [11]. On the other hand, fresh chili is in high demand for domestic use. Therefore, postharvest treatment of fresh red chilies requires knowledge of and expertise in technology to keep them fresh or transform them into a more durable product. Ozonisation technology is one way to maintain the freshness of golden chili cultivars for as long as storage because it is capable of shedding contamination of pesticides, bacteria, and heavy metals attached to fruits and vegetables, so it is safe for consumption. Treatment of 1% ozone concentration and storage at a temperature of 10°C can maintain the color and freshness of chili for 14 days, with products still preferred by consumers.

6. Chili drying

The most common primary technique of food preservation is drying [9]. Chili is dried to manufacture chili powder and to store for lengthy periods of time [9]. Drying chili into dried chilies or powdered chilies is one method of extending the shelf life of chili. Drying is done to lower the water content of the chili to the point where microbial activity is reduced. That cause putrefaction will be stopped. In drying chilies cayenne pepper, pile weight and drying time using a cabinet dryer really influence the quality of chili powder [12].

Chili is a vegetable commodity that is easily damaged. Therefore, there needs to be an effort to maintain its freshness or process it into products that are more durable. One effort can be made by drying and manufacturing into chili powder. The purpose of drying hot peppers is to reduce the water content, shrink the volume, reduce the growth of microorganisms, and reduce enzyme activity. In principle, in the drying process occurs simultaneously heat and mass transfer. In line, for the most part, the method of drying chili commodities can be distinguished from natural drying using sunlight and artificial drying (mechanical drying).

Mechanical drying is done while monitoring the temperature, humidity, and drying speed. Typically, this drying consists of a propulsion system, fans, heating elements, and control mechanisms. There are several different types of mechanical drying, including (1) cabinet/rack type [13], (2) solar dryers with combined energy [14–17], (3) tunnel type dryers [18], and (4) freeze dryers, which involve the processes of freezing and [19, 20].

Drying chilies can lower their volume and weight, increase their shelf life, increase their economic value, and make them easier to transport as a solution to the issue of damage from low storage temperatures and explosive chili production. There are several methods of drying, including: (1) natural drying in the sunlight, although this method makes it difficult to regulate temperature and humidity and results in changes to the finished product's color; (2) artificial drying techniques, including oil-burning tool dryers, Tropical Plants Research Institute and the Indonesian Institute of Sciences solar dryer models, and simple solar dryers. Immediately after drying, begin packaging with plastic bags [7].

The simplest and least expensive drying process is sunlight-based. However, to decrease dependency and weather interruptions, this activity depends on the location, weather, amenities, and supporting structures. Employing intermediary tools such as an oven, microwave, through-flow air dryer, and far infrared lamp is another mechanical method that can be used. The tool's capacity influences the outcome, the drying process, and the temperature. According to preliminary research findings, drying with FIR results in dried chilies with the maximum quantities of capsaicin and a significantly shorter drying time, i.e. 12 min at 60°C.

Dried red chilies are ground into chili powder (flour) by grinding them until smooth, then passing them through an 80-mesh sieve to smooth them out and storing the flour in a clean bottle or plastic container. Chili powder can be kept at low temperatures of 5–10°C or at room temperature of 28–31°C. This chili powder can be used immediately as a seasoning [7].

The efficiency of drying chili using different technologies (sunlight, oven, and microwave) did not significantly affect the drying process; the efficiency of drying ranged between 20.39% for curly red chilies and 20.49% for big red chilies. In addition, there was no discernible difference in the drying process efficiency between different types of chilies or between whole and Halved Chilies. According to a review of the product's quality and functionality, the drying and production of the chili powder allowed it to remain effective and consumer-acceptable after eight weeks of storage [8]. This further extended the product's shelf life.

The length of the drying process is frequently encountered in the postharvest handling of chilies because after the balancing process (immersion in hot water or heating with steam), the water content of the chili will increase, in addition to the chili itself having a high-water content [21]. This technique will cause drying to take longer, requiring much work and energy. For this reason, extra treatment is carried out by pressing. Suppose the compression results do not significantly influence the settlement quality of red cayenne pepper. In that case, this will also bring benefits and advantages to speed up the drying process.

The first thing to do is add pressing (pressing) in a series of postharvest handling activities of red chili to speed the reduction/decrease in water content and hasten the drying process. Pressing is done with a hydraulic press, followed by guiding, drying, and postharvest processing as usual; the results are dried red chilies and red chili powder. **Table 2** shows the average results of observations with and without compression treatment during the storage period for red chili products.

The data analysis results by t-test on the quality of dry red chili and red chili pepper powder after adding compression and without compression in postharvest handling, with observations during storage of almost the same pattern. The results of this data analysis can be explained as follows:

1. The water content in pressing significantly differs from without pressing; water content with lower pressing indicates better condition. Referring to the recommended water content for storing dried chilies (SNI Chili 4480: 2016 is 12%, while UNECE Standard 2012 is 13.5%) then the average water content with the pressing process meets these standards, while without pressing is seen that only dry cayenne pepper that meets or is close to the standard. From the results of observations during the storage process, it can be said that there is pressing can

Number	Parameter	With compression	Without compression	T-test
1	Water (%)	12.2	13.35	Significant
2	Rot	1.00	1.00	Not significant
3	Aroma	2.46	2.52	Significant
4	Color	2.00	2.12	Significant
5	Taste	2.79	2.73	Significant

Table 2.
Average results of observations with and without compression treatment.

significantly reduce the water content in dried red bird's eye chilies and powdered red cayenne pepper, in addition to the water content conditions of red cayenne pepper dry is better (meets standards/recommendations) compared to water content powdered cayenne pepper.

