THE ANALYSIS OF DRIED FOOD PRODUCT MOISTURE DIFFUSIVITY UNDER INDIRECT SOLAR DRYER PROCESS

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2021

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF MECHANICAL ENGINEERING

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2021

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DECLARATION

I hereby declare that the project entitled -"The Analysis Of Dried Food Product Moisture Diffusivity Under Indirect Solar Dryer Process"- which is being submitted as Final Year Project of 8th semester in Mechanical Engineering to Faculty of Engineering is an authentic record of my work done under the guidance of Dr. Mohd Kamel Bin Wan Ibrahim.

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ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere indebtedness toward Dr Mohd Kamel Wan Ibrahim for his invaluable guidance, suggestions and supervision throughout the work. Without his kind patronage and guidance the project would not have taken shape. I would also like to express my gratitude and sincere regards for his kind approval of the project, time to time counseling and advices.

My deepest gratitude goes to Miss B Norerama D Pagukuman for her guidance throughout this project. I also would like to thanks my family member for the morale support and not to forget all my friends that always with me throughout this project. Without them, this project would not have been possible.

ABSTRACT

Potato has become the primary food for humans for many centuries. Over 359 million metric tons of potatoes were harvested worldwide and about 20% to 25% of the potatoes were damaged due to poor storage and poor marketing. The focus of this project is to dry the potato to reduce the amount of damaged potato by increasing the potato marketability. The dried potato will be dried using an indirect solar dryer. The objective of this project is to determine the drying efficiency of the indirect solar dryer drying the potato slice and to analyze the proximate composition of moisture in the potato slice. The project was done by running the dryer in two conditions, with and without a pump. Each condition with four different speed of exhaust fan which is 0.2m/s, 0.4m/s, 0.6m/s and 0.8m/s. The potato slice will be blanched before going through the drying process. The initial and final mass of the potato slice will be measured and recorded. The final mass of the potato slice then will be compared with the potato slice that was dried in an oven at 103°C. from there the efficiency of the solar dryer under different conditions can be found.

ABSTRAK

Kentang telah menjadi makanan utama manusia selama berabad. Lebih 359 juta tan metrik kentang telah dituai di seluruh dunia dan kira-kira 20% hingga 25% daripada kentang telah rosak akibat penyimpanan yang baik dan pemasaran yang lemah. Fokus projek ini adalah untuk mengeringkan kentang untuk mengurangkan jumlah kentang yang rosak dengan meningkatkan kebolehpasaran kentang. Kentang kering akan dikeringkan menggunakan pengering suria tidak langsung. Objektif projek ini adalah untuk menentukan kecekapan pengeringan pengering suria tidak langsung mengeringkan hirisan kentang dan untuk menganalisis komposisi proksimat kelembapan dalam hirisan kentang. Projek ini dilakukan dengan menjalankan pengering dalam dua keadaan, dengan dan tanpa pam. Setiap keadaan dengan empat kelajuan kipas ekzos yang berbeza iaitu 0.2m/s, 0.4m/s, 0.6m/s dan 0.8m/s. Hirisan kentang akan dicelur sebelum melalui proses pengeringan. Jisim awal dan akhir hirisan kentang akan diukur dan direkodkan. Jisim akhir hirisan kentang kemudiannya akan dibandingkan dengan hirisan kentang yang telah dikeringkan dalam ketuhar pada suhu 103°C. dari situ kecekapan pengering suria di bawah keadaan yang berbeza boleh didapati.

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M_i	Initial mass
M_f	Final mass
M_c	Mass of crucible
M_w	Moisture removed
D	Average drying rate
t_D	Drying time
A_D	Drying area

CHAPTER 1

INTRODUCTION

1.1 Introduction

Drying products is an important and necessary step in the manufacturing process. Drying is a method of eliminating moisture from material by passing gas, such as air, through or over it. Fruit and vegetable drying has become a popular and oldest technique of food preservation. Many other industries, such as the automotive, food, industrial, and utility industries, rely on heat energy to dry their products. (Abhay Lingayat et al., 2021). For food preservation, there are a few techniques for drying the food. Traditional sun drying, indirect or direct solar drying, freeze-drying, and oven or dehydrator drying are all options (Naseer Ahmed et al., 2013).

