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A Study the Solar Energy Powered by Solar Dryers and its Mechanism

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Abstract- Sun drying is the most popular technique utilised to preserve agricultural products in India. The rate of drying is affected by a number of factors, including but not limited to: the amount of available solar radiation, the temperature & wind speed of the surrounding area, the initial moisture content of the crop, the crop's absorptive surface area, and the product's mass per unit of exposed area. The drying process is slowed by the sun's sporadic appearance, cloud cover, and rain. Due to the limited availability of solar power throughout the night, it is necessary to employ effective thermal energy storage in order to utilise the daytime heat surplus. Continuous drying is often favoured over intermittent drying. The purpose of solar drying is to subject the product to higher temperatures than would normally be available in the surrounding environment.

Keywords- Solar Energy, Drying, Solar Technology, Solar Dryers, Mechanism

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INTRODUCTION

Technology based on renewable energy sources fills the gap created by the world's growing energy needs & limited supply of conventional energy sources. The effectiveness & economics of deploying such an application are the two aspects that need to be continually considered. Depending on how they capture, transform, & disperse sunlight, solar technologies can be roughly categorized as passive or active. Photovoltaic panels, solar thermal collectors, and electrical or mechanical equipment transform solar energy into beneficial outputs in active solar approaches. A building's orientation toward the Sun, the use of materials with advantageous thermal mass or light-diffusing qualities, & creation of naturally ventilated rooms are all examples of passive solar approaches. The globe recognizes the importance of solar energy utilization. Energy conversion devices, heating systems, cooking, drying, & refrigeration utilize solar thermal technology. Every industrial process needs to involve drying, which is a significant conventional energy-consuming process. The two main inputs to the system, as well as the substance's moisture content, temperature, and air, all vary concurrently during the continuous solar drying process (namely, the solar isolation & the ambient air temperature).

SOLAR ENERGY

Solar energy is the most promising renewable energy source which will prove crucial whenever other sources run out. From the sun, the planet receives energy. This energy maintains the earth's temperature above that of colder space, drives ocean and atmospheric currents, drives the water cycle, & fuels photosynthesis in plants.

Solar power on the surface of the planet is 1016 watts, whereas solar power when the sun strikes the atmosphere is 1017 watts. All of modern societies electrical needs add up to 1013 watts. As a result, the sun provides us with 1000 times more energy than we require. It will be 50 times more energy than the world needs if we can only use 5% of it. On a bright sunny day, the sun emits about 1 kW/m2 of energy. This energy has been used to generate steam for prime movers to generate electricity. Due to the large amount of space needed, the uncertainty of energy supply at a steady rate, and other elements like clouds, winds, haze, etc., this source is only used for limited electric power production. Hydrogen can be created, mechanical or electrical devices can store energy, & eutectic or phase-changing salts can store energy. Due to their high heat capacity, these salts melt when heated & release heat when they cool and crystallize. 5000o C solar furnaces solidify energy. As shown in commercial energy estimates, the world's coal, oil, & gas reserves will run out in a few decades, favoring solar energy. Solar energy can be used technically, unlike these technologies, which are currently unproven. Nuclear fusion has not answered all fundamental scientific issues, & nuclear energy is risky. India relies heavily on solar energy because it's in a sunny climate.

APPLICATIONS OF SOLAR TECHNOLOGY

The term "solar energy" primarily discusses to the usage of solar radiation for industrial purposes. Except than geothermal & tidal, all other renewable energy sources get their power from the sun. Passive or active solar technologies capture, convert, and disperse sunlight. Active solar systems convert sunshine into energy utilizing photovoltaic panels, pumps, & fans. Passive solar design involves choosing thermally efficient materials, designing natural air circulation, and considering a building's orientation to the Sun. Active solar technologies increase energy supply, although passive solar technologies reduce demand for alternative resources. The solar energy applications that are now having the most success are:

