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Review on Study & Analysis of Effect of Various Parameters Like; Technical, Economic & Environmental Aspects for Various Type of Solar Driers

Mr.Housalmal Rajabhau Shivaji¹, Dr. Sandeep kale²

Phd. Student, Department of Mechanical Engineering, Trinity College of Engineering and Research, Pune, India¹

Professor, Department of Mechanical Engineering, Trinity College of Engineering and Research, Pune, India²

ABSTRACT: Solar drying is the basic process to reduce the moisture content of the products to certain level below which deterioration of product does not occur. There are mainly three types of solar dryers; direct solar dryer, indirect solar dryer and mixed-mode solar dryer with various sizes, capacities, and designs. The main aim of this study is to review all these types of solarDryer based on characteristics of the product being dried and technical, economic and environmental aspects. Also Simulation software conducts a numerical analysis that predicts air velocity and temperature profiles to dry fruits. It estimates the exact shape and size of the solar dryer and saves money which is experimentally a prolonged exercise. For evaluating the performance of solar dryers, three criteria, i.e., energy analysis, economic analysis, and environmental impacts, are the most important, showing the actual benefits of solar dryers.

I. INTRODUCTION

Drying is a traditional preservation technique used for drying various agricultural products. The drying process reduces the moisture content in agricultural products and provides a longer shelf-life. It prevents harvested products' spoilage by preventing bacteria, yeasts, and mold growth (Bahnasawy and Shenana, 2004). Improper preservation of products and storage methods has led to spoilage and loss of harvested products. It is reported that a huge amount of cereals (10–30%) and fruits (50–70%) are lost due to improper preservation techniques (Yaldýz and Ertekýn, 2001). proper drying of the agricultural products reduces the weight and the volume significantly, leading to lower transportation and packaging cost (Akpınar, 2006). The latent heat is released from the products during the removal of moisture content. The energy required to remove moisture content is supplied from fossil fuels, biomass, and solar energy. However, due to continuous depletion of fossil fuel resources followed by an increase in the price and environmental concerns, the importance of using renewable energy sources is highlighted globally. In recent times, the focus is shifted to solar energy-operated dryers (Borah et al., 2015). Small-scale farmers dry agricultural products (around 60–80%) using the open sun drying method (OSD) (Murthy, 2009). In the OSD method, the products are exposed to direct sunlight. However, drying of food or agricultural products in the OSD method has many limitations like contamination, ineffective controlling of drying air temperature, prolonged exposure to sunlight and poor appearance (colour) and quality of the dried products. Drying in open space without enclosure also results in consuming larger drying area, drying time and increased labour cost. Further, continuous drying of food products is not possible due to adverse weather conditions. These shortcomings of the OSD method led to the development of the solar dryer. Drying hygroscopic materials with solar energy in an enclosed space built with either a transparent or an opaque material is usually termed as solar drying. It is an efficient drying process where a suitable drying environment can be provided and controlled



It is reported that the conductive temperature range for drying agricultural products is between 45 °C and 70 °C, as shown in Table 1. [2]

Sr.no.	Product	Moisture content		Maximum allowable temperature (°C)
		Initial (w.b) %	Final (w. b)%	
1	Apple	80	24	70
2	Apricot	85	18	65
3	Bananas	80	15	70
4	Corn	24	14	50
5	Carrots	70	5	75
6	Cauliflower	80	6	65
7	Chilly	80	14	90
8	Crops	50	5	90
9	Cabbage	80	4	55
10	Chillies	80	5	65
11	Fish, Raw	75	15	30
12	Figs	80	24	70
13	Green Peas	80	5	65
14	Green Beans	70	5	75
15	Grapes	80	15–20	70
16	Guavas	80	7	65
17	Garlic	80	4	55
18	Groundnuts	40	9	50
19	Maize	35	15	60
20	Mango	85	18	70
21	Onions	80	4	55
22	Onion Ring	80	10	55
23	Potatoes	75	13	75

