PERFORMANCE ANALYSIS OF FORCED CONVECTION SOLAR DRYER FOR TURMERIC

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Abstract - *Food is a basic need for all human beings along with air and water. Food problem arises in most developing countries mainly due to the inability to preserve food surpluses rather than due to low production. Agricultural yields are usually more than the immediate consumption needs, resulting in wastage of food surpluses during the short harvest periods and scarcity during post-harvest period. Hence, a reduction in the post-harvest losses of food products should have considerable effect on the economy of these countries. India produces a wide variety of turmeric, each unique in itself for its innate properties and values .It is observed that turmeric dried in solar dryers take lesser time to reach the safe level of moisture content for storage when compared to open sun drying and the quality of turmeric produced are far more superior.*

Key Words: Solar dryer, turmeric, performance

1. INTRODUCTION

Drying is an essential process for preservation of agricultural products. Traditionally all agricultural crops were dried in open sun drying. Drying is one of the important post handling process for agricultural crops. It can extend shelf life of the product and improve quality also. Drying of food products reduces the post harvest losses and reduces the goods transportation cost as most of the water is removed from the product during the drying process [1]. Food problems arise in most of the countries due to inability to preserve food surpluses rather than due to low production.

Sun shines in India over an average of 3000-3200 hr/year, delivering about 2000 kWh/m^2-year of solar radiation on horizontal surfaces [2]. Open sun drying requires large floor area and also dependent on availability of solar energy, more than 75% of food is being produced by small farmers. These farmers dry food products by natural sun drying as solar energy is available abundantly at free of cost. Natural sun drying under hostile climate condition can cause adverse effect to quality of food product to be dried. Conventional fuel operated dryers are more energy consuming and they are costly for rural farmers, therefore need is to be use renewable energy sources as much as possible. Solar dryers are now being extensively used since they are better and energy efficient one.

1.1 Solar Drying

Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. The prime objective of drying apart from extended storage life can also be quality enhancement, ease of handling, further processing and sanitation and is probably the oldest method of food preservation practiced by humankind. Drying involves the application of heat to vaporize moisture and some means of removing water vapor after its separation from the food products. It is thus a combined and simultaneous heat and mass transfer operation for which energy must be supplied. The removal of moisture prevents the growth and reproduction of microorganisms like bacteria, yeasts and molds causing decay and minimizes many of the moisture-mediated deteriorative reactions. It brings about substantial reduction in weight and volume, minimizing packing, storage, and transportation costs and enables storability of the product under ambient temperatures.

2. DESIGN AND DEVELOPMENT OF SOLAR DRYER

Fig.1 Overview of solar dryer

A forced convection solar dryer consists of a solar flat plate air heater, centrifugal blower, reducer flexible connector and a supporting stand. The solar air heater consists of an absorber (painted black) glass cover. The air duct beneath the absorber was made from an aluminium sheet (0.91 mm thick and 1m × 0.7m × 0.12m in size) through which air was passed. The toughened glass plate (4 mm thick, 1m ×0.6 m in size) was fixed on the frame of the absorber surface. The glass was fitted to the frame along with the help of galvanized iron angles and screws. For connecting the collector outlet to the inlet of dryer chamber, a connector made from special fibre reinforced plastic pipe (stable up to 200°C) was provided. The inlet and outlet ends of the connector were made by using two rectangular cross-sectional ducts. Centrifugal blower was used to force the air through solar air heater, at the outlet section of blower orifice meter is fitted with manometer arrangement to measure the air flow rate through the blower outlet and flat plate solar air heater inlet.

The reducer was used to connect the outlet of the blower to inlet of solar air heater with reinforced plastic pipe and collector outlet to inlet of drying chamber by reinforced plastic pipe. The cross section of the reducer was increased gradually from inlet to outlet, which helps in maintaining the uniform distribution of air in the drying chamber. In the dryer cabinet, arrangement was made to keep three number of trays on which boiled turmeric rhizomes were placed.