1) Residential building heating & cooling.
2) Solar-powered water heating.
3) Drying agricultural & animal products under the sun.
4) Localized solar distillation on a modest scale.
5) Making salt by evaporating brines from land or the sea.
6) Solar-powered stoves.
7) Water pumping using solar engines.
8) Cooling of food.
9) Indirect sources of solar energy include bioconversion & wind energy.
10) Solar ovens.
11) The production of solar electricity using-
    a. Solar ponds.
    b. Steam generators heated by tower heating or revolving reflectors (heliostat mirrors).
    c. Reflectors with fluid-circulating pipelines & lenses (cylindrical parabolic reflectors). Solar photovoltaic cells, utilized to directly transform sun energy into electricity or to pump water for rural agricultural uses.

SOLAR DRYERS

Solar power is a great option because it doesn't cost anything to use and it's a renewable, clean energy source that will never run out. Farms and agricultural businesses can benefit greatly from solar power because it provides a renewable energy source which is used to augment their various energy needs. With the development of new technologies, solar-assisted drying has emerged as the most effective, efficient, and sustainable way for drying agricultural products. Solar dryers are used extensively in the food & agriculture industries for drying. Solar dryers quickly & consistently dry crops, grains, fruits, and vegetables while protecting your produce. Solar-heated air dries goods. Natural & forced convection solar dryers are the major types.

- **Natural Convection**

Type Natural convective drying doesn't rely on any kind of external heat source to achieve its goal of reducing moisture content. Direct, indirect, & mixed-mode solar dryers that utilise natural convection are all possible.

- **Direct solar dryer**

The product is immediately showing to the sun in a direct solar dryer. The drying chamber alone is enough to dry the product. Black ceiling paint maximizes dryer drying capacity. Through a ceiling hole, sunlight warms the drying chamber. Due to the difference in vapour pressure, the substance being dried receives solar light directly & evaporates its moisture. Due to their portability, cost, and simplicity, large & small farmers employ these dryers. The primary drawback is that direct exposure to sunlight can produce unwanted changes in product quality, and it is sometimes impossible to regulate the amount of heat received by the product.

- **Indirect solar dryer**

Indirect solar dryers have their own dedicated machines for collecting solar energy & drying the product. One can divide these dryers into two sections. It has a flat black plate air heater or drying chamber.

The drying chamber's flat plate air heater heats & flows air. Eventually, the heated air escapes through a chimney after being dried out by the convective heat transfer it underwent with the moisture given off by the wet product. Depending on what you're drying, you'll need to set the oven at different temperatures. The ability to reach precise, high temperatures is the fundamental benefit of these dryers. Large-scale farmers typically utilise these dryers due to the high cost & high intricacy of their manufacture.

- **Mixed-mode dryer**

Mixed-mode dryers combine direct & indirect sun dryer effects. Flat plate air heaters & drying chambers make up mixed-mode dryers. The solar collector heats & dries the goods. Meanwhile the drying temperature may be adjusted, the drying process is more efficient & final product is of higher quality. Due of the complexity of the build, only commercial farms can afford it.

- **Forced Convection Type**

These dryers are the same in design & operation as natural convection dryers, but they dry things much more quickly & efficiently by continuously blowing hot air over them. These dryers may be utilized to dry a wide variety of agricultural products are relatively thermodynamically competent.

PRINCIPLE OF WORKING OF SOLAR DRYERS

A sun dryer transfers heat from a heat source to an object to remove moisture from its surface. Solar dryers lower the virtual humidity of drying air to rise product moisture vapour pressure. The brittle product literature gets rehydrated by the warm air. The amount of moisture removed is proportional to the air's temperature, with warmer air being more effective at absorbing moisture. This cheap solar cabinet drier uses the greenhouse effect to trap solar heat inside the drying chamber & raise the temperature. It's entirely natural. No energy is used. Atmospheric air enters the dryer at the bottom of the solar collector & escapes through the exhaust air outlet at the top. A figure 1 illustrating the solar dryer's operation method of operation is provided.

