Automated Food Dryer Optimization Using Thermal Energy

[1]S.Malaiamy
Associate Professor, Department of EEE, Latha Mathavan Engineering college,
mdusmalaisamy@gmail.com

[2]Dr.A.Srinivasan
Professor and Head, Department of EEE, Sethu Institute of Technology, Anna University, Chennai

Abstract:

Depending on the application, thermal energy storage is based on materials that are believed to be capable of storing thermal energy and can be used at a later time. There are many applications that require thermal energy for heating or cooling; therefore, controls are necessary to ensure that the application's requirements are met efficiently. Researchers have conducted several investigations on thermal energy storage materials. The aim of this study is to enhance drying performance of conventional solar drying systems used for food drying by using novel temperature management methods. Consider the factors that lead to more energy being consumed during the drying process. In the proposed method, dry air is used as a coolant to control the temperature during drying. Furthermore, the findings of the impact are presented.

Keywords— *Thermal energy, Drying Process, Food drying, Coolant*

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I. INTRODUCTION

Sun drying is a sustainable and environmentally beneficial process. Sun drying is a step up from organic sun drying. Fruits and vegetables can be dried using a variety of methods nowadays, including dehydration, canning, etc. However, these techniques lower the quality of the finished product, reducing waste, boosting agricultural productivity, and raising output. Solar dryers are employed to improve the quantity and quality of production.

A compact piece of fruit drying equipment, the solar-powered automatic fruit drying system is ideal for drying a range of fruits. The fruits can be dried and kept, extending their useful life. Fruit drying is a crucial procedure that has been used since the dawn of civilization. Infrared radiation can be used to dry grapes. It is a unique procedure that differs from organic drying and conventional drying. The disadvantages of natural drying are numerous, and medium-sized farms cannot afford the extra time, pricey drying equipment, or space requirements. Farmers in developed nations can improve their financial status by providing sophisticated, automated, and cheap fruit drying facilities. The fruit is first internally heated using infrared radiation to remove any moisture that may still be present. After that, it forces humid air out of the space while pumping air into the space to maintain the humidity below a predetermined threshold.

Heating, ventilation, timing, and keeping a constant chamber temperature are all controlled by a microcontroller. Microcontroller power is provided by a solar panel. The solar system makes use of its radiant energy. Sludge, agricultural waste, paints, and non-radiation sensitive substances can all be dried using this method. Use a manual process or an automatic homogenizer to evenly distribute the dehydrated particles throughout the greenhouse. The energy from the sun is used by greenhouse structures to heat and evaporate the moisture in the mud. The enclosure shields the mud from bad weather in addition to creating a semi-controlled atmosphere that promotes evaporation and contains odors.

A mobile bridge mixer gently spreads and moves the sludge along the length of the solar dryer to provide a

thoroughly mixed and uniformly dried product. We use a sun dryer to get over these issues. The product's quality will be impacted by high heat, such as sun drying. Product fading and prolonged drying times, expensive costs, increased space use as a result of these issues, and decreased production have a negative impact on agricultural development. By directly absorbing solar radiation, the sun dryer boosts the temperature of the product. A greater temperature for drying than solar drying reduces drying time and enhances product quality. However, there is a temperature issue that prevents the heat needed for drying, depending on the season. The product mentioned above concludes that there may be an issue maintaining the temperature.

II. Related Work

Food can be effectively dried to preserve it. The best food preservation technology for sustainable development is solar food dryers. The primary objective of this effort is to construct a solar-powered automatic dryer with electric and solar heaters for cost-effective, high-quality drying. He divided the work into two sections. We must first design a productive dryer. The temperature within the heating chamber used for the drying process must then be maintained using both the conventional PI controller and the fuzzy controller. The efficient utilization of solar energy in heating processes should also be thoroughly examined.

Oven dryers, tray dryers, continuous dryers are a few examples of the various dryer kinds. This model was chosen because it is more cost-effective than the previous ones, which was important given the unique characteristics of hand-made brick manufacturing. This is due to the very low amount of energy needed for its operation. A convection dryer's fundamental structure consists of a designated chamber in which the product is placed, a mechanism for producing hot air, and a network of ducts. The surface of the material is dried by a process, and the air entering the dryer is heated by a solar panel.

