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Research Article

Convective Drying of Chilies Using a Concentrating Solar Collector

M. Hanif[1*], M. K. Khattak[1], M. Rahman[1], M. Aamir[1], M. Ramzan, M. Amin, M. Khan[2], and S. Shiekh[1]

[1]Department of Agricultural Mechanization, Faculty of Crop Production Sciences, University of Agriculture, Peshawar, Pakistan
[2]Nuclear Institute for Food and Agriculture (NIFA), Peshawar, Pakistan

Abstract: A concentrating solar collector was developed for convective drying of green chilies by providing optimum drying environment. A temperature in the range of 45-65^{o}C and relative humidity of less than 10% was observed during the drying period provided by the solar collector from 9.00 am to 5.00 pm. Different levels of drying temperature and air mass flow rates were tested to find their effect on drying time of the chilies. The experiment was laid out as a randomized complete block design with a factorial arrangement of the treatments consisting of 3 levels of temperature and 3 levels of air mass flow rate, replicated 3 times. Drying temperature and air mass flow rates effected the drying time significantly. The means comparison showed that minimum drying time of 17.96 h was recorded at high temperature of 65^{o}C followed by a drying time of 20.27 and 21.43 h at temperatures of 55 and 45^{o}C. The means of air mass flow rates showed that minimum drying time of 18.49 h was noted at high air mass flow rate of 3.50 kg min^{-1} followed by 20.32 and 20.86 h at air mass flow rates of 1.5 and 2.30 kg min^{-1}. Chilies dried at temperature of 65^{o}C and air mass flow rate of 3.5 kg min^{-1} showed an average drying rate of 0.02 $g_{(H_2O)}$ hr^{-1} cm^{-2} as compared to the slow drying rates at 55 and 45^{o}C. It was concluded that chilies must be dried at high temperature and high air mass flow rates to get on time quality dried chilies.

Keywords: Concentrating solar collector, green chilies, drying rate

1. INTRODUCTION

Solar drying of condiments is most famous and ancient technique for preserving food. This technique is very economical as we save energy and preserve food as well. Most of the condiments were dried with the help of the sun drying method. If chilies were dried in open sun, then there would be chances of microbial infestation and the products would be spoiled quickly. For this purpose development of solar drier which provides controlled drying conditions in a scientific way is the best option [1-2].

Chili (*Capsicum sp.)* is the main ingredients for making condiments as it adds flavor and spiciness in our food. Chilies in the form of dried powder can compliment any dish with better taste. They can enhance our gastronomic experience with a mild heat. The chili powder gives your recipe a distinctive flavor and a unique culinary flair [3]. During drying, chilies must be dried at a temperature of 50 to 60^{o}C and air mass flow rates of more than 3.0 kg min^{-1}. It is due to a reason that drying rate is directly proportional to the air temperature and air mass flow rates. Thus the increase in both temperature and the air mass flow rate will accelerate the drying mechanism. Drying time is minimized when a drying rate is accelerated. So drying must be accomplished at high temperatures and air mass flow rates. The upper limit for drying chilies is 60 °C and air mass flow rate of 3.5 kg min^{-1} [4].

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*Corresponding author: M. Hanif; Email: hanif_mechanization@aup.edu.pk

The present research study was on solar drying of green chilies using a concentrating solar collector to get good quality dried chilies. After drying, the chiles were ground to make powder. Different parameters studied were drying conditions of drying chamber, moisture lost in each hour by chilies on wet and dry basis. The objective of the study was to find the effect of different levels of drying temperatures and air mass flow rates on the drying time and drying rate of chilies.

2. MATERIALS AND METHODS

2.1. Site Selection

The collector was tilted on the rooftop of the Department of Agricultural Mechanization, The university of Agriculture Peshawar, Pakistan located between the longitudes 71.0.15^o and 72.0.45^o East and Latitudes 33. 0. 45^o and 34. 0. 01^o.

2.2 Description of the Concentrating Solar Collector Assembly

The concentrating solar collector assembly consists of two parts (Fig. 1).

2.2.1 The Concentrating Solar Collector

The dish solar collector was composed of a concentrating reflector. The reflector was basically a mirror which concentrates the solar radiation on the Absorber. The absorber consists of two black painted steel pipes having a diameter of 0.05 m. Both the pipes are covered by a glass to minimize heat loss. The pipes receive air from outside environment which was heated here and then this hot air was delivered to the drying chamber.