2.1 Design of drying chamber

The amount of moisture removed from the turmeric, Mw (kg) was calculated by using the following equation. The quantity of moisture present in a material can be represented on wet basis and expressed as percentage. About 10 gm samples were taken and kept in a convective electrical oven, which was maintained at 105 ± 1°C until constant weight has reached. The initial and final mass, *Mi*, and final mass, *Mf*, of the samples were recorded with the help of electronic balance. The moisture content, *Mwb*, on wet basis was calculated by using Eq. (1). The procedure was repeated for every one hour interval till the end of drying.

$$Mw = Mp \times \frac{(Mi-Mf)}{(100-Mf)}$$

$$M_W = 15 \times \frac{(85.33-10.76)}{(100-10.76)}$$

$$M_W = 12.53\ kg$$

2.47 kg of moisture is to be removed from 15 kg of turmeric

Where,

M_p = Mass of product to be dried=15 kg

M_i = Initial moisture content in turmeric =85.33%

M_f = Final moisture content=10.76%

Q= $Mw \times \mathrm{h_{fg}}$

Now, $\mathrm{h_{fg}} = 4186(597 - 0.56 \times T_{pr})$

T_{pr}= Product temperature = 26^{0}C

h_{fg}=$2438.09KJ/kg$

=$2.43MJ/kg$

h_{fg}= Latent heat of evaporation

Q= $M_w \times h_f$

= 12.53×2.43

= $30.44MJ$

2.1 Total collector area required

Assuming the efficiency of collector (η) = 24%

(Generally efficiency of flat plate collector is 24-28%. But by Using Reflector Surfaces the Flat Plate Collector Efficiency can be enhanced up to 30%)

Intensity of radiation (I) = 800 W/m^2

According to Solar Radiation Hand Book data by Solar Energy Centre, MNRE Indian Metrological Department it gives the 25.12MJm^2 per day.

Assuming area of flat plate collector to be 0.7m^2

Energy retracted from FPC= η×25.12×Area = 5.72 MJ per Day

Total Energy supplied from FPC =7.455×7 = 36.92 MJ

The Flat Plate collector area required for supplying the essential heat energy is 0.7m^2

2. PERFORMANCE OF SOLAR DRYER

This chapter gives test methodology to analyze the performance of developed forced convection solar dryer for turmeric. Parameters needed to analyze the performance are recorded as per test methodology. Test methodology have been planned and executed in order to find the drying time with forced convection in solar dryer. The effect of mass flow rate of air on moisture content, moisture loss, drying rate, drying time and dryer efficiency has to be evaluated and accordingly test have been executed.

- Boiling of turmeric affect drying time hence it is decided to carry out the experiment with boiling of turmeric rhizomes into water for 30 minutes.
- Experimentation has been carried out for drying the turmeric from initial moisture content 85.33% to final moisture content 10.76% for a fixed mass flow rate.
- Mass flow rate of air is kept 0.01569 kg/sec through the dryer cabinet.
- With selected mass flow rate of air, time to time reduction in weight of turmeric sample, flat plate collector air inlet and collector air outlet temperature, dryer cabinet exit temperature, intensity of solar radiation are noted till final moisture content reduced to 10.76%.

3. RESULTS AND DISCUSSION

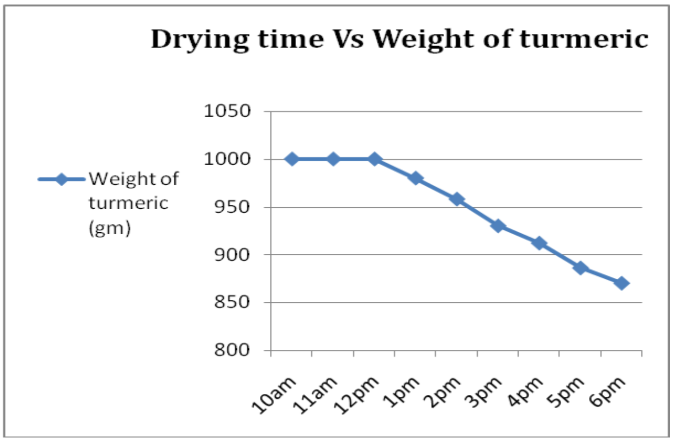
The results obtained from the experimentations carried out on the solar dryer by the mentioned methodology are presented in the following section. Total six numbers of days are required for drying of the turmeric considering eight sunshine hours (from 10 am to 6 pm). Various graphs are plotted for the study of variation of intensity of solar radiation with respect to drying time, variation of moisture loss with respect to drying time.