2. Both with and without the addition of compression treatment, the level of spoilage on dry red cayenne pepper and cayenne pepper powder throughout the storage process was similar, and neither showed rot (nearly all without Mold growth). This issue is related to the low water content and high capsaicin concentration of chilies, making them an unfavorable medium for bacteria.

3. For dry and powdered red bird's eye chilies, the results of the organoleptic tests (aroma, color, and taste) show significantly different values with pressing and without pressing the therapy with pressing produced much superior organ emetic test results than the treatment without compression. The presence of pressing treatment does not appear to affect the organoleptic quality of dried red bird's eye chilies or powdered red bird's eye chilies, even when, with this procedure, quality can be preserved while being stored.

Through weekly inspections of quality parameter data (up until week ten), the accuracy of the dry red cayenne pepper was investigated. The analysis involved comparing the quality conditions in the test week to the original state (zero weeks) and comparing the quality circumstances to the parameters of gradual observation. **Table 3** summarizes the findings from evaluating the dried red cayenne pepper's quality throughout storage using pressing and no-pressing methods.

It may be described as follows based on the data analysis results for dried red chilies provided in **Table 3**:

1. Based on the parameters observed (water content, aroma, color, and taste), it was shown that during the 4 weeks of observation (1 month), the condition of dried red chilies had not shown any difference (still the same as the initial conditions of observation).

2. During storage until the tenth week, all quality parameters show a downward trend (except for the level of decay). This shows that the rates of the theoretical superiority of dried red cayenne pepper continue to decrease over time storage. Until the 10th week, the water content becomes 13.05%; this condition is still quite good and still meets and is close to the recommended storage of the

Numbers	Week	Observation parameters (average)			
		Water	Aroma	Color	Taste
1	Beginning (0)	10.28	1.00	1.00	1.00
2	1	11.05^{aa}	1.00^{aa}	1.00^{aa}	2.00^{aa}
3	2	10.23^{aa}	1.33^{aa}	1.67^{aa}	2.33^{aa}
4	3	10.71^{aa}	2.00^{aa}	2.00^{aa}	2.66^{aa}
5	4	10.41^{aa}	2.30^{aa}	2.33^{aa}	2.00^{aa}
6	5	11.16^{ab}	3.33^{aa}	2.00^{aa}	3.67^{ab}
7	6	12.15^{ab}	3.67^{ab}	3.33^{ab}	3.67^{ab}
8	7	13.06^{ab}	3.00^{ab}	2.00^{ab}	3.00^{ab}
9	8	15.22^{ab}	3.16^{ab}	2.83^{ab}	3.33^{ab}
10	9	13.16^{ab}	2.67^{ab}	3.00^{ab}	3.33^{ab}
11	10	13.50^{ab}	5.00^{ab}	3.33^{ab}	4.00^{ab}

^{aa}*Not significant.*
^{ab}*Significant.*

Table 3.
Observation results of dry red chilies storage by pressing treatment.

UNECE Standard 2012, which is 13.5%, but when referring to the SNI recommendation standard for chili 4480: 2016, then only up to the sixth week meets the standard.

3. Organoleptic parameters until the 10th week also showed a significant decrease different from the initial conditions. The scent level by week the tenth is at a score of 5.00, meaning it does not smell good anymore. The color parameter receives a score of 3.33, indicating that the hue becomes dull red rather than brownish, reducing the strength of attraction, while the taste receives a score of 4, indicating that it lacks spice.

4. The organoleptic test showed that up to the ninth week of quality, dry red cayenne pepper is still in acceptable condition (nothing exceeds a score of 3.33). Thus, using it as a raw material for the next stage of chili processing is still feasible.

5. Based on **Table 2** shows that changes in the conditions of the observation parameters compared to the initial conditions of the observations occurred in the fifth week for the moisture content parameter, the sixth week for the aroma parameter, the sixth week for the color parameter, and the fifth week for the taste parameter.

7. Roasting chili (*Capsicum annuum* L.) using Far-Infrared Radiation (IR)

Energy Infrared radiation is defined as electromagnetic waves with wavelengths ranging from 0.78 to 1000 m. It transfers heat more quickly than convection and conduction. When compared to standard hot air drying, IR radiation has lately gained a lot of attention due to its benefits in terms of Reduced drying time, increased energy transfer rate, energy savings, and higher product quality [22]. FIR heat applications are classified into four major groups according on their wavelength: baking, drying, thawing, and pasteurization are all methods of preserving food.