2.2.2 Drying Chamber

The drying chamber was made of steel, fully insulated from inside with the help of polystyrene foam. The chamber was 1.0 m high and 0.55 m wide and 0.57 m long. The chamber was divided internally into two compartments in which upper compartment was provided for drying while the lower compartment was filled with rocks for solar energy storage. This stored energy in the rocks was used when there was no sunlight available or after sunset. There are three exhaust fans each having a diameter of 0.054 meters is fixed to each outlet which sucked hot air from the absorber inside the drying chamber. The flow rate of each fan was 3.56 kg.min^{-1}. These fans run on a solar panel during day time. The total volume of the drying chamber was 0.3135 m^3. The total air flow of three fans is 10.5 kg.min^{-1}. There was an outlet fixed at the top of the

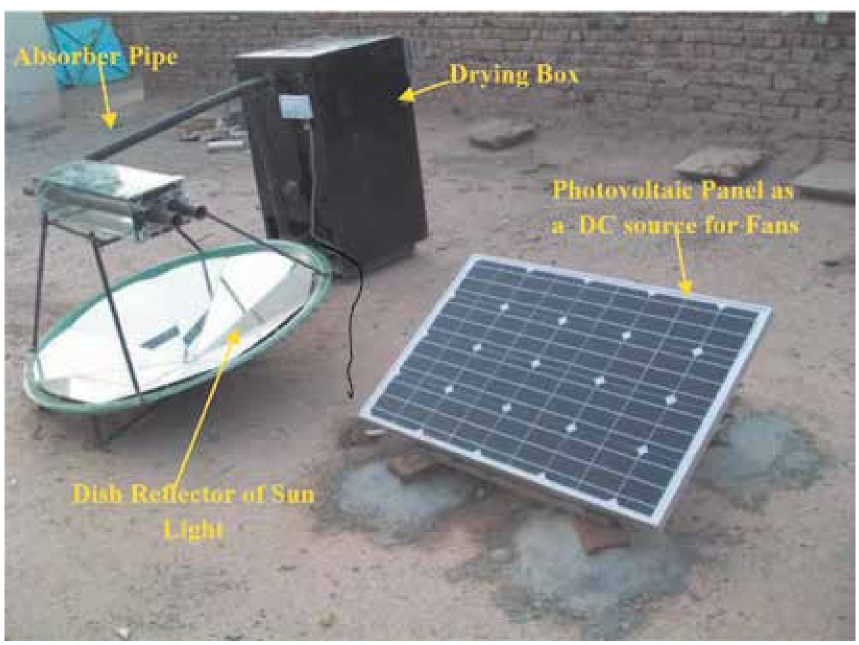

Fig. 1 The concentrating solar collector assembly showing different parts of the collector.

drying chamber having a diameter of 0.02 m for emission of humid air.

2.3 Relative Humidity and Temperature of air pumping through the collector

Relative humidity and temperature data were recorded with the help of digital thermo-hygrometer after each hour during drying of chilies.

Moisture content of green chilies was determined after each hour of drying. The products were dried down to 5% moisture content to minimize mold, insects and bacterial attacks. The initial moisture content was determined by the oven method while the moisture loss after each hour in drying on wet basis was determined by using equation 1 [5].

$$M.C. = \frac{Wi - Wf}{Wi} \; x \; 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where M.C. is moisture content (%), W_i is the intial weight of each sample before drying (g) and W_f is the finalweight of sample after each hour of drying (g).

2.4 Determining Drying Rate

Similarly moisture loss on dry basis was calculated using equation 2 [6].

$$Dr = \frac{M.L}{t \; XA} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where Dr is the drying rate of samples ($g_{(H2O).}$ $hr^{-1}.cm^{-2}$), M.L is the moisture lost per hour of drying (g), t is drying time (hr) and A is area of the product (cm^{-2}).

Chilies were considered dried when their moisture content reached to less than 10%. Drying time was noted as soon as the chilies were placed on the trays in the dryer till the required level of moisture was achieved.

2.5 Experimental Procedure

Only good quality and disease free chilies were used in this experiment. About 4.0 kg of fresh chilies were dried, without any chemical pre-treatment, until the required final moisture content was attained. The fresh chiles were loaded over the trays of the dryer. The initial moisture content was calculated by the oven method by taking three different samples. Then the fan switched on and the air flow rate through the collector was adjusted to 1.5 kg min^{-1}. The velocity of air at the inlet of the tray was measured with the help of Digital anemometer. Solar intensity was measured using pyranometer. Temperatures at the inlet and outlet of the solar collector and drying chamber were measured at one hour intervals. During idle conditions, the chiles were covered with polyethylene sheet to avoid re-absorption of moisture. All the experimental observations were made after the drier attained the required drying condition. The experiments were repeated thrice and an average value was considered. The drying characteristics of chilies such as moisture content, drying rate, and drier thermal efficiency were determined [4, 8].

2.6 Experimental Design and Treatment Applications

The experiment was laid out as a randomized complete block design. Both the Temperature and air mass flow rates were consisting of 3 levels. The data were replicated three times, resulting in a total of 27 treatments. Factors and their treatment levels are given as below

Temperature

T1 = 45°C

T2 = 55°C

T3 = 65°C

Air mass Flow Rates

F1 = 1.50 kg min^{-1}

F2 = 2.30 kg min^{-1}

F3=3.50 kg min^{-1}

3. RESULTS AND DISCUSSIONS

3.1 Drying Conditions for Chilies

Chilies were dried at a temperature of 50°C and humidity of less than 10%. Chilies took almost 26 hours of drying in the drying chamber to reduce moisture from 76% at initial to 5% when fully dried, as Brewer et al [8] reported that moisture content less than 10% in any product increases its shelf life and also attack of mycoflora, bacteria and other pathogens are minimized.