3.1 Variation of weight of turmeric with time

The variation of solar intensity, weight of turmeric was measured against the drying time during the days of experimentation with a constant mass flow rate.

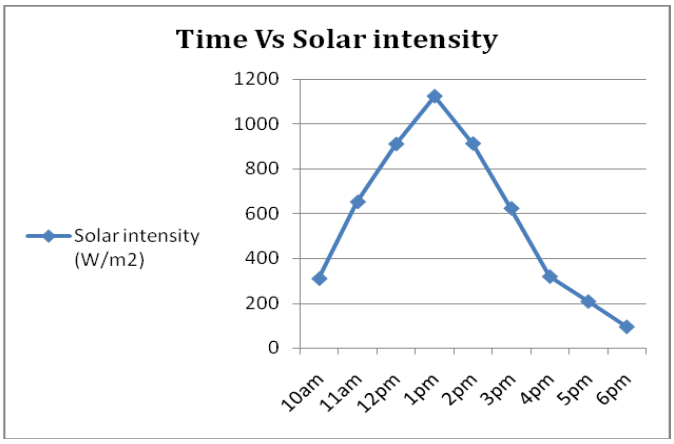
Table 1-Variation of weight of turmeric with drying time at a constant mass flow rate 0.026 kg/sec:

Time (hr)	Drying time in hr	Solar intensity (W/m²)	Weight of turmeric
10am	0	312	1000
11am	1	654	1000
12pm	2	912	1000
1pm	3	1125	980
2pm	4	914	958
3pm	5	625	930
4pm	6	321	912
5pm	7	210	886
6pm	8	97	870



Graph 1: Variation of weight of turmeric vs. drying time for a mass flow rate of 0.026 kg/sec

The experiments were conducted for six numbers of days, weight of turmeric is measured hourly by using electronic weighing machine and is plotted against time also solar intensity was measured by using solar meter and plotted against time. Experiment was conducted using the mass flow rate of 0.026 kg/sec.



Graph 2: Variation of Solar intensity vs. drying time for a mass flow rate of 0.026 kg/sec

4. INSTRUMENTATION

In the fabricated forced convection solar dryer, the RTD sensors (range -10^{0}C to +200°C and accuracy ± 0.2°C) were fixed at the inlet and outlet of the solar air collector and at each tray in the drying cabinet to measure the dry bulb temperature at these locations. The ambient, temperatures were also measured near the solar dryer under the shade. A solar meter (resolution 0.1 W/m^2, accuracy ±10 W/m^2) used for measuring the global solar irradiance. Wind speed was measured with a hot wire anemometer (accuracy ± 0.01 m/s) and air flow rate was determined by measuring the air velocity by orifice meter at the blower outlet. For measuring the weight loss of the sample, an electronic weighing machine (capacity 10/20kg, resolution 1 gm) was used. In the drying experiments, boiled turmeric was used as the test samples in the dryer. Drying experiments were performed during the period March–May 2017. After the pretreatment, turmeric rhizomes were spread out uniformly on the trays inside the dryer. In order to compare the performance of the solar dryer the samples were also dried by traditional methods, i.e. open sun drying and shade drying. The reduction in moisture content was determined by weighing the sample at every hour.

4. CONCLUSION

In this project work, the forced convection solar dryer for turmeric is designed, developed and successfully tested experimentally. The boiled turmeric rhizomes have been dried with the forced convection solar dryer. The effect of drying time, air mass flow rate, solar intensity, drying time has been evaluated.

Following conclusions have been arrived from the experimental investigation carried out in the present work of solar turmeric dryer.

- The drying experiment conducted with boiled rhizomes and it is found that the complete drying cycle could be attained within 48 sunshine hours for forced convection which is very less compared with open sun drying.
- Dried turmeric production is possible with developed solar dryer in much shorter time with better quality.
- All this work put forward an extension of renewable energy based drying technology in the field of turmeric drying so that it can be economical for small scale farmers.

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