IR enters the exposed material after striking the surface of the substance. Because of radiation absorption, the vibration rises and concurrently generates heat at the material's surface and internal layers, increasing the heating rate [9]. The greatest depth of infrared penetration into agricultural systems output is 18 mm. As a result, the use of IR heating to achieve A high drying rate should concentrate on thin-layer drying—this treatment tried to investigate the feasibility of using FIR radiation to roast red chili. The findings concerning the red chili roasting procedure in this article are based on Fernando et al. [9] research.

8. Red chili samples

A 15 cm 5 cm electric Keramikemitter (660 W) was used to create FIR radiation (450–500°C surface temperature) on a single sheet of red chili pods (average length 10.54 cm, breadth 1.31 cm, and thickness 0.34 cm, bulk density 0.725 g/cm^3). With varied exposure times, at 3240, 3920, 5260, and 7188 W/m^2 FIR radiation intensities, the moisture content, temperature, and color change of chili pods were measured.

A prominent spice processing plant provided dried and factory-roasted red chili samples. The dried red chili samples were collected from the factory's unroasted bulk chili. For the studies, the samples were temporarily kept in polythene pouches (gauge 200) in the laboratory. The sample had a moisture content of 11% DB. The unroasted chili sample (250 g) was roasted for 25 min in a 24-kW drum roaster. To create a comparable hue using FIR radiation roasting, the roasted sample was utilized as a reference. Experiments with FIR radiation roasting was carried out using 12.191.16 g of unroasted red pepper sample.

9. Experimental setup

The FIR chili roasting setup's schematic design is illustrated in **Figure 6**.

A 15 cm 5 cm Keramik electric IR model with 660 W power was installed on top of the device to create FIR. The IR waves are focused onto the sample by an aluminum reflecting waveguide (30 cm height and 25.4 cm radius) that surrounds the FIR emitter and has a highly uniform IR dispersion across the cross-section. Chili (1919 1.16 g) was exposed to FIR radiation for 240 s by putting the sample at specified distances on a 5 mm thick hardwood sample tray (15 cm 5 cm). 7188, 5260, 3920, and the distance necessary to reach the appropriate FIR intensities. The results at 10 were 3240 W/m^2 measured at 15, 20, and 25 cm. These intensities were chosen because their relevance was highest at 1000 W/m^2 intervals.

The FIR heating unit was turned on for 5 min before placing the samples to ascertain the operational temperature. The intensity of FIR radiation was evaluated using an OPHIR FL205A Thermal Excimer Absorber Head (Ophir Optronics Inc., Wilmington, MA, USA), and the height adjustable stage was adjusted

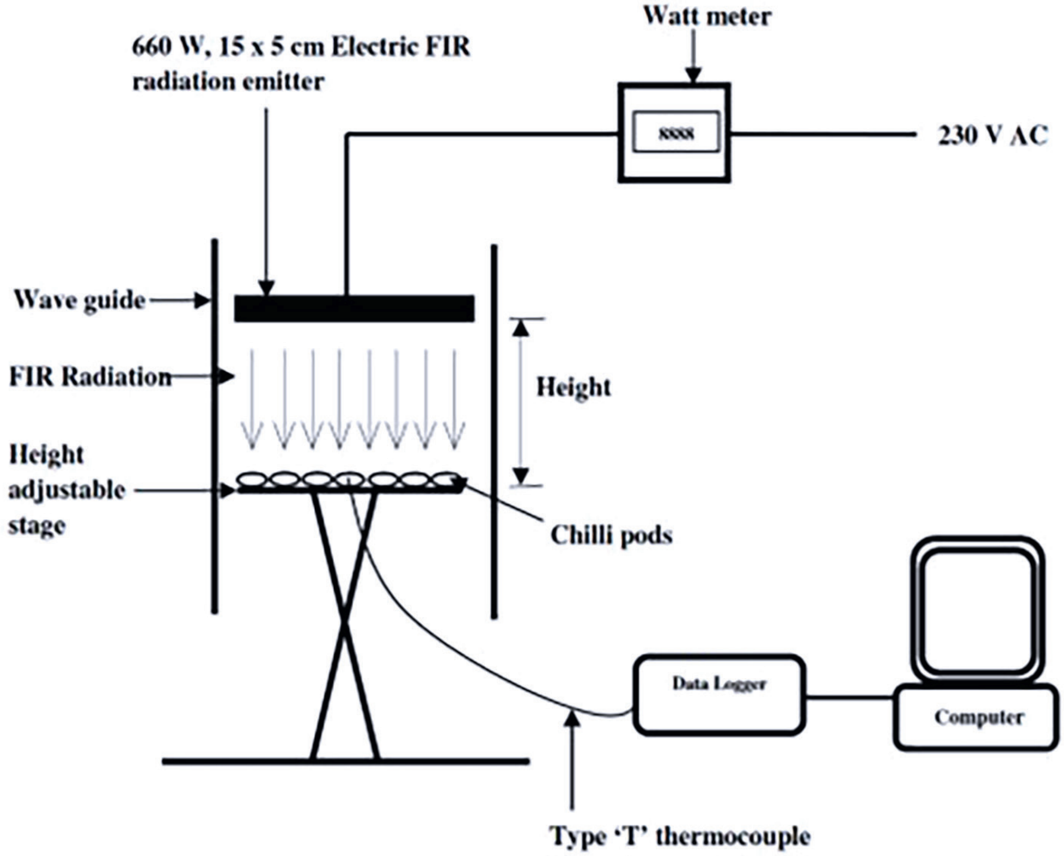


Figure 6.
The FIR red chili roasting apparatus is depicted schematically.

correspondingly. To eliminate FIR reflection during the experiment, chili pods were housed in a single layer on a wooden plate. Temperature and moisture content were measured during the FIR exposure. A single chili pod was used to measure color changes.