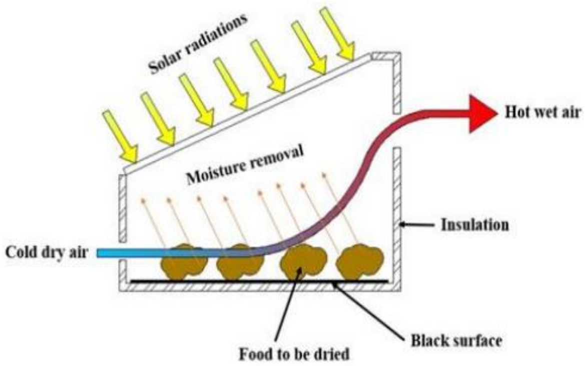

Figure 1: Working Principle of Solar Dryer

METHODS OF SOLAR DRYING TECHNOLOGIES

- **Open Air Solar Drying**

Normal techniques & solar energy are shown in fig.2 for drying in the open air. When drying crops in the open sun, they are typically spread out on the ground, surface, or cement floor so that the short-wavelength solar rays can hit them directly. Depending on the characteristics of the crop's surface, some of the sun's rays will be absorbed by the crop after they fall, while others will be reflected back. The crop dries out as its moisture content evaporates. Products dried in the open air are more likely to be under- or over-dried, to acquire dust or color affects, and to be unfit for sale on foreign markets than those dried using more standard methods. Because of the many problems associated with drying crops in the open sun, a more scientific approach known as controlled drying or solar drying has developed.

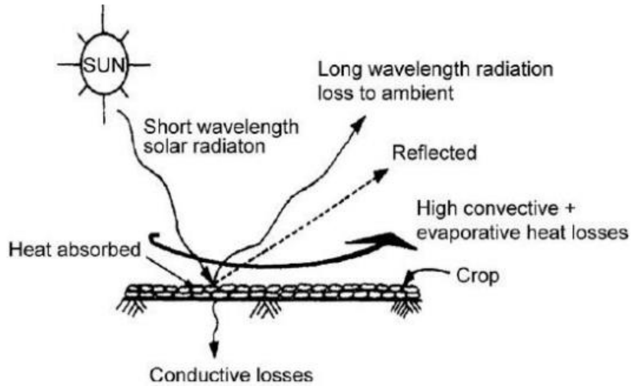

Figure 2: open sun drying

- **Direct Solar Drying**

Products are often dried using the time-honored method of direct solar drying. This method evaporates product moisture into the air using the sun. The air currents are caused by variations in air density. It will take a considerable amount of time for the products to dry to the necessary degree. Outside direct sun drying is possible on the surface of a floor made of concrete or a specific piece of soil. According to Mohana (2020) research, this technique is effective for drying grains. Long periods of time, often 10-30 days, are spent with materials lead on the outdoor floor. The following is a drawback of the easiest product drying method:

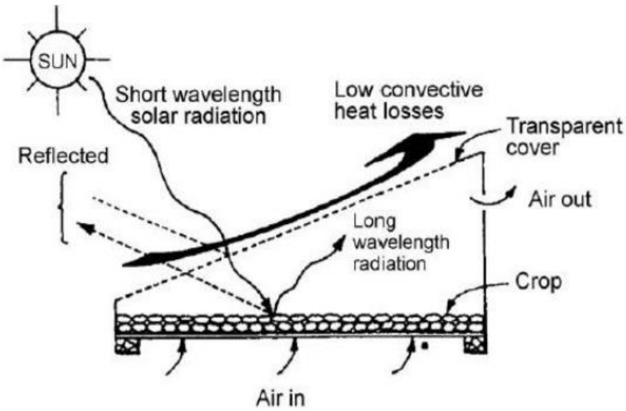

Figure 3 Direct solar drying

Drawbacks of Direct Solar Drying:

1. It needs a vast surface area and plenty of time in the sun, both of which are variables depending on the season and weather.
2. The finished output must pass the test of an untrained observer.
3. The dried product's final condition is impossible to predict scientifically.
4. Animals & birds can do significant damage to a product's supply.