The drying equipment for indirect solar drying is an indirect solar dryer. The indirect solar dryer is a device that uses sunlight to dry a range of items, such as fruits, fish, and seaweed. It works by converting sunlight into heat energy, which is then stored and used to dry the food. There are two types of indirect solar dryers. The first is active, whereas the other is passive. The difference between both is that the active solar dryer has a fan or a blower, whereas the passive solar dryer does not. The fan or blower's function is to make it easier for air to move through the drying chamber and to improve heat transmission to the product (Azwin Kamarulzaman et al., 2021).

The solar dryer is made up of a few main components. A drying chamber, solar collector, and auxiliary system are used. In the drying chamber, the product to be dried will be placed. The drying chamber can be built of a variety of materials, and it is sometimes insulated to prevent hot air from dissipating from the drying chamber. After that, there's the solar collector. The solar dryer's most important component is the solar collector. Its purpose is to absorb solar radiation and transform it into thermal (heat) energy. Before the air flows to the drying chamber, it will be heated when flowing through the solar collector. Solar radiation passes through the transparent cover before being absorbed by the thermal absorber, which is usually painted in a dark color like black to enhance absorption efficiency. Finally, there's the auxiliary system. Basically, a solar collector with a drying chamber is sufficient. However, installing the auxiliary system will help to improve the solar dryer's performance and efficiency. The biomass burner and thermal storage system may be used as an auxiliary system to raise the temperature and efficiency of the drying chamber (Azwin Kamarulzaman et al., 2021).

1.2 Problem Statement

Humanity cannot survive without food, which is one of their three basic needs. Potato has been one of the most major food sources for many people in various parts of the world for hundreds of years (Shyam S. Sablani & Arun S. Mujumdar, 2006). One of the issues in potato production is post-harvest loss. Around 20% to 25% of potatoes are lost after harvesting due to poor marketing techniques and storage (Tadesse, B. et al., 2018). Potatoes may become injured and vulnerable to microorganisms such as yeast, molds, and bacteria during harvesting. Mold and yeast can spread throughout the storage facility due to the duration of storage period and microbial contamination (Rioux Amanda 2007). To compensate for the loss of potatoes, part of them can be dried or dehydrated into potato slices. Dried potatoes have a longer shelf life, especially when properly stored. Dehydrated or dried potato slices, on the other hand, have a great flavour and can be used in cooking. The potatoes can be dried using a few methods, traditional method which is open sun drying or modern method which is by using an indirect or direct drying method. By using the open sun drying method, the potato is more prone to contamination, especially if it is laid out on the ground. They are also at risk of being infested by insects, rats, or birds. Apart from losing certain vitamins due to direct sunlight exposure (Onyinge G. O. et al. 2015). Since the European Union has banned food that do not satisfy quality and hygiene standards from being sold in developed nation marketplaces and most farmers in developing countries are not exposed to the indirect solar drying method enough, further research is required to determine how the solar dryer would dry the marine food products so it will give some exposure to the farmer (United Nations

Conference On Trade And Development, 2017). Therefore, the objective of this project is to see how efficient and effective the solar dryer is.

1.3 Research Objective

1. To determine the drying efficiency of indirect solar dryer drying the potato.
2. To analyze the proximate composition of moisture in potato.

1.4 Scope of Work

An overall understanding of the project title's keyword, such as the drying efficiency, and proximate composition of the potato, is essential for completing this project paper. A review of previous research papers that provide a comprehensive understanding of the project title and background must be reviewed and analyzed. A study of how to design the experiment for this project is both relevant and essential for this project paper. A literature review of past researches related to the project from various sources must be carried out.

This project is focused on experimental works. To finish this project, numerous trials must be conducted to obtain an average result and to see the trend of the result when various parameters are used. The measurement of a related parameter such as mass before drying and the mass after every one hour until completely dry using the measuring scale. Then the thickness of the potato before the drying process and every one hour after the drying process using the vernier caliper. The temperature 10 different place must be recorded. Those 10 temperature need to be measure is the temperature of ambient air, chamber, chamber body, inlet pipe, outlet pipe, potato slice, air when entering solar collector, air after entering solar collector, solar collector glass and chamber glass. Those temperature will be recorded using thermocouples and the data logger. Then the humidity inside of the chamber and relative humidity by using a hygrometer and the wind speed at the exhaust fan by using the hot wire anemometer.

The dryer's efficiency will be evaluated by gathering important data such as the product's initial and final mass, the recorded temperatures, the humidity inside the chamber, the speed of wind at the exhaust fan and other relevant data. Last but not least, determining the proximate composition of the slice potato after it fully dried.