10. Moisture variation with FIR radiation

Chili had a starting moisture content of 11% db, and the weight loss of the roasting sample was monitored at predefined time intervals (0, 60, 120, 180 s) using an electronic scale (C.T.G. 602B-600, CITIZEN SCALE Inc. U.S.A.). On a height-adjustable platform, chili pods (12.191.16 g) were dispersed and subjected to FIR radiation.

11. Temperature and color variation of chili exposed to FIR radiation

T-type thermocouples implanted in three chili pods were used in each experiment to monitor and record the temperature of chili pods subjected to varying radiation intensities. Thermocouples were coupled to a data logger (TC-8, OMEGA, Japan), which was subsequently connected to a computer, as illustrated in **Figure 1**. Up to 240 s, the temperature was monitored in one-second increments. The color shift of chili pods roasted with FIR radiation was measured using a Chroma meter (Minolta CR 300, Japan). The results of three replicates were given as an average. The L*a*b* values of 20 chili pods were averaged after evaluating the color of a factory-roasted chili sample from Kundasale's finest spice processing plant. The figures served as the norm. The roasted chili color was contrasted with the FIR roasted chili color.

12. Moisture removal under different drying treatments

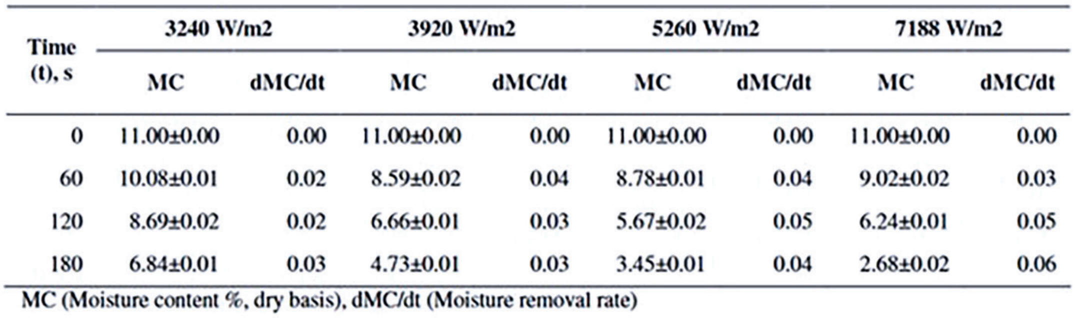
Figure 7 demonstrates the moisture content fluctuation during FIR roasting chili at various radiation intensities. In comparison to typical drying, the moisture loss of Chili with FIR heating demonstrated a linear relationship with time (**Figure 8**), showing logarithmic drying capabilities. As the intensity of the radiation grew, so did the rate of drying.

13. The temperature of chili samples

The temperature of chili is a crucial consideration during roasting. The use of the high-temperature short time (HTST) technique helps to achieve speedier roasting. **Figures 9** and **10** depict the fluctuation in chili temperature with FIR exposure at various radiation intensities. The roasting temperature was above 100°C. Even after 240 s of exposure at 3240 W/m^2, the FIR intensity chili did not exceed 100°C. According to the statistics, 7188 W/m^2 is the best FIR radiation intensity in industrial applications since it raises the temperature by 100°C in 60 s. Due to space constraints, it was difficult to achieve greater FIR radiation intensity. The FIR emitter's distance from the sample was measured. When employing FIR radiation at 7188 W/m^2, 10 cm would be the practically shortest distance permitting safe handling for chili roasting.

14. Color of chili with FIR radiation

The color of the chili pods was utilized to determine the roasting degree, and the difference in lightness (L*), redness (a*), and yellowness (b*) values was compared to a factory sample drum-roasted (**Figure 11**). L*a*b* values decreased after exposure to FIR radiation. **Figure 9** depicts chili's color change with a FIR radiation intensity of 7188 W/m^2. The factory roasted color values (L*a*b*) for chili are shown in **Figure 9** as



Time (t), s	3240 W/m2		3920 W/m2		5260 W/m2		7188 W/m2	
	MC	dMC/dt	MC	dMC/dt	MC	dMC/dt	MC	dMC/dt
0	11.00±0.00	0.00	11.00±0.00	0.00	11.00±0.00	0.00	11.00±0.00	0.00
60	10.08±0.01	0.02	8.59±0.02	0.04	8.78±0.01	0.04	9.02±0.02	0.03
120	8.69±0.02	0.02	6.66±0.01	0.03	5.67±0.02	0.05	6.24±0.01	0.05
180	6.84±0.01	0.03	4.73±0.01	0.03	3.45±0.01	0.04	2.68±0.02	0.06

MC (Moisture content %, dry basis), dMC/dt (Moisture removal rate)

Figure 7.
Moisture content and drying rate with varying sunlight intensity.