2.1 Existing System:

Existing structural elements include outlets, dryer chambers, drying materials, and solar collectors. A temperature sensor has also been employed in addition to this to forecast the temperature. Figure 1 illustrates the existing drying system. Based on the study, the temperature for different foods is given in Table I.

Table I. Temperature based on Food Types

Food Types	Temperature
Fruits	148 ° F/ 61°F
Vegetables	127 ° F/ 54°F
Yogurt	117 ° F/ 48°F
Bread	112 ° F/ 45°F
Herbs	96 ° F/ 37°F

Figure 1 Existing drying system

2.2 Problem Statement:

The focus is on hardware design due to the absence of automatic temperature management. Here, various temperature ranges are maintained depending on the product, and the temperature is modified in accordance with the moisture content. By weighing the product, we may assess whether it is dry.

III. Proposed Methodology

The fundamental concept of solar drying is to transform the incoming solar radiation into the thermal energy needed for drying. In essence, a solar dryer is made up of a number of collectors that heat the air before sending it through a drying chamber to remove moisture. The latent heat of vaporization required to vaporize the product's moisture is provided by the heated air moving through the drier. The airflow through the dryer, a crucial step in the drying process, makes it easier for water vapor to convectively migrate from the raw material via the output to the dry ambient air. Two different types of solar dryers were conceived, investigated, and produced throughout this effort over a period of several months.

1. Solar dryer with a low price and power

2. Large-scale manufacture of solar dryers

Based on the notion of convective forces, the translucent cover is made of glass with a thickness of a few millimeters, and the case is made of wood. The drying chamber had a fan attached to it to promote airflow. It had a steady exhaust. The sizes and shapes of the entry apertures varied. The design employed a circular intake mold. To make loading and unloading of dried goods easier, a door has been installed to the side of the drying chamber. Figure 2 illustrates the proposed food dryer which contains Solar collector, Temperature acquisition sensing technology, Food dryer and coolant.

When the temperature (T) falls within the acceptable range, the dryer is employed; however, when the temperature rises above the acceptable range, an additional cooling unit is added before the dryer. The environment generally affects temperature. Perhaps the key factor is seasonal variability.

During the drying process, no organic ingredients are lost, and no extra ingredients are required. Dry matter is great for using up future resources because it has a high calorific value. In regions with significant seasonal swings, the notion works great as a backup plan. It is dried and dehumidified using the most recent low temperature technology without the use of additional chemicals or physical treatments.