1.5 Project Flowchart

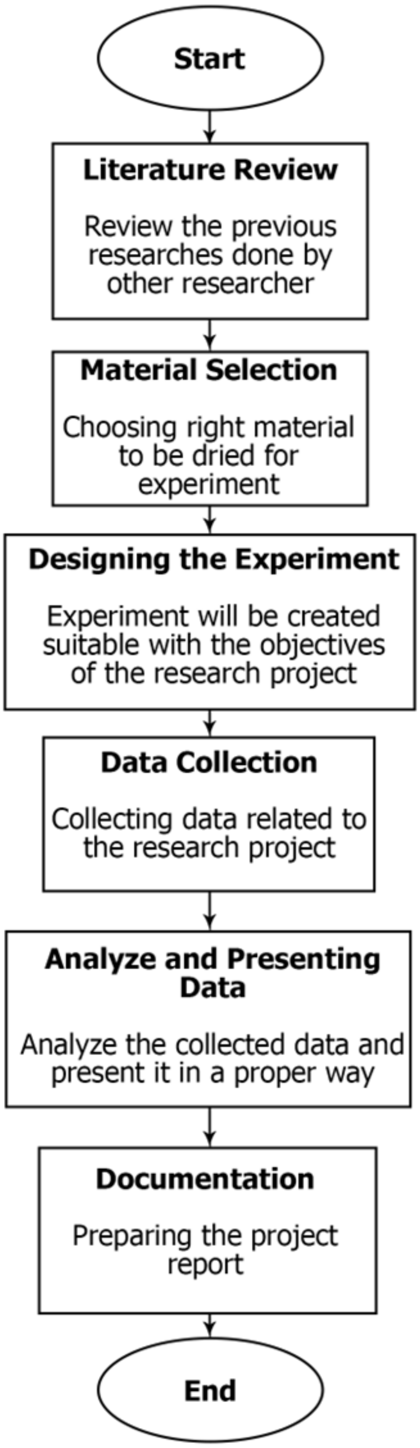

Figure 1.1: Project flowchart

1.6 Equipment And Material Cost

Table 1-1: Equipment and material cost

NO	EQUIPMENT/MATERIAL	UNIT	COST PER UNIT (RM)	TOTAL (RM)
1	Portable Drying Chamber Unit	1	-	-
2	Potato (*Solanum tuberosum*)			
3	Hot Wire Anemometer	1	-	-
4	Hygrometer UNI-T UT333B	2	80	160
5	Thermocouple with Data Logger	1	-	-
6	Laptop	1	-	-
7	Measuring Scale	1	-	-
8	Vernier Calliper	1	-	-
9	Pyranometer with Data Logger	1	-	-
10	AC/DC Power Supply	2	-	-
11	Laboratory Oven	1	-	-
12	Slicer	1	-	-
13	Square Cookie Cutter	1	-	-

1.7 Research and outcome

The expected outcome of this project is the identification of the efficiency of the drying chamber when drying the potato slice. The efficiency of the drying chamber will be displayed with related table and graph. Then, after the drying process, the proximate composition moisture of the potato slice can be determined.

1.8 Research contribution

The findings of this project will convince society to reconsider the use of indirect solar dryers in the production of potato slice since dried potato slice can be used in cooking. When compared to the traditional method, the findings will show the advantages of utilizing an indirect solar dryer.

1.9 Research Commercialisation

As an outcome of the research paper's findings, local industries will be able to export their dried potato slice to other countries, including Europe, if they implement the indirect drying method, which is cleaner than the traditional method. This is due to the fact that European countries have banned a few countries who do not meet their quality and hygiene standards. It will increase their production and profit right away. Plus, dried potato slice has become a new ingredient to add when cooking.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

2.1.1 Solar Drying

Drying is the process of removing water particles or any other solvent by evaporating it from a body. It is a necessary step in the manufacturing process. It is usually used as a final step before a product can be sold or packed. It is also an essential step in preserving crops and some industries. The energy required for the drying process can be obtained from fossil fuel, natural gas, electricity, solar and many more. There are a few ways of drying process by using the solar. There are traditional ways just to place the product to be dried in an open place. This method has been used for ages and is still being used today due to the minimum cost required and easier to be done. Then, there are indirect and direct solar drying.