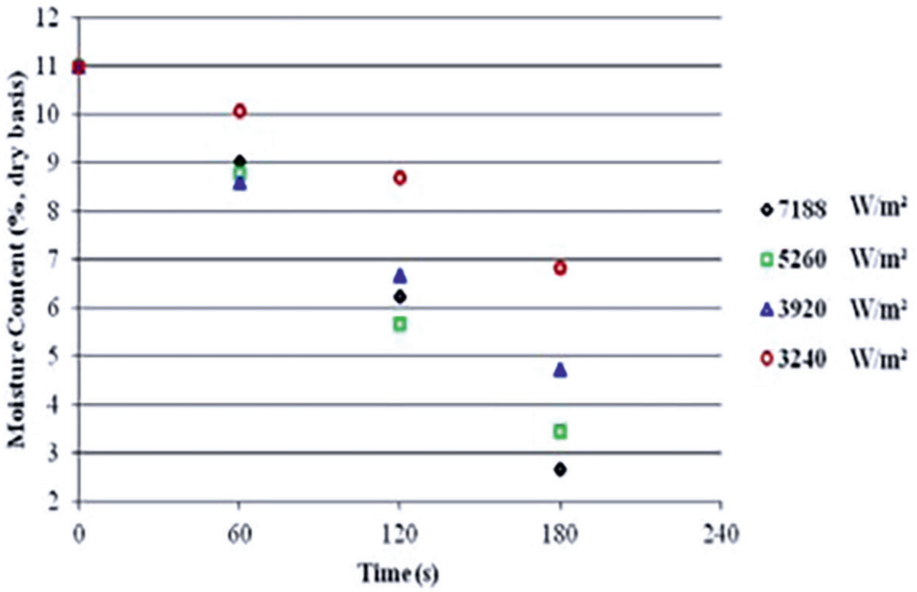
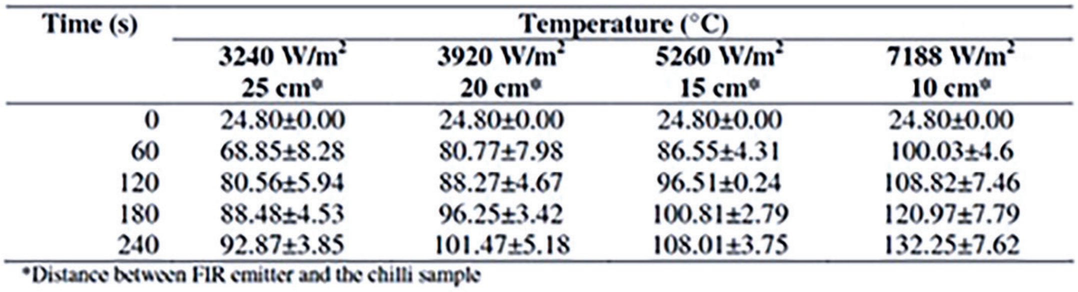


Figure 8.
The relationship between average chili moisture content and FIR heating time under various radiation intensities.



Time (s)	Temperature (°C)			
	3240 W/m² 25 cm*	3920 W/m² 20 cm*	5260 W/m² 15 cm*	7188 W/m² 10 cm*
0	24.80±0.00	24.80±0.00	24.80±0.00	24.80±0.00
60	68.85±8.28	80.77±7.98	86.55±4.31	100.03±4.6
120	80.56±5.94	88.27±4.67	96.51±0.24	108.82±7.46
180	88.48±4.53	96.25±3.42	100.81±2.79	120.97±7.79
240	92.87±3.85	101.47±5.18	108.01±3.75	132.25±7.62

*Distance between FIR emitter and the chilli sample

Figure 9.
Chili temperature varies with cooking time under different radiation intensity.