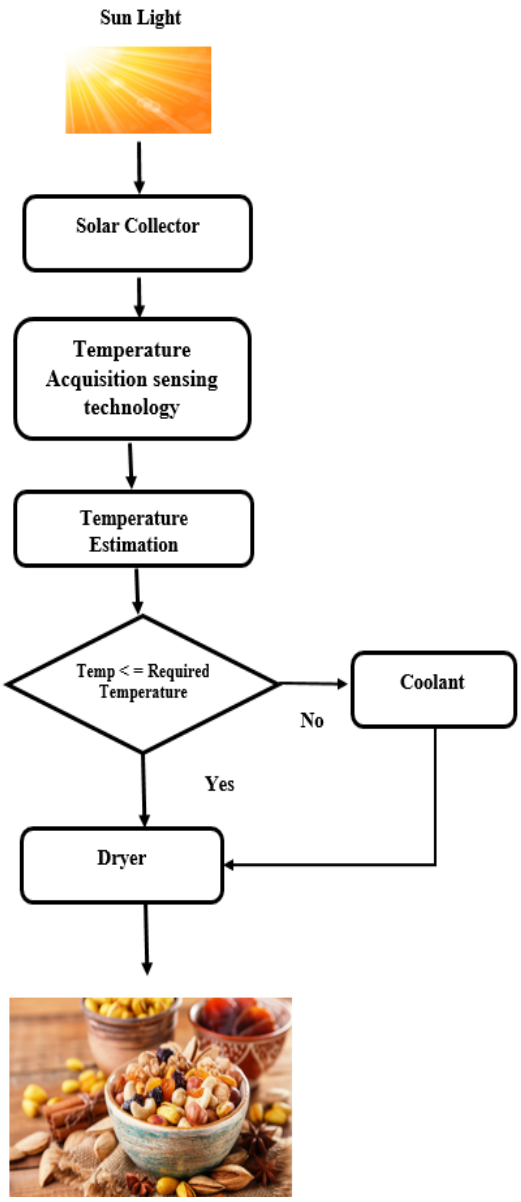

Figure 2 Proposed Food Dryer

IV. Optimization Results

After drying, the moisture content of the sludge can be controlled and adjusted according to this control technology and central monitoring of the system. To achieve the best outcomes, numerical and graphical optimization methodologies (moisture content, drying rate, and drying efficiency) were applied.

For numerous fruits used for drying, the actual base-level temperatures and the recommended optimum values for this approach are presented in Table II.

4.1 Drying process parameters

i) Determination of moisture content

$$M.C=[(W_w-W_d)/W_w] \times 100\ \%$$

where Ww is the sample's initial weight (g), M.C. is the moisture content (%) of the wet base, and Wd is the sample's ultimate weight (g)

ii) Drying rate

$$M_{dr}= M_w/t_d$$

Mw is the mass of water that has evaporated due to solar heat. Mdr stands for drying rate (g/h), and td for product drying time.

iii) Drying efficiency

$$Efficiency= ML_v/ I\ At$$

I = solar radiation incident on the dryer (w/m^2), M = amount of water extracted from the product (g), t = product drying time (s), and A = collector area. Lv = latent heat of evaporation (J/kg) (m^2)

Table II: Base Temperature and Temperature Optimization in drying material

Drying material	*Base temperature*			*Optimized temperature*		
	summer	*winter*	*rainy*	*summer*	*winter*	*rainy*
Gooseberry	**35**	**29**	**25**	**33**	**27**	**24**
Fig	**28**	**23**	**19**	**27**	**21**	**18**
Coconut	**42**	**37**	**33**	**40**	**36**	**31**
Black Grapes	**25**	**21**	**18**	**24**	**20**	**16**
Kiwi	**32**	**25**	**22**	**30**	**24**	**21**

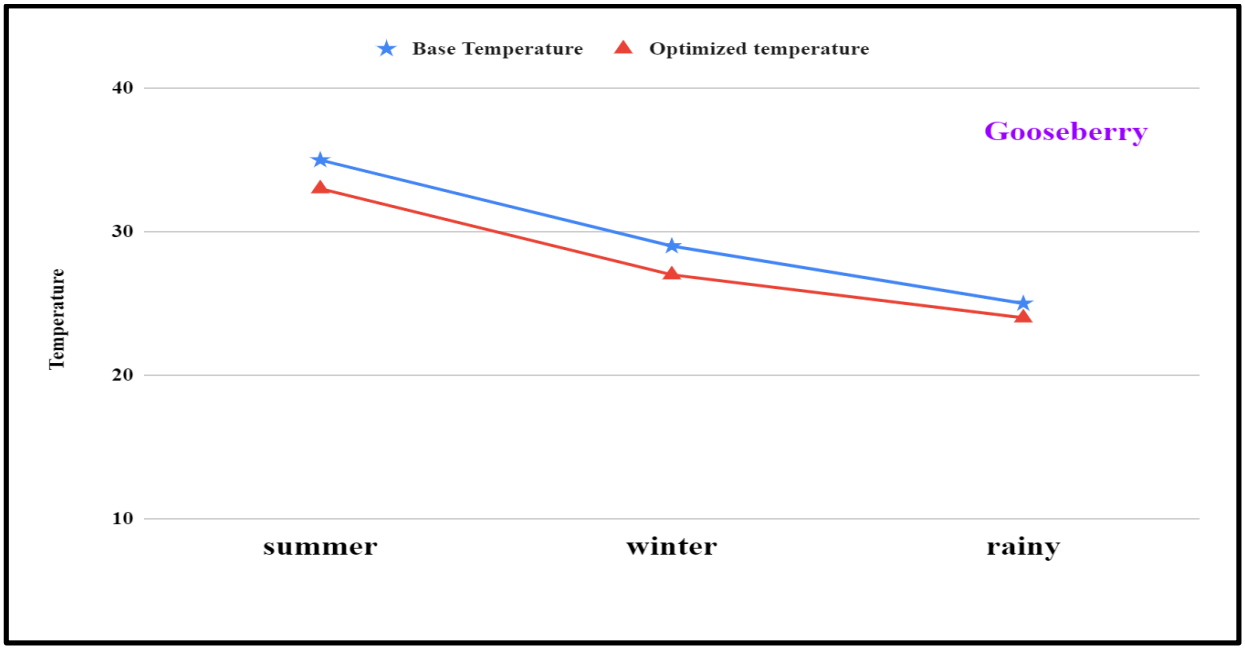

Figure:3 Seasonal temperature analysis of gooseberries

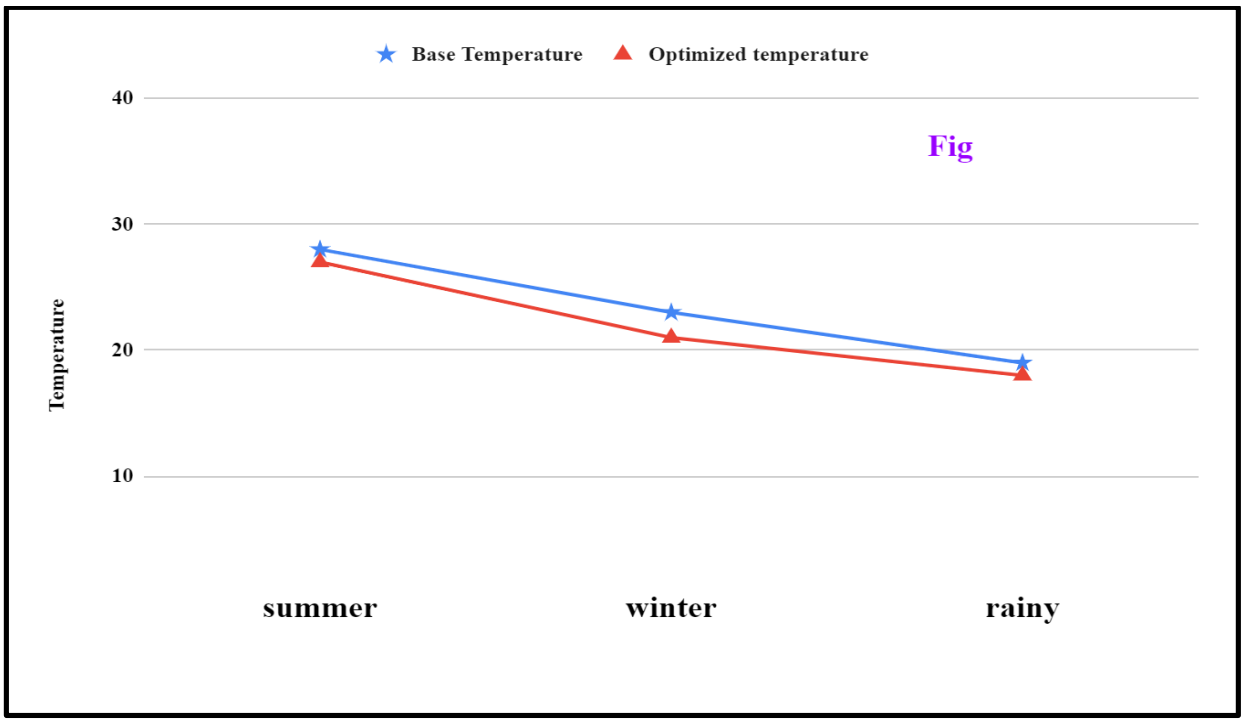

Figure: 4 Seasonal temperature analysis of Fig

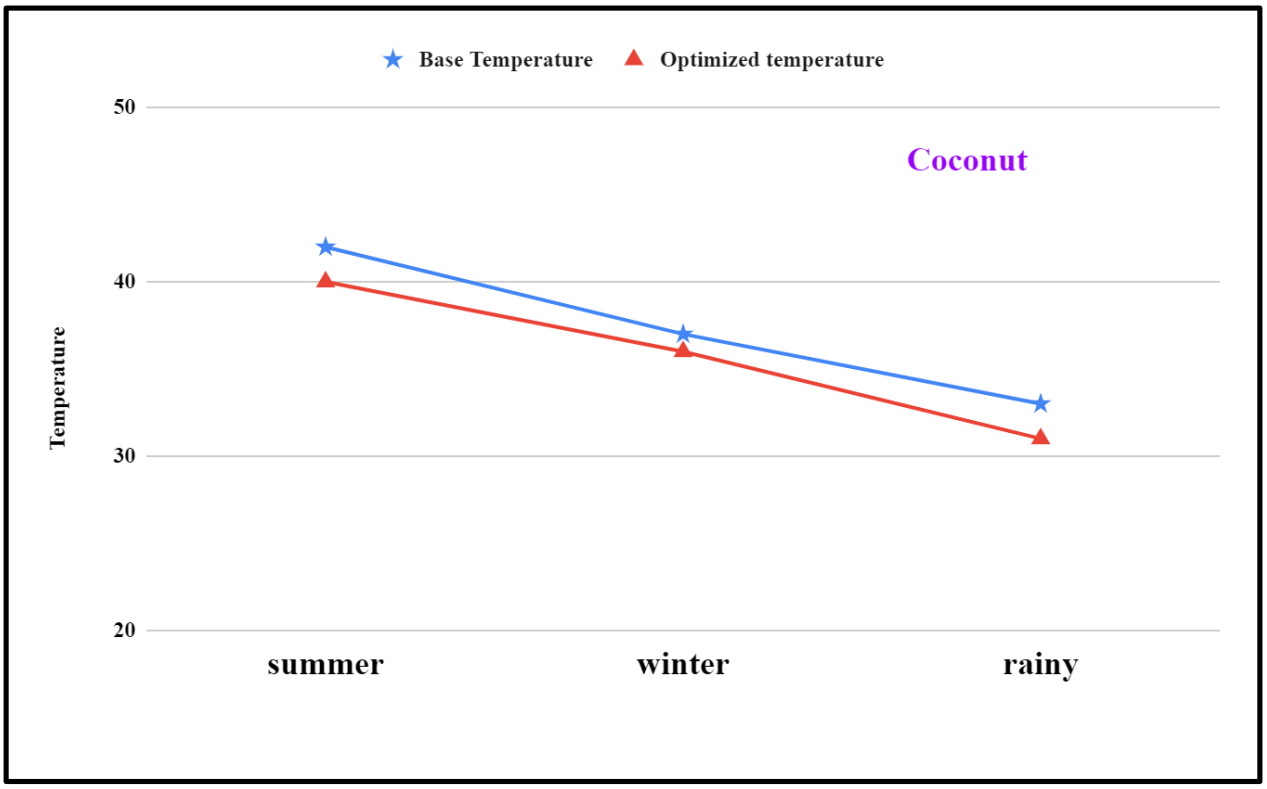

Figure:5 Seasonal temperature analysis of Coconut

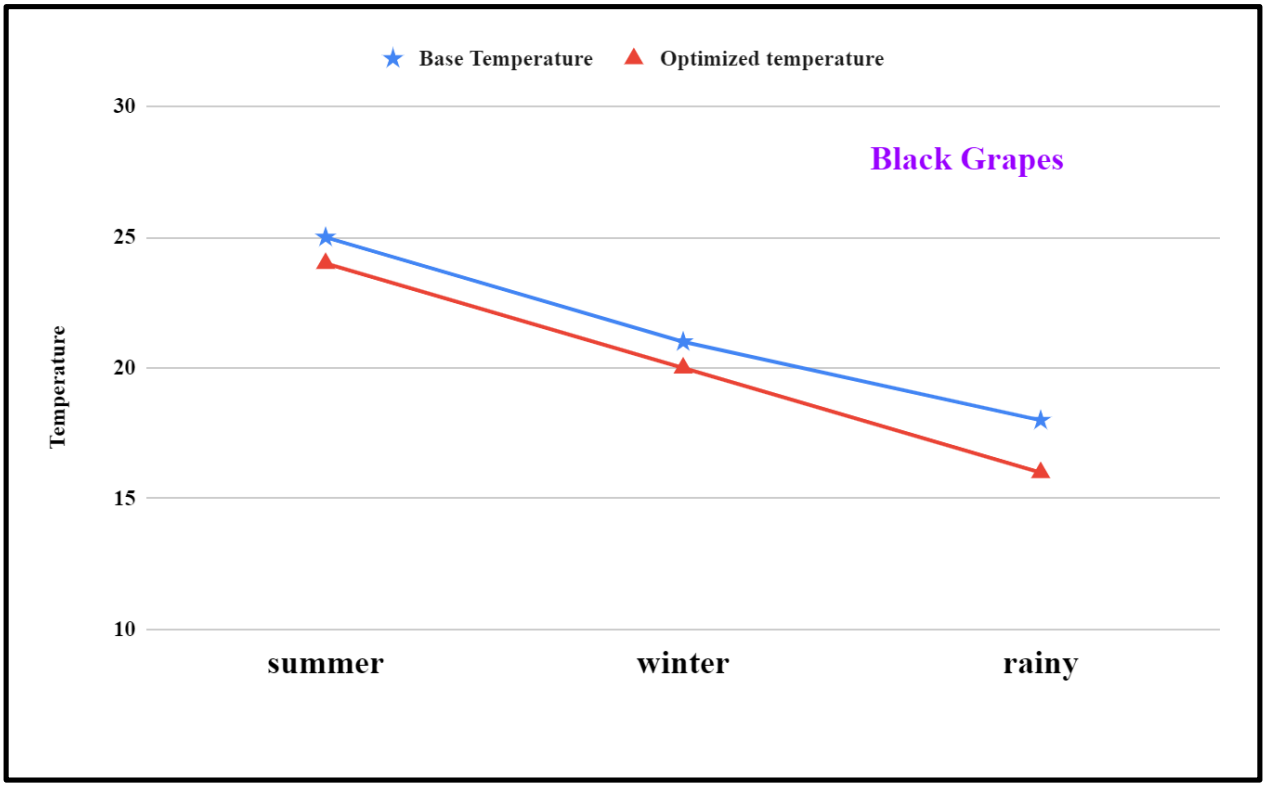

Figure:6 Seasonal temperature analysis of Black grapes

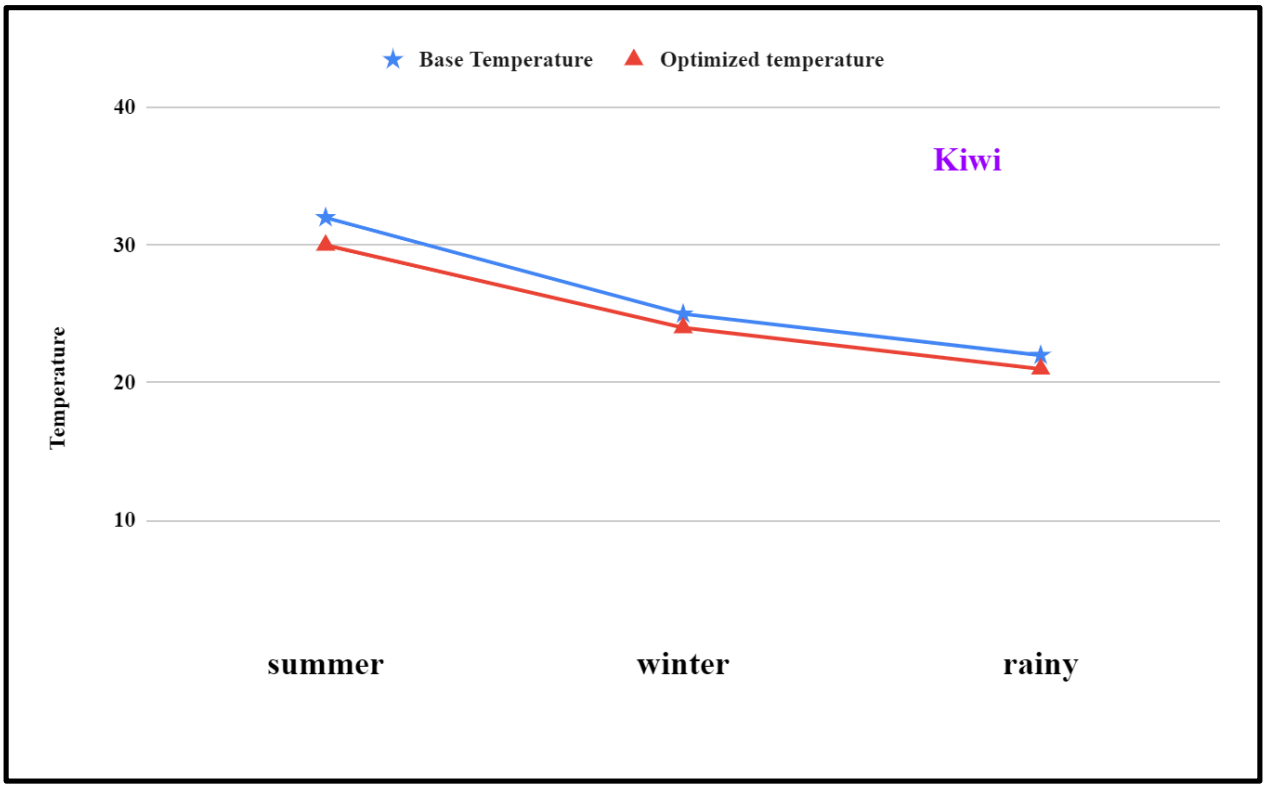

Figure:7 Seasonal temperature analysis of Kiwi

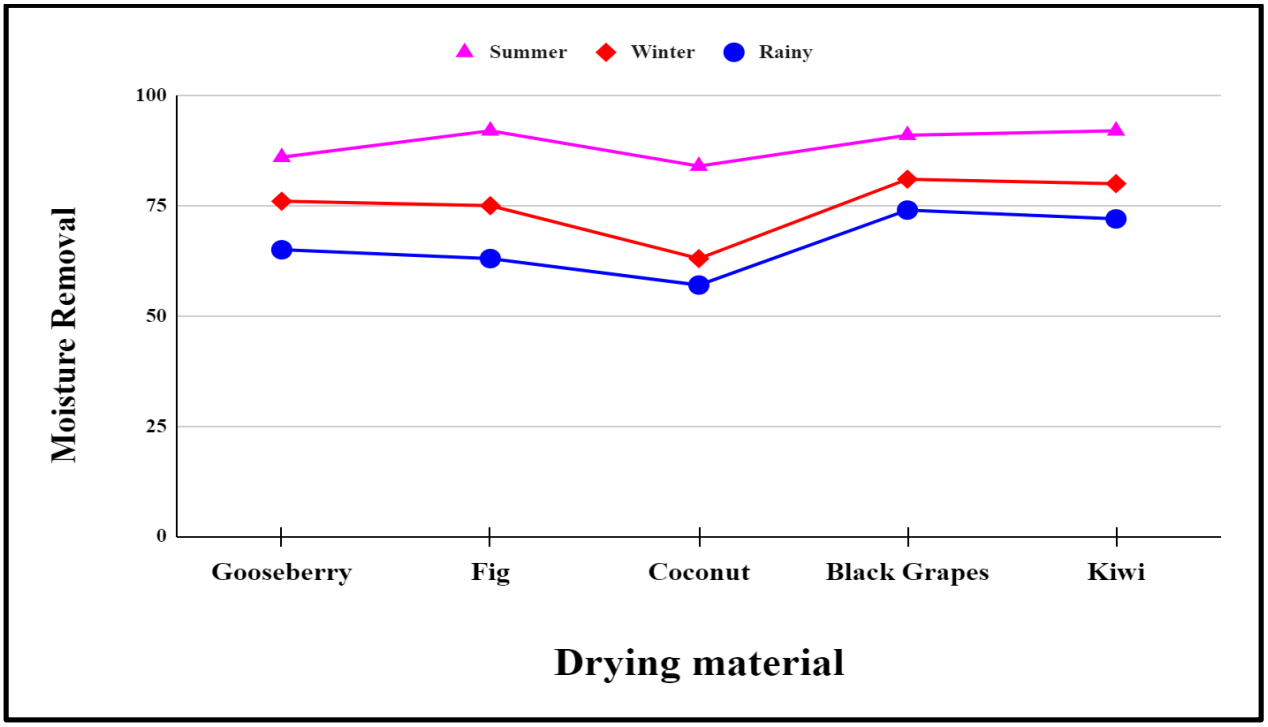

Figure:8 Moisture Removal

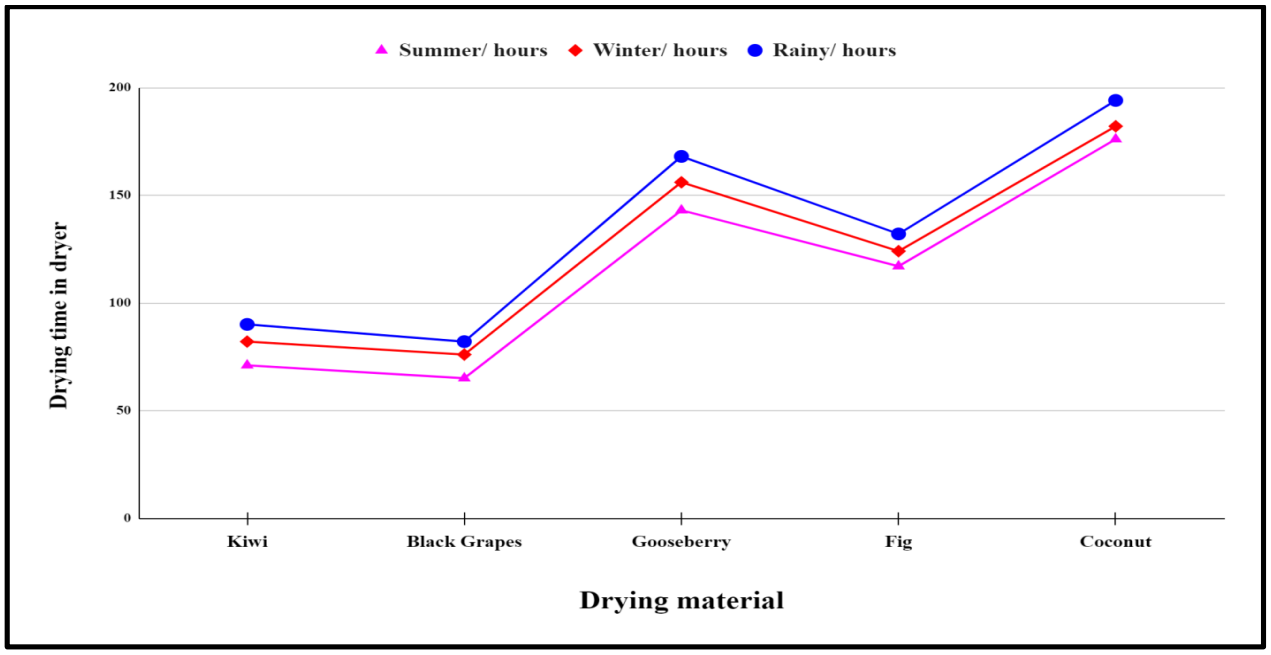

Figure:9 Drying time in dryer

Figures 3-7 illustrate the seasonal temperature analyses of Gooseberries, Figs, Coconuts, Kiwis, Blacks, and grapes. The drying time in the dryer is depicted graphically in Figure 4. The berries must be dried by evaporating the moisture. This procedure somewhat lowers the moisture content. Performance of drying is affected by reductions of even 1%. Figure 5 illustrates this. According to the findings, the proposed technique's greatest benefits are its low operating costs and quick drying time.

V. Conclusion:

By enhancing the basic idea of a solar conduction dryer with automation and design changes, the system's effectiveness and nutrient output have increased. Based on the results of the experiment, it can be determined that the dryer maintains a reasonable temperature range, which serves as a secondary purpose of maintaining the food's nutritional value. This enables the system to multitask, which is also accomplished with it.

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