The mechanism of drying process is illustrated in Fig. 1. [2]Based on the drying rate, the drying process is divided into constant and falling drying rates. Initially, during the drying process, the product temperature increases and subsequently, the surface gets cooled due to evaporation of moisture content. This period is called warming-up or initial adjustment period and is represented in dotted lines a'b and ab. After the initial adjustment period, the heating and cooling process gets stabilized. The product's temperature remains constant, as shown in the dotted line between b and mc1, known as the constant drying period. During this period, the moisture content is evaporated from the product surface at a constant rate. Point mc1 represents the first critical moisture content where the constant drying rate ends. Due to evaporation at the product surface, the water molecules migrate from the core to the product's surface. The migration of water molecules to the surface due to capillary force causes the first falling rate period, starting at point (mc1). The drying rate starts to decrease after first critical moisture content (mc1). The dotted line between mc1 and mc2 represents the first falling rate period. After point mc2, the drying rate reduces further and reaches the equilibrium moisture content mce (Belessiotis and Delyannis, 2011; Tiwari, 2016).

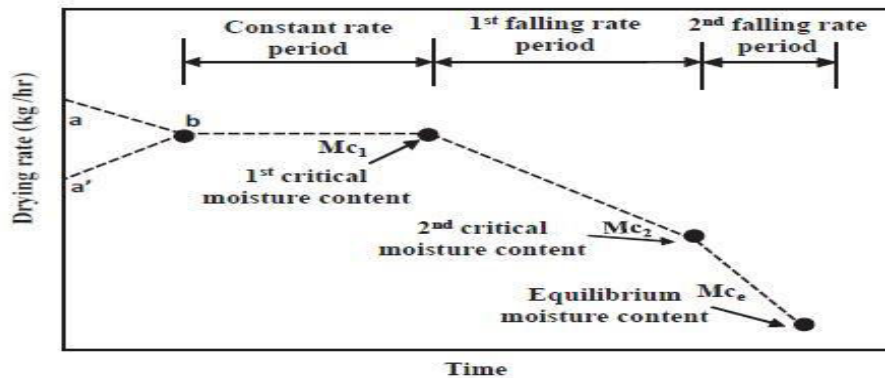


Fig. 1. Mechanism of the drying process (Maloney, 2007; Visavale, 2012).

II. BENEFITS OF SOLAR DRYERS

Solar dryers are in general of relatively low cost because they are made of locally available materials and their mode of construction is relatively simple [3, 4]. They offer several advantages such as drying food without affecting its flavour, texture or colour in which the dried food is tasty and nutritious. Moreover, solar dryers reduce losses of products, promote longer storage duration and prevent spoilage of stored materials [5, 6]. Furthermore, the energy required to dry food is less than that needed to freeze or can, and the storage space is negligible in comparison with that required for freezing containers or canning jars. That said, solar dryers mitigate consumption of conventional sources of energy such as fossil fuels, thus they allow to reduce CO₂ emissions.

III. DRAWBACKS OF SOLAR DRYERS

Despite its several advantages, solar dryers have some limitations that deteriorate its performance and negatively affect its drying rate. Indeed, the use of solar dryers is exclusively limited to daytime where there is sufficient amount of solar radiation. Consequently, they can't be utilized during night. As a matter of fact, their use varies with month since the daytime varies from month to month. That is why an electric backup heater should be harnessed which increases the cost of the solar dryers [11, 12].

IV. BARRIERS OF SOLAR DRYERS

Having said that utilization of solar dryer is very beneficial, some barriers inhibit adaptation of such vital technology. The first barrier is the lack of funding and governmental support to perform advanced research program on solar drying. Besides, the high initial investment and initial cost of some types of solar dryers are major affecting barriers. Another key barrier is the lack of technical expertise which is a vital factor for manufacturing and installing a solar drying system with high efficiency. In addition to that, the lack of awareness of the importance and benefits of solar drying prevents utilizing solar dryer.