The indirect and direct solar drying process both required a drying chamber. The indirect method will not expose the product to direct solar radiation, while the product in the direct drying method will be exposed to direct solar radiation. Indirect solar radiation will require a solar collector in addition to the drying chamber to work, while direct solar drying only requires a drying chamber with transparent glass (Fauziah Sulaiman et al., 2013).

2.1.2 Type Of Solar Dryer

The solar dryer can be divided into active and passive dryers. The active solar dryer is also a forced convection solar energy dryer. Active solar dryers are usually equipped with extra equipment such as fans, pumps and solar collectors. The fans work as supplying air into the chamber or solar collector and some works to prevent the air from entering back into the chamber after it leaves the chamber. The solar collector will usually be attached to the chamber at the lower part and tilted (Om Prakash, Anil Kumar, 2013). An active solar dryer can be designed in many ways to increase the efficiency of heating the circulating air process or increase the air circulation in the drying chamber. Some chamber uses copper pipe filled with water to heat the air.

A passive solar dryer, known as a natural circulation solar energy dryer, only depends on the natural movement of the warm air. This dryer is usually cheaper than the active solar dryer because it can be fabricated from locally available materials. However, this type of dryer is ideal for a small business or personal use only. For the direct passive dryer, the product to be dried will be exposed to direct solar radiation because the drying chamber is usually covered with a glass panel or any other transparent material that can allow the sunlight to pass through. To maximize the dryer's efficiency, a shallow and insulated chamber design will be used. Holes will be created to allow the air to enter and exit the chamber. The product will be placed on a perforated tray usually made of a plastic net that will allow the air to pass through it (Om Prakash, Anil Kumar, 2013).

2.1.3 Drying chamber

A drying chamber is equipment used in both direct and indirect solar drying. The drying chamber is the essential equipment used in both drying processes as it works as a place to store the product during the drying process and is also a place where most things happen during the drying process. The drying chamber usually had a multi-shelf design to dry more products simultaneously. In this project, a portable active indirect drying chamber was used. It equips with wheels beneath it to make it easy to move and be placed at a suitable place.

2.2 Working principle

2.2.1 Active Indirect Solar Dryer

In an active indirect solar dryer, a solar collector will be attached to the chamber at the lower part and tilted. The solar collector was tilted due to some reasons. The first reason is to help the warm air rise into the drying chamber naturally since hot air is less dense. However, in some cases, a solar collector comes with intake fans. The function of the intake fan is to supply air into the solar collector and push the air into the drying chamber. The second reason for tilting the solar collector is to increase the amount of solar energy collected since the angle of the tilting plays an important role in determining the maximum solar energy collected. The air supplied by the intake fan or entered the solar collector will be heated by solar radiation. After that, the warm air will rise and enter the drying chamber. In the drying chamber, the product will be placed on a perforated tray to let the warm air pass through the tray and the product. The perforated tray will be arranged vertically as the chamber use the multi-shelf design. The warm air will make the temperature inside the chamber rise and the moisture inside the product will diffuse out. After that, the exhaust fan will suck the air in the chamber with the moisture out and make sure the air will not enter the chamber back.

2.2.2 Direct Passive Solar Dryer

While in the direct passive solar dryer, the dryer was not equipped with any solar collector. The design of the dryer was usually shallow and was covered with any transparent cover such as glass panel and was insulated with a heat insulator material. In a direct passive solar dryer, the solar radiation will pass through the transparent cover and produce low-grade heat. So, since the drying chamber was insulated with a heat insulator material, the heat produced due to the solar radiation will trap inside of the drying chamber. This phenomenon is called the greenhouse effect. In a direct passive solar dryer, the air is free to enter from below and escape from the chamber through the opening at the top since the dryer does not equip with any intake and exhaust fans.

2.2.3 Project Solar Dryer

In this project, the type of drying chamber is an indirect active solar dryer. The dryer was made of stainless steel. The drying chamber was equipped with an exhaust and intake fan, a pump, a solar collector, and a heat exchanger made using copper pipe divided into two parts. The drying chamber was also covered with a glass panel at the top side and had a water tank for a heat exchanger outside the chamber. The first part of the heat exchanger was installed near the glass panel, and the second part was installed at the bottom part of the drying chamber. The product will be placed on a perforated tray inside the chamber. Then during the drying process, the chamber will be placed in an open place and exposed to sunlight. When the pump is running, the water inside the tank will circulate inside the heat exchanger. The water will be heated when flowing through the heat exchanger's first part since it is exposed to direct sunlight. When the water flows to the second part of the heat exchanger located at the bottom of the drying chamber, the hot water will release its heat to the surrounding air. The function of the solar collector is to harness the heat energy from the solar collector. The heat energy then will be used to heat up the air that enters the solar collector through the intake fan. The warm air will be pushed and rise to the top of the chamber through the product in the chamber. The warm air also will evaporate the moisture inside the product. Then the warm air with the moisture will be sucked out from the chamber by the exhaust fan.