3.2 Drying Time Taken by Chilies

The initial moisture content of chilies was 76% and was dried until the final moisture content reached to less than 10%. It is due the fact that pathogen attack was minimized when chilies have a moisture content less than 10%. Drying temperature, air mass flow rate and their interaction have significant ($P \leq 0.01$) effect on the drying time of chilies. Minimum drying time of 17.96 h was recorded at high temperature of 65°C followed by a drying time of 20.27 h and 21.43 hr at temperatures of 55°C and 45°C. The means of air mass flow rates revealed minimum drying time of 18.49 h, which was noted at high air mass flow rate of 3.50 kg min^{-1} followed by 20.32 and 20.86 h at air mass flow rates of 1.5 and 2.30 kg min^{-1}. These results are in accordance with the findings of Mohanraj & Chandrasekar [7], Brewer *et al* [8] and Morison [9] and Santos et al [3] and Mahmood et al [4] also found significant effects of mass flow rates and temperature on drying time of chilies.

3.3 Moisture Loss in Each Hour

Chilies were dried at an average temperature of 50°C and a humidity of 5%. Chilies took almost 26 hours of drying period (Fig. 2) in the drying chamber to be dried. The initial moisture content of chilies was 75%, which was reduced up to 5% in the 26 hours of drying period, these results are in argument with the findings of Brewer et al [8]. Chilies showed a very slow drying rate (Fig. 3) of 0.003 $g_{(H_2O)}$ $hr^{-1}.cm^{-2}$ at first four hours of drying, which was constant rate drying, which was then decreased to 0.0015 $g_{(H_2O)}$ $hr^{-1}.cm^{-2}$ after 13 hours of drying because 50% reduction in the moisture content of the chilies. The drying rate becomes at falling rate and slower at the end of drying chilies which were about 0.0010 $g_{(H_2O)}$ $hr^{-1}.cm^{-2}$ because

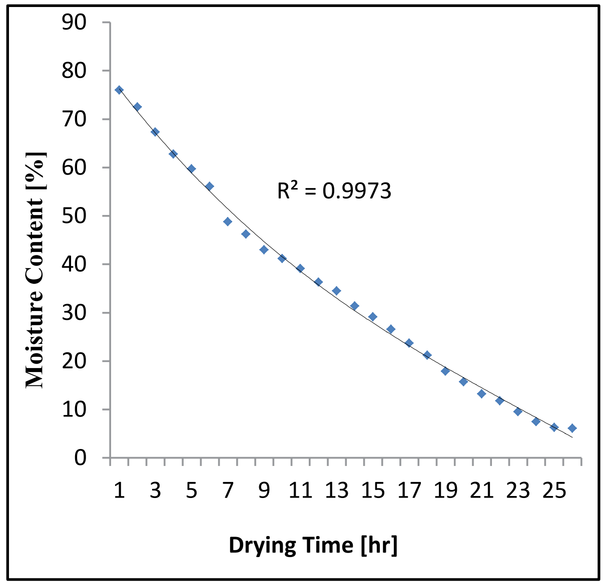

Fig. 2 Moisture loss on wet basis by chilies.

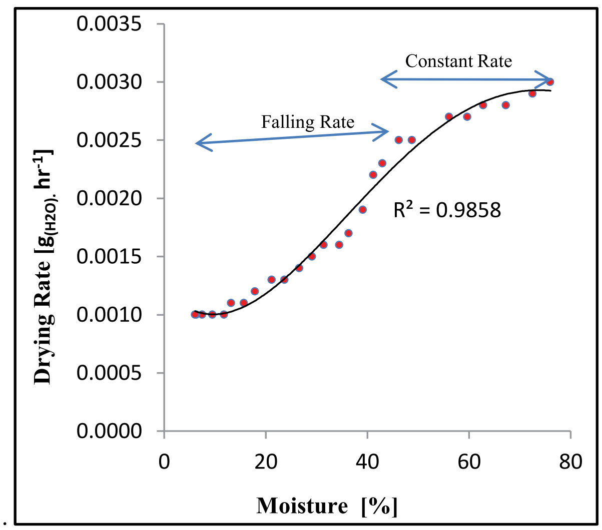

Fig. 3 Moisture loss on dry basis by chilies.

chilies were having less moisture of 15%, which was difficult to be dehydrated from chilies by the hot convective air. These results are in accordance with the findings of Santos *et al* [3], Morison [9], Ahmad [10], Henderson and Perry [11] and Masit et al [12].

4. CONCLUSIONS

It was concluded that concentrating solar drier provided optimum drying conditions for drying of green chilies. Chilies must be dried at high temperature and high air mass flow rates to get minimum time for drying. Solar drying of green chilies using a concentrating solar collector is time saving, economical and the product dried were safe from pathogen attack. It is recommended that to get good quality and valuable dried green chilies they must be dried at a temperature of 60°C and high air mass flow rate of 3.5 kg min^{-1} to get spicy and valuable dried green chilies to be ground easily to powder for taste in food.

5. ACKNOWLEDGMENTS

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