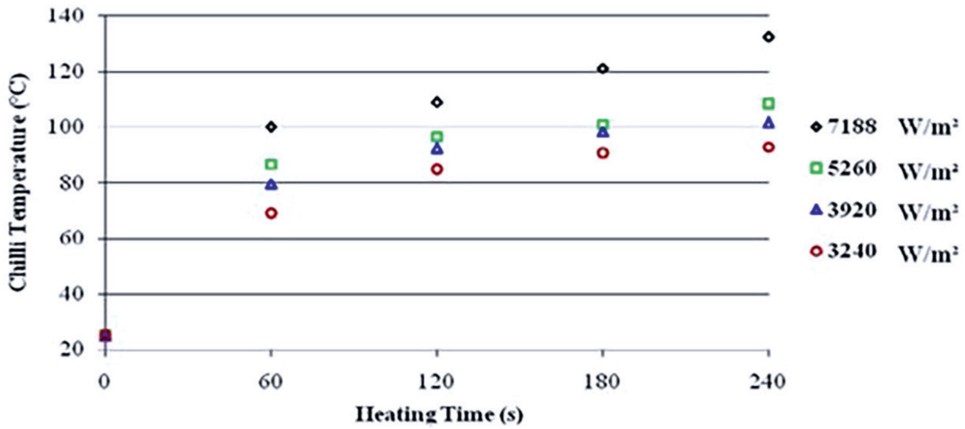
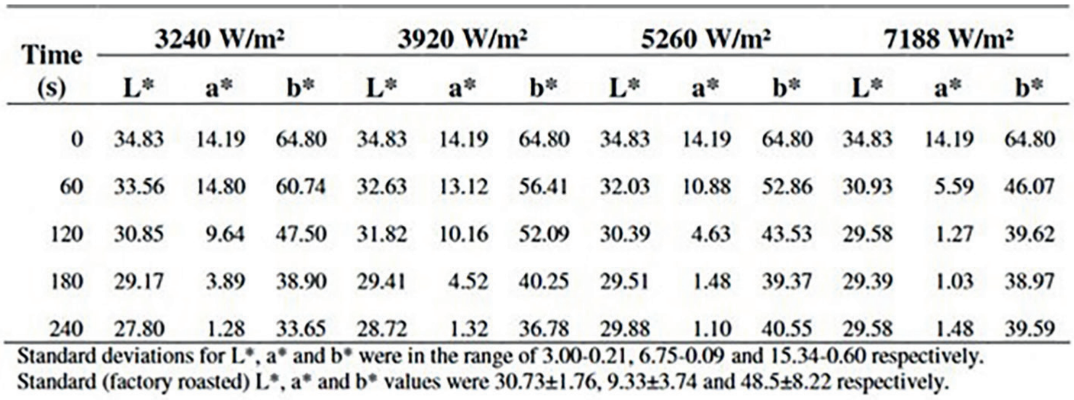


Figure 10.
The relationship between chili temperature and heating time under various radiation intensities.



Time (s)	3240 W/m²			3920 W/m²			5260 W/m²			7188 W/m²		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
0	34.83	14.19	64.80	34.83	14.19	64.80	34.83	14.19	64.80	34.83	14.19	64.80
60	33.56	14.80	60.74	32.63	13.12	56.41	32.03	10.88	52.86	30.93	5.59	46.07
120	30.85	9.64	47.50	31.82	10.16	52.09	30.39	4.63	43.53	29.58	1.27	39.62
180	29.17	3.89	38.90	29.41	4.52	40.25	29.51	1.48	39.37	29.39	1.03	38.97
240	27.80	1.28	33.65	28.72	1.32	36.78	29.88	1.10	40.55	29.58	1.48	39.59

Standard deviations for L*, a* and b* were in the range of 3.00-0.21, 6.75-0.09 and 15.34-0.60 respectively.
Standard (factory roasted) L*, a* and b* values were 30.73±1.76, 9.33±3.74 and 48.5±8.22 respectively.

Figure 11.
*L*a*b values vary with FIR exposure time at various radiation intensity.*

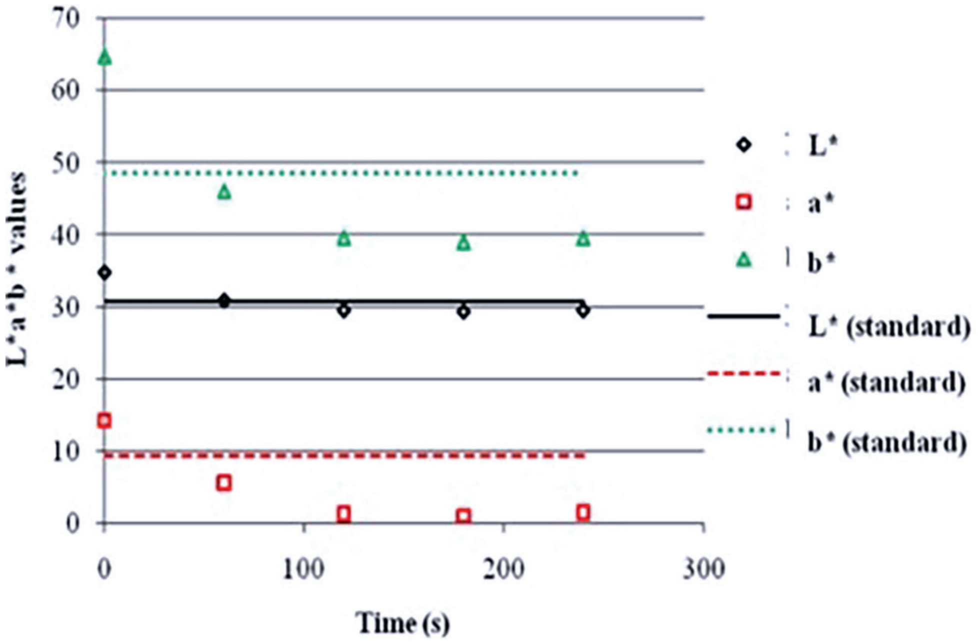


Figure 12.
*L*a*b values as a function of time and standard values of L*a*b at 7188 W/m² FIR the level of radiation.*

horizontal lines L* (standard), a* (standard), and b* (standard). The standard values for L*, a*, and b* were determined to be 30.73 (L*), 9.33 (a*), and 48.51 (b*). Similarly, with an FIR radiation intensity of 7188 W/m^2, similar results could be obtained in 60 s. Chili factory roasted color at 124, 117, as well as 107 s the radiation intensities measured were 3240, 3920, and 5260 W/m^2 (**Figure 12**) [22].