2.3 Advantages And Disadvantages

The traditional sun drying method had many disadvantages. The product can get spoiled because of the rain, wind, too much moisture, and dust from the surrounding. The product is also vulnerable to animals and pests. Cats or dogs, or even birds can steal it. The product was also even exposed to the attack of fungi and insects. Apart from that, this process is time-consuming and require a large area to spread the product to dry them. In addition, some of the previous research found that direct exposure to solar radiation during high-temperature days can cause the outer layer of the product to harden, and it will trap the moisture inside the product and cause spoilage, especially in the agriculture field (Om Prakash, Anil Kumar, 2013).

Using the indirect or direct solar dryer can ensure the hygiene of their product is at the topmost. It uses optimum energy and time while also requiring less area than the traditional method since the dryer can hold up to several trays vertically. The drying process also becomes more efficient, and the product will be protected from the environment, especially particulates. At once, it improves the product quality. The most important advantage of the solar dryer is that it promotes renewable energy sources. The solar dryer is more affordable than the artificial drying process. Using the indirect solar dryer can minimize the discolouration of the product (Om Prakash, Anil Kumar, 2013).

The solar dryer does have a few shortcomings. For example, a direct solar dryer only has a small capacity, can cause discolouration of the product and trap moisture that causes condensation inside the chamber, especially at the glass panel due to no exhaust fan. Due to the small capacity of the dryer, it might need several dryers to dry the same amount of product as the open drying method, but still, the area required will and can be reduced. Then, the product's discolouration only occurs in the direct solar dryer and not in the indirect solar dryer due to the direct exposure to solar radiation for a long time. It is the same as the open drying method. The moisture condensation in the solar dryer can reduce the solar radiation's efficiency and transmissivity (Om Prakash, Anil Kumar, 2013).

2.4 Ban In Developed Country

The entrepreneur must begin to advance to the next level and identify a new target market to be successful and develop the business. Entrepreneurs must understand the rules and regulations to grow their business in a new country. Some European countries' suppliers were banned from doing business because they did not comply with their regulations. Primarily just for sanitation. Following a heart problem in the 2000s, Japan revised its Food Sanitation Act and enacted the Food Safety Basic Law. They had banned imported foods with possible harmful residues. Bangladesh, for example, was banned from importing its products to the European Union in 1997 because of infrastructural and sanitary issues, resulting in a $15 million loss in seafood export sales. The European Union then prohibited Uganda from exporting its product to the European Union from 1996 to 2000 due to quality and safety concerns (United Nations Conference On Trade And Development, 2017).

2.5 Previous Research

Previous research found that the indirect solar dryer had reduced the drying process time, was cleaner and gave a better-quality product. The sample was fruits such as sultana grapes, sweet pepper, green beans, and chilli pepper during that research. The experiment used different airflow rates for different food products (Tiris et al. 1995). S. Dhanushkodi et al. also found that the drying time can be decreased when using the solar dryer (force convection method) compared to open sun drying from 14 hours to 6 hours. The use of the solar dryer had reduced about 42.86% of the time required to achieve 5% moisture content when using the open sun drying method (S. Dhanushkodi et al., 2014). A review by A. Fudholi et al. found that solar dryer produces a well-dried product and has an excellent long storage life. The review also found that solar drying for agricultural and marine products has huge potential from a technical and energy-saving point of view (A. Fudholi et al., 2009).

2.6 Content of Dried Potato

Based on research done by T. Puttongsiri et al (2012), they found that, potato consist of 63% to 83% moisture content, 13% to 30% carbohydrate, 0.7% to 4.6% protein and 0.44% ash. Potato had a density of 675 kg/m^3 (G. Sharan and K. Rawale, nd). it also had a specific heat of 3660±447.4 $Jkg^{-1}K^{-1}$ (A. Farinu and O. Baik, 2006). In this project, the specific heat of potato will be used is 3.43$kJkg^{-1}K^{-1}$