5. The product might be subjected to a wide range of climatic conditions.

6. Direct solar drying has a slow drying rate

7. Direct sunlight reduces vitamin levels in dried products.

- **Indirect Solar Drying**

Indirect or convection solar drying is the latest product drying method. It outperforms solar drying. Flat plate or concentrated solar collectors heat the air here. Heating can be passive or active. After being heated, the air is sent to the warehouse's storage rooms. Hence, the product may experience moisture loss due to convection and diffusion (point 9). The main disadvantages of conventional solar drying are reduced using this technique.

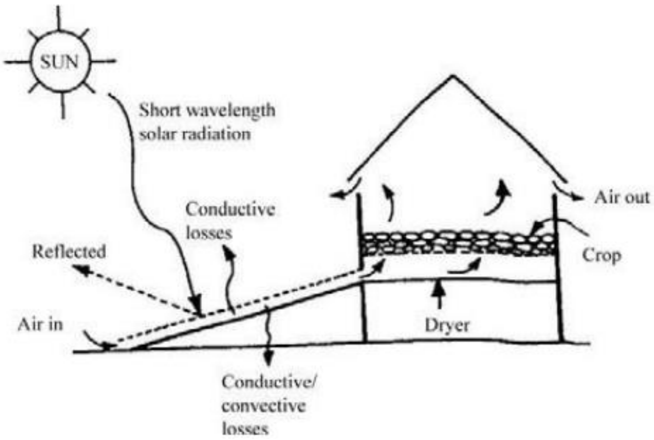

Figure 4: Indirect solar drying

Benefits & Drawbacks of Indirect Solar Drying:

1. The drying rate is much higher than that of drying in the sun directly.

2. The product's final state after drying is amenable to scientific manipulation.

3. In the event of natural disasters, there will be no product loss.

4. Direct solar drying requires a small footprint compared to other methods

5. The same dryer may be utilized for a variety of items throughout the year.

6. Avoiding direct sunlight is important for keeping the product's nutritional value intact.

7. The high start-up cost is the primary drawback of indirect solar drying.

- **Mixed Mode Solar Drying**

Together direct & indirect solar drying techniques are used. Solar drying & hot air blowing on the product are also viable options. It's possible that a solar energy collector might be used to preheat air before it entered the storage chamber. Convective moisture loss could be used to dry the product throughout this procedure. To expose the products to solar radiation, Abubakar (2018) uses the same chamber and covers it in transparent material, either partially or entirely.