15. Conclusion

The conclusions obtained from this article based on several previous studies are as follows:

1. Price fluctuations in the consumer market for fresh red chilies occur owing to a variety of variables. First, because there is an abundance of fresh red chilies during harvest, the price of fresh red chilies falls to its lowest point. Second, because the

availability of fresh red chilies is limited, especially during the dry season, when demand for fresh red chilies increases, the price of fresh red chilies rises.

2. Overcoming the occurrence of high price fluctuations in fresh red chilies is accomplished by adjusting the time and location of planting fresh red chilies, improving the goods distribution system, implementing appropriate technology for fresh red chili products (drying, compressing, and roasting), and preparing a warehouse receipt system to store fresh red chili products resulting from post-harvest technology to meet demand for fresh red chilies, particularly during the dry season.

3. Drying and continuing to manufacture capable chili powder increases the shelf life of red cayenne pepper. Until the fifth week, the quality of cayenne pepper dry remains as before (excellent condition), whereas cayenne pepper just arrived 3–4 weeks with initial conditions.

4. Storage of red cayenne pepper in the form of dried chili is better compared to storage in the form of chili powder. For cayenne pepper, dry generally can last in good condition until the ninth week (still up to standard), whereas powdered red cayenne pepper survives until the sixth week.

5. The results showed that FIR radiation may successfully roast red chilies. In this study, the greatest FIR intensity employed was 7188 W/m^2. The proximity of the FIR emitter to the sample prevented further intensification of the sample.

6. The drum roaster needed 25 min to create roasted red chili, when the red chili was exposed to 7188 W/m^2, it retained the same color and moisture content. FIR radiation intensity for 60 s. The roasted color of red chili was attained at 124, 117, and 107 s at 3240, 3920, and 5260 W/m^2 radiation intensities, respectively the interpolated moisture levels were 8.38, 6.70, and 6.59% db, respectively.

7. As a result, FIR radiation might be employed to efficiently roast red sauce. Before adopting the method on an industrial scale, more research is needed to improve the quality of roasted red chili using FIR radiation.

Author details

Amos Lukas[1], Agustinus N. Kairupan[2]*, Agung Hendriadi[1], Arief Arianto[1], Lamhot Parulian Manalu[1], Lanjar Sumarno[1], Joni Munarso[1], Mulyana Hadipernata[1], Huda M. Elmatsani[1], Bonnie O. Benyamin[1], Akhmad Junaidi[3], Mochammad Jusuf Djafar[1], Roosganda Elizabeth[3], Sahlan[1], Nasruddin[1], Puji Astuti[1], Subandrio[1], Heryoki Yohanes[1], Ermi E. Koeslulat[1], Eko Bhakti Susetyo[1], Suharto Ngudiwaluyo[4], Abdul Halik[5], Wahyu Purwanto[1], Guntur Haryanto[6], Sitti Ramlah[1], Noverina Sjafrina[1], Agus Budiyanto[1], Sari Intan Kailaku[1], Rienoviar[1], Alvi Yani[1], Nenie Yustiningsih[1], Himawan Adinegoro[1], Henky Henanto[1], Payung Layuk[1], Meivie Lintang[1], Gabriel H. Joseph[1], Derek Polakitan[2], Heri Wahyudianto[7], Joko Saptohadi[8], Kusumawati Dewi Budiarti[6], Taufik Hidayat[1], Josep Ginting[5], Amsal Rasyid[5] and August Polakitan[9]

1 Research Center for Agroindustry, National Research and Innovation Agency, Indonesia

2 Research Center for Animal Husbandry, National Research and Innovation Agency, Manado, Indonesia

3 Research Center for Cooperative, Corporation and Peoples' Economy, National Research and Innovation Agency, Indonesia

4 Directorate of Environment Maritime, Natural Resources, and Nuclear Policy, National Research and Innovation Agency, Indonesia

5 Research Center Domestic Government, National Research and Innovation Agency, Indonesia

6 Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency, Indonesia

7 Regional Development Planning Agency Papua Agency, Indonesia

8 Regional Research and Innovation Agency for Kutai Kartanegara Regency, Indonesia

9 Research Center for Food Crops, National Research and Innovation Agency, Indonesia

*Address all correspondence to: audikairupan@gmail.com

References

[1] Wardhono A, Nasir MA, Qori'ah CG, Indrawati Y. Improving chili agribusiness policies to support food security: Evidence from Indonesian districts. In: IOP Conference Series: Earth and Environmental Science. 2021;**759**(1):1-8. DOI: 10.1088/1755-1315/759/1/012048

[2] Astuti FS, Wanto HS, Koesriwulandari K. Elasticity of demand for red pepper (*Capsicum annuum* L.) in the city of Surabaya. Jurnal Ilmiah Sosio Agribis. 2021;**21**(1):76-93. DOI: 10.30742/jisa21120211343

[3] Badan Pusat Statistik (BPS). Distribusi Perdagangan Komoditas Cabai Merah Indonesia. Jakarta: Badan Pusat Statistik; 2022

