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Research Article

EXPERIMENTAL INVESTIGATION ON DRYING OF VEGETABLES IN SOLAR TUNNEL DRYER

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ABSTRACT
An experimental study was conducted to investigate the drying properties of some selected vegetables such as beet root, yam, radish, green chilli and mint in a natural convection of small scale solar tunnel dryer. The roof of the solar drier was made of a transparent low density polyethylene sheet covered flat-plate collector. The samples to be dried are initially blanched at a temperature of 90^{o}C for 5 minutes to inactivate the enzymes and it dipped in the brine solution. After that the vegetables are spread evenly over the raised platform in the solar drier. This system can be used for drying various agricultural products with low cost. At the end of process, the level of the moisture content in all of the selected vegetables was reduced below 30% on dry basis. During the process of drying the samples, hygienic practices are followed so that the yield of the end produce was better quality. In this study, temperature, relative humidity, solar radiation and lose of moisture are measured for appropriate time period intervals.

Keywords: *Solar Tunnel Dryer; Vegetables; Temperature; Relative Humidity; Brine Solution; Moisture*

INTRODUCTION
Drying process is the most common form of food preservation and extends the shelf life of the food products. In vegetables, about 80 – 90% is the moisture content so that the shelf life of the vegetables is of about very short period of time. In order to preserve the vegetables, drying is a better option without the application of any chemical treatments. For that purpose, solar dryer was used to remove the moisture content of the samples. Dehydration is a common technique for preservation of agricultural and other products, including fruits and vegetables (Narinesingh and Mohammed, 1988). In developing countries, the traditional method of dehydration is by open air, which often results in food contamination and nutritional deterioration. Some of the problems associated with open-air drying can be solved through the use of solar drying (Sundari *et al.*, 2013). To produce a high quality product economically, it must be dried fast but without using excessive heat, which could cause product degradation. The quality of the dried products is the most important parameter in drying technology. Patil (1989) compared the quality of peppers after sun drying, polythene solar drying and solar cabinet drying. He found that the solar cabinet drying offers some advantages over direct sun drying in terms of better quality and faster rate of drying. Drying time can be shortened by two main procedures; one is to raise the product temperature so that the moisture can be readily vaporized, while at the same time the humid air is constantly being removed. The solar dryer works on the principle of absolute humidity and temperature dependent. Natural convection solar dryer is of low cost, can be locally constructed and does not require any power and energy from electrical grid or fossil fuels. High-quality product is obtained economically in a shortened drying time period, but the capacity of the air for taking up this moisture is dependent on its temperature, higher the temperature higher the absolute humidity and larger the uptake of moisture. If air is warmed, the amount of moisture in it remains same, but the relative humidity falls; enable air to take up more moisture from its surroundings. Thus, they can be useful in areas where fuel or electricity is expensive, land for sun drying is in short supply or expensive, sunshine is plentiful but the air humidity is high. Moreover, they may be useful as means of heating air for artificial dryers to reduce fuel costs. Solar food drying can be used in

most areas but how quickly the food dries is affected by many variables amount of sunlight, relative humidity, etc. Typically drying times in solar dryers range from 1 to 3 days depending on sun air movement, humidity and type of food to be dried.

MATERIALS AND METHODS

Experimental Methods

For this experimental study, solar tunnel dryer with 0.72m^2 base area was used for drying of samples. The samples are well washed with chlorinated water for twice and the twigs are removed. The samples to be dried are initially blanched at a temperature of 90^{o}C for 5 minutes to inactivate the enzymes and it dipped in the brine solution. The samples are then set for drying inside the solar tunnel dryer. Then the samples are weighed with a weigh balance. The temperature and the relative humidity inside and outside the solar dryer are monitored and noted for every one hour interval. The dryer was oriented in the south under the collector angle of 20^{0}c for receiving maximum solar energy. UV radiation of (200µ thickness) is stabilized by polyethylene film materials was used as transparent material for the air collector to prevent the heat loss. Tunnel shaped semi cylindrical prototype model solar drier in the size of 1.2m x 0.6m was fabricated for drying of fruits and vegetables. No post is used inside the green house allowing a better use of inside space. A slope of angle 10^0-15^0 is provided along the length of the tunnel. Chimneys on the top of the tunnel are provided to remove the moist air. Inside the drier the vessel was coated with black paint which keeps the samples to get exposed for higher drier performance. The drier is provided with black sheet bottom cover.

Beet Root

One of the Indian favourite vegetables is beet root and it has various medicinal properties. The samples were cleaned and washed before placing in the solar dryer. The product was dipped in the brine solution and it can place in the solar tunnel dryer to reach a final moisture content of 29.6%.

Yam

Before drying process, the yam are peeled and sliced into desired shapes. The brine solution is used as coating of product to preserve colour and texture. The final moisture content obtained by the end of five hours of drying is 23%.

Radish

Radish is the most popular vegetables consumed in tropical and subtropical countries. Before loading into solar dryer, radish was washed and head is removed. The product was dipped in the brine solution and it can place in the solar tunnel dryer. Temperature maintained in the solar dryer 50 - 55^{0}C in order to reach a moisture content of about 30.2%.

Green Chilli

Before placing the green chilli in the dryer it may be washed and dipped in the brine solution. It can be placed in the temperature of 50^{0}c. The moisture is reduced to about 27.2% by the end of drying period.

Mint

Mint is one of the herbal plants which contain various medicinal values. The leaves were washed and blanched in hot water prior to drying. Temperature maintained in the solar dryer 50 - 55^{0}C in order to reach a moisture content of about 34.8%.