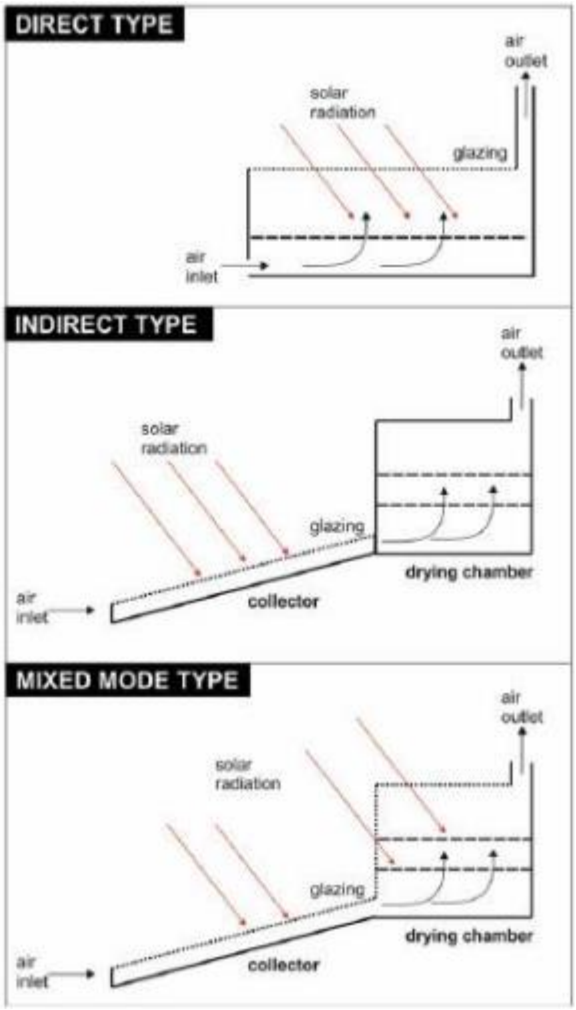

Figure 5: Types of Solar Dryer

DRYING MECHANISM

Evaporation is the process by which water moves from the surface of a substance to the surrounding air. Drying is affected by a wide variety of factors, including the product's size & form, chemical makeup (sugars, starches, etc.), physical structure (porosity, density, etc.), & surface quality (rough or smooth surface). The rate at which moisture moves from the interior to the exterior of a product is highly dependent on whether or not the product is hygroscopic. They cannot be dried to an absolute minimum moisture level, unlike non-hygroscopic materials like most food goods. Hygroscopic materials can hold onto water for a variety of reasons, such as bound water that is unable to escape due to capillary constriction or surface pressure, and surface-tension-bound water.

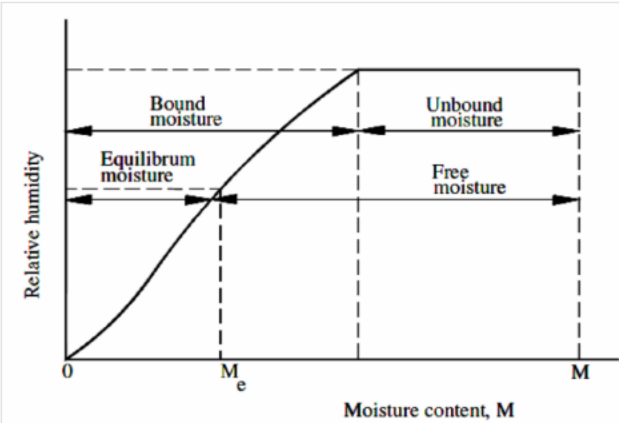

Figure 6: Moisture in the drying material

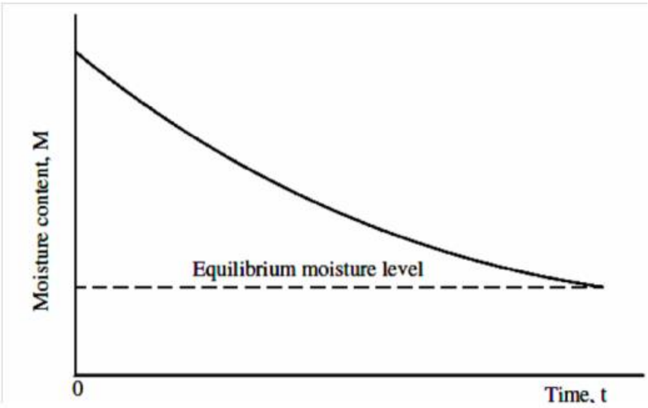

Figure 7: Rate of Moisture Loss

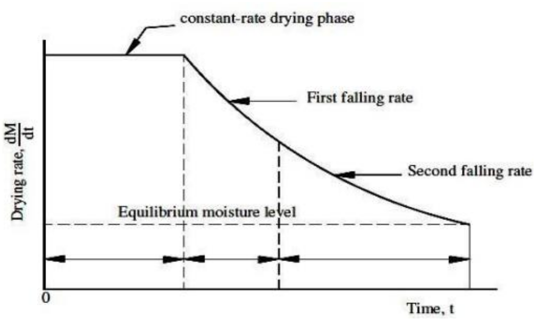

Figure 8: Drying Rate with time Curve

Hygroscopic compounds absorb or release moisture depending on atmospheric humidity. Once its water vapour pressure matches the air's partial pressure, a material's equilibrium moisture content (EMC= Me) is got quickly. Drying equilibrium moisture content reveals the minimum moisture level the material could be dried to under specific drying conditions. Different drying curves can be plotted. Plotting the material's mean M moisture content versus time is desirable.