V. ECONOMIC AND ENVIRONMENTAL CONCERNS

Solar dryer serves in mitigating usage of conventional sources of energy, mainly fossil fuels. [13]. As a matter of fact it reduces production of CO₂ gas which is the main factor causing global warming. As a result, solar dryer could be a contributor in protecting the environment. It was reported in [7] that the electricity demand of Lebanon in year 2009 was 2300 MW, where the "Électricité Du Liban" (EDL) is permanently struggling to cover the needed load however the production is lower than the local demand. Moreover, energy demand is rising; nevertheless there is a continuous shortage in local resources of energy and limitations in power generation capabilities. In addition to that, Lebanon is suffering from economic shortage which limits its ability to cover the need in terms of fuel. In other words, to find new renewable techniques that permit to decrease the use of conventional sources of energy.

Another key element that should be mentioned is the nutritive value of dried food. Indeed, it contains large quantity of vitamins, fibre, minerals and carbohydrates, and low in fat which make them healthy. Also, this improves the economic flexibility of farmers, since they sometimes sell at low prices during harvest periods because they can't preserve excess products [8]. Moreover solar dryer can open new markets and income in which it offers employment opportunities.



VI. ECONOMIC ANALYSIS

To analysis the economic impact of using solar dryer, a study is require to perform a typical dryer of 15 kW input power, 120 kg/batch capacity and 50-140°C working temperature. The study is conducted to compute the amount of electrical energy consumed when drying several types of fruits and vegetables. Then, the cost of electric energy is calculated to estimate the money saved when replacing this conventional dryer by new developed solar dryer. Besides, the *PP* of solar dryer is calculated depending on the amount of *SM* and the cost of a solar dryer which has similar specifications as the conventional dryer.

AMOUNT OF SAVED MONEY

The energy consumed by the electric dryer can be calculated using the formulas of equations (1) and (2).

$$E_{day} = P_{input} \cdot t \text{----- (1)}$$

Where “*E day*” is the energy consumed per day (kWh/day), “*P input*” is the input power (kW) and “*t*” is the time where the dryer is used per day (h/day), it can be calculating according to equation (2).

$$t = \frac{M}{C} \cdot d \text{----- (2)}$$

Where “*M*” is the mass of food to be dried per day (kg/day). In this study, several cases were taken into account where in each case the amount of load (mass) is varies and four different values are considered: 120 kg, 360 kg, 600 kg and 960 kg. “*C*” is the capacity of the dryer (kg /batch) and “*d*” is the drying time (hr./batch). It defers according to the type of food. Table 2 illustrates the drying time for the studied type of fruits and vegetables.

Food	Carrot	Corn	Mushrooms	Potatoes	Apples	Bananas	Cherries	Peaches
Drying time (hr)	5	7	9	10	11	8	21	16

VII. ENVIRONMENTAL ANALYSIS

From an environmental point of view, solar dryer serves to a great extent in reducing the amount of CO2 emissions. Fudholi et al [9] reviewed various economic and environmental analyses that have been developed on solar dryers. Kumar and Kandpal [10] estimated the mitigated CO2 emission relying on the amount of fuels that would be saved when solar dryer is harnessed. To size the environmental influence of solar dryer, a study is conducted on the aforementioned electrical dryer to compute the amount of CO2 produced per month. Thus, by replacing this dryer by a solar dryer CO2 emission will be mitigated. The amount of CO2 produced (*M produced CO2*) and amount of reduction in CO2 emission (*M reduced CO2*) produced can be calculated from equations (6) and (7) respectively.

$$M_{Produced CO2} = E_{month} \cdot M_{co2/1kgwhr} \text{----- (6)}$$

Where “*MCO 2/ 1 Kwhr*” is the amount of CO2 produced from 1 kWh electricity. In Lebanon it is estimate approximately 0.71 kg CO2/1 kWh.

$$M_{reduced CO} = Pr \cdot M_{produced CO2} \text{----- (7)}$$

VIII. CONCLUSIONS

A review on solar dryers will be present in this work. Principle, components and various classifications of solar dryer has been reported. In addition to that, impact of several parameters on performance of solar dryer and its benefits and limitations will be described. Nevertheless, technical, economics and environmental aspects analysis will be conduct to quantify the effects of utilizing solar dryer

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