RESULTS AND DISCUSSION

The studies of drying process of above vegetables were carried out in the solar tunnel drying method. The dryer was designed as prototype model fabricated with 1.2m length and 0.6m wide. This system has superior drying efficiency in terms of increased rate of drying and also the quality of product which helps improved shelf life. In solar drying the average removal of moisture for vegetables was found to be 20% at the end of the third hour, 55% for the sixth hour, and 36% for the end of ninth hour. Hence the increased the rate of drying during the subsequent period. The free availability of solar energy is utilised food processing industries will probably increase and become more economically in future. Solar dryer have certain advantages over sun drying. It gives faster drying rates by heating the air to 10 to 20^{0}c above ambient temperature, which causes air to move faster through the dryer and reduces humidity. The faster drying reduces the risk of spoilage and improves the quality of the product at higher output. In this study the maximum solar intensity temperature inside the solar tunnel is 65^0c at peak time of solar radiation. The range of RH% of air inside the solar tunnel drier was to be 12 % with air velocity varies during the drying period under the natural convection. Demir and Sacilik (2010) recorded that the use of solar tunnel drier let of considerable reduction in drying time in comparison to open sun drying apart from the protection from insects and dust.

The present report coincide well with the above findings in recording the faster drying rate in solar tunnel drier and recommends for better quality of vegetables as reported earlier. The solar drying was found to be superior in maintaining the shelf life of the agricultural product. These types of solar drying suggest and supports the results of the findings the nutritional qualities of perishable vegetables could well be maintained and retained. The moisture removal rate from fruits and vegetables was high during initial stage of drying. Reduction in moisture content of the particular product is higher which is placed in the centre of the chamber.

Table: 1 (Temperature and Relative Humidity at Different Time Period)

Time (Hrs.)	Temperature (^{0}c) Outside	Inside	Relative Humidity (RH %) Outside	Inside
1.	44	55.5	39.8	40.5
2.	45.2	54.8	40.5	37
3.	43	55.5	38.8	44
4.	46	56.8	41.5	43.5
5.	45	54.1	43.4	43.9

Table: 2 Weights in Grams of Agro Products under Drying Process

S.No	Products	Initial Temperature Inside the dryer (^{0}C)	Weight (gms) 0th Hr.	1st Hr.	2nd Hr.	3rd Hr.	4th Hr.
1.	Beet root	55	100	91.9	85.7	77.5	70.4
2.	Yam	54	100	92.6	90.5	82.3	77.0
3.	Radish	54	100	91.1	86.9	75.4	69.8
4.	Green Chilli	55	100	70.3	69.4	65.4	72.8
5.	Mint	53	100	71.1	75.7	65.7	65.2

Table 3: Moisture Content Recorded

S.No	Products	Moisture %
1.	Beet root	29.6
2.	Yam	23
3.	Radish	30.2
4.	Green Chilli	27.2
5.	Mint	34.8

Digital thermometers and RH meters were fixed inside and outside the drier to measure air temperature and humidity. Ambient humidity and temperature was calculated. On the basis of measurement, potential sunshine duration at this location was measured as 5hrs (10.00a.m to 3.00pm) with a matured and good quality of vegetables (beat root, green chilli, radish, yam, and mint) were cut into similar small pieces. The moisture reduced product is weighed and packed. The increased rate of drying during subsequent hours is showed through graph by X – axis is temperature in degree Celsius and Y – axis is time in hours.

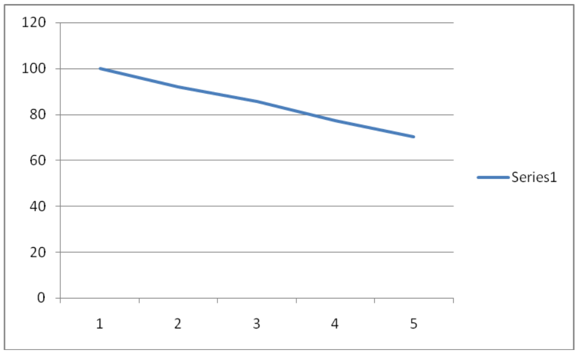

Figure 1: Drying Rate of Beet root

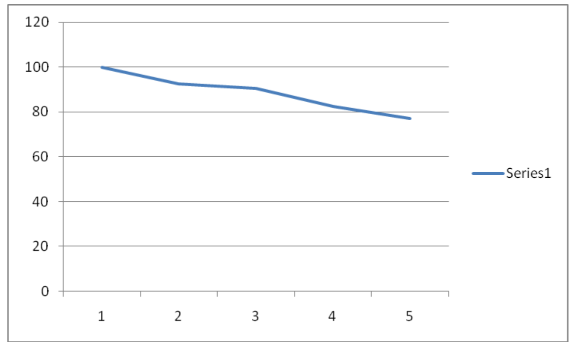

Figure 2: Drying Rate of Yam

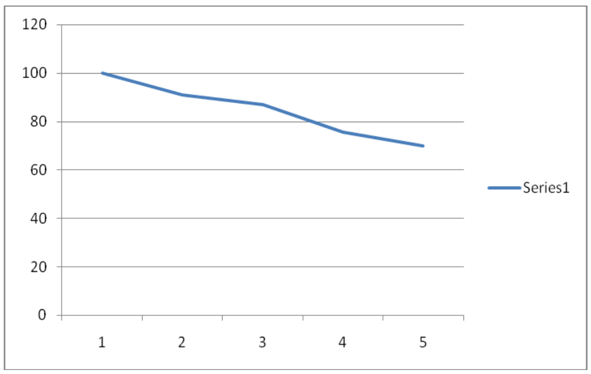

Figure 3: Drying Rate of Radish