LITERATURE REVIEW

M. Ssemwanga et al. (2020) One of the most effective ways to improve incomes, food, & nutrition security in East Africa is to cut down on postharvest losses of fresh perishable agro-products. As an alternative to the conventional open sun drying approach, an enhanced Hybrid Indirect Passive solar dryer with a redesigned solar collector plate & drying cabinet has been created and shown. In addition, a traditional active-mode Solar Photovoltaic & Electric dryer was built, complete with a secondary thermal-backup system. Pineapples and mangoes were used to assess how well the HIP & SPE dryers dried fruit in comparison to the more OSD technique. Drying times using SPE, HIP, & OSD ranged from 10 hours to 30 hours for the same amount of food. The enhanced HIP dryer achieved drying efficiency on par with the SPE dryer & 18% greater than the OSD technique. Adding numerous metallic solar concentrators to the solar collector plate & upgrading the greenhouse cabinet results in a significant increase in the HIP dryer's drying efficiency. As a result, the HIP dryer is preferred over the OSD technique.

P.K. Devan et al. (2020) As a result of rising prices of fossil fuels in developing nations like India, the creation of an efficient & cost-effective solar dryer for continuous drying of agricultural food products has become a potentially viable alternative. The most vital agricultural items, such fruits & vegetables, require drying in order to preserve their nutritional value. This method is commonly employed for the long-term storage of food crops. The tremendous nutritional value of fruits & vegetables necessitates their careful preservation. Freshness is the most important factor in preserving nutritional content. There are a number of options for this preservation, but drying food is the most popular because it extends its shelf life. Agricultural items like fish, cocoa, coffee, rubber, cotton, tobacco, maize & tea are dried using solar energy. Solar drying systems for agricultural foods were available in a number of configurations. Therefore, the purpose of this review study is to attempt to synthesise the existing literature on solar dryers for drying agricultural food products. Design considerations for solar tunnel dryers, experiments with drying vegetables, cost estimates, & quality assessments of dried crops were all covered. The moisture level of these products might approach 90% in rare situations. The growth of microorganisms that aid in decomposition is generally blamed on poor water quality. This article compares and contrasts the performance of a natural and a forced convection solar dryer for drying fruits & vegetables. We talked about drying times, moisture reduction, & weight loss.

Ahmed Djebli et al. (2020) Potatoes have a strong demand in the consumer sector and are easily accessible throughout the country of Algeria. Given the widespread availability of solar energy in the country, sun drying presents a promising new path for the commercial production of solar dried potatoes. Indirect solar dryers & mixed solar dryers with forced convection are investigated and compared for their effectiveness in drying potatoes. The drying rate was lower in the mixed sun dryer despite the tray temperature being greater than in the ISD, with times of 4 hours & 45 minutes compared to 3 hours & 40 minutes, respectively. The diffusivity equation was solved using Fourier series & Laplace transformations. The experimental data was used to verify the relative accuracy of seven theoretical models. In both dryers, a novel dimensionless model better approximated the drying curve of potato slices. The proposed models were found to be more accurate than models given in the literature using different solar dryer designs under varying operating conditions when describing the drying process of Sultana grapes, chilli peppers, bananas, mangoes, and cassava.

László Imre et al. (2020) The investment costs can be regulated in part by optimizing the drying process to take use of the sun's unique properties. The primary factors, their roles, & mechanisms by which they influence solar drying have all been identified through research into the economics and technology of the process. Solar dryers can be customized in terms of size, power source, and drying capacity based on the quantity, kind, & classification of the material to be dried. Annual solar output describes the total quantity of usable sunlight in a year & length of time needed to dry something are two economic considerations related to solar dryers. However, there are still unavoidable interruptions even during the drying season, and the collector system cannot be used for harnessing solar energy during the wetter months. As part of a comprehensive energy infrastructure, solar dryers benefit from optimal energy conditions. But there's also more ancillary devices to buy, higher initial prices, and more complexities in system management.