[4] Dudzinski J, Knap R. Price, volume and level of economic development as determinants of export value in countries and regions. Procedia Computer Science. 2022;**207**:3865-3874

[5] Rizaty MA. Indonesia's Cayenne Pepper Production Rose to 1.55 Million Tons in 2022. Indonesia Data. Id. Available from: https://dataindonesia.id/sektor-riil/detail/produksi-cabai-rawit-indonesia-naik-jadi-155-juta-ton-pada-2022; 2023

[6] Yusuf F, Rauf A, Halid A, Agribisnis J, Pertanian F. Cayenne pepper farming development strategy in Dungaliyo District, Gorontalo Regency. Agrinesia. 2018;**2**(2):133-144

[7] Bahar YH, Achdiyat, Promosiana A, Suharto YB, Ichniarscyah AN. Assess the Application of Post-Harvest Handling Technology of Red Cayenne Pepper (*Capsicum frutescens* L.). Bogor: Politeknik Pembangunan Pertanian; 2022

[8] Bahar YH. Analysis of drying efficiency process and producing dried and powder chilli for improving the durability. Jurnal Agroekoteknologi Dan Agribisnis. 2017;**1**(1):39-47

[9] Fernando AJ, Amaratunga KSP, Priyadarshana LBMDL, Galahitiyawa DDK, Karunasinghe KGWU. Using far-infrared radiation to roast chilli (*Capsicum annum* L.). Agricultural Research in the Tropics. 2014;**25**(2):180-187

[10] Bakar A, Tjahjohutomo R. Post-Harvest Technological Innovation of BioIndustrial Agriculture. Center for Research and Development of Post-harvest Agriculture; 2015

[11] Asgar A, Musaddad D, Setyabudi DA, Hassan ZH. Ozonization technology to maintain the freshness of chili cultivar kencana during storage. Jurnal Penelitian Pascapanen Pertanian|. 2015;**12**(1):21-27

[12] Jamilah M, Fadilah R. Uji Kualitas Bubuk Cabai Rawit (*Capsicum frutescens*) Berdasarkan Berat Tumpukan dan lama Pengeringan Menggunakan cabinet dryer test quality of Cayenne pepper (*Capsicum frutescens*) powder based on stack weight and long drying using cabinet dryer. Jurnal Pendidikan Teknologi Pertanian. 2019;**5**:98-107

[13] Ajuebor F, Aworanti OA, Agbede OO, Agarry SE, Afolabi TJ, Ogunleye OO. Optimization of the drying process and modeling of the drying kinetics and quality attributes of dried chili pepper (*Capsicum frutescens* L.). Trends in Sciences. 2022;**19**(17):1-21. DOI: 10.48048/tis.2022.5752

[14] Jangde PK, Singh A, Arjunan TV. A overview of efficient solar drying processes. Environmental Science and Pollution Research.

2022;**29**(34):50970-50983. DOI: 10.1007/s11356-021-15792-4.202

[15] Maryana YE, Saputra D, Priyanto G, Yuliati K. A review of the inflated solar dryer for improving the quality of agricultural products. IOP Conference Series: Earth and Environmental Science. 2023;**1160**(1):1-10. DOI: 10.1088/1755-1315/1160/1/012075

[16] Meghwar BL, Khan A, Lakhiar IA, Mirani AA, Daper MS, Kalroo MW. Drying red chilies in a solar tunnel, a solar-cum gas dryer, and in the open sun. Pakistan Journal of Agricultural Research. 2023;**36**(1):63-70. DOI: 10.17582/JOURNAL.PJAR/2022/36.1.63.70

[17] Vishwakarma A, Sinha S, Malik P. A solar dryer study to reduce postharvest losses. In: Lecture Notes in Mechanical Engineering. Singapore: Springer Nature; 2022. DOI: 10.1007/978-981-16-8341-1_28

[18] Getahun E, Gabbiye N, Delele MA, Fanta SW, Vanierschot M. Chili drying in a two-stage solar tunnel: Drying characteristics, performance, product quality, and carbon footprint analysis. Solar Energy. 2021;**230**:73-90. DOI: 10.1016/J.SOLENER.2021.10.016

[19] Alves-Filho O, Eikevik T, Mulet A, Garau C, Rossello C. The kinetics of mass transfer of red pepper under air freeze drying. Drying Technology. 2007;**25**(7-8):1155-1161. DOI: 10.1080/07373930701438469

[20] Gutiérrez BLC, Cardozo CJM, Rojano BA. Effect of the freeze-drying on the functional properties of Rocoto chili pepper. Artículo Científico. 2017;**20**(1):111-119

[21] Setyabudi DA, Broto W, Jamal IB. The effect of immersion in benomyl solution on the freshness of chili pepper (*Capsicum annum* L. Var. Kencana) at low temperature storage and space. Jurnal Penelitian Pascapanen Pertanian. 2016;**13**(2):53-62

[22] Saengrayap R, Tansakul A, Mittal GS. Effect of far-infrared radiation assisted microwave-vacuum drying on drying characteristics and quality of red chili. Journal of Food Science and Technology. 2015;**52**(5):2610-2621. DOI: 10.1007/s13197-014-1352-4