Abhay Bhanudas Lingayat et al. (2020) When agricultural products aren't properly preserved or stored, their quality suffers. With the use of modern processing techniques, postharvest losses have been reduced. Drying is a typical processing technique used to lengthen the storage life of goods that might otherwise spoil quickly. Sun drying has been used to preserve food for a very long time. Solar dryers can be found in a variety of shapes, sizes, & capacities, making them ideal for meeting the drying needs of the agricultural industry. One of the most common dryers employed in the food industry is the indirect type sun dryer (ITSD), however little is known about this dryer's specific characteristics, varieties, or the techniques used to enhance its performance. Examining the merits & advantages of ITSD is the focus of this study. A standard system for categorizing solar dryers is also provided. Improvements in heat transfer during ITSD & impact of pretreatment prior to drying are also thoroughly discussed. We examine the ROI & cost effectiveness of ITSD. We have summarized, discussed, and tabulated key data pertaining to ITSD. Air temperature & velocity are the most important factors in determining the drying rate, followed by solar radiation, product type, beginning moisture content, and overall mass. Unlike active dryers, passive solar dryers were simple to make. Pre-treated foods dried quickly & retained their quality after being dehydrated.

Hadi Samimi-Akhijahani et al. (2018) The purpose of this research was to analyze how a sun tracking system affected the rate at which biological materials dried in the sun. A lab-scale PV-assisted solar drying system with a sun tracking device was designed and constructed to study the drying behaviour of tomato slices. The samples were tested in a number of conditions, including varying air velocities (from 0.2 m/s to 2 m/s) & product thicknesses (from 3 mm to 7 mm). Tomato slice drying behavior was analyzed to determine the impact of a solar monitoring system by measuring drying time, effective moisture diffusivity, and activation energy. The results showed that drying times were reduced by between 16.6% and 36.6% because to the solar tracking device. While the system had no detrimental impact on the quality metrics of dried samples (color, rehydration ratio, or shrinkage), it did raise the actual moisture diffusivity & activation energy by significant amounts in the ranges of 9.1-64.6%. In sum, a sun tracking system has potential as a means of both speeding up the solar drying process and pushing this drying technique closer to practical industrial use.

Mahesh Kumar et al. (2016) Renewable energy sources, in the form of alternative power sources, were developed in response to the rising uncertainty in pricing & rapid depletion of fossil fuels. Researchers from all over the world have been drawn to the topic of solar energy because the sun provides an abundant, renewable, & sustainable energy source. Solar drying can provide a sustainable source of income and meet the rising demand for natural, low-cost foods in poor nations. Solar dryers utilized in agriculture have the potential to be the most effective energy-saving equipment, since they not only reduce carbon emissions but also reduce the amount of space required for drying, the amount of time needed to dry the product, the quality of the product, and the quality of life for the workers. Recent innovations in drying process that integrate other kind of auxiliary heating source with sun energy are also in trends for decreasing fuel consumption, so a solar crop drying system does not solely depend on solar energy for its functioning. This paper provides a comprehensive overview of solar dryers, including direct solar dryers, indirect solar dryers, & hybrid solar dryers, as well as the many uses for each.

CONCLUSION

The use of solar energy for drying and preservation of food products has been used for a long time. Due to technical improvements, a variety of solar dryers have been developed to efficiently utilise solar energy for drying meals. Using sun energy alone, solar dryers are completely sustainable and excellent for drying & storing food indefinitely. Based on their approach to collecting, transforming, and disseminating sunlight, solar technologies can be classified as either passive solar or active solar. Active solar methods use photovoltaic panels, solar thermal collectors, and other similar devices to transform sunlight into usable outputs using electricity or mechanical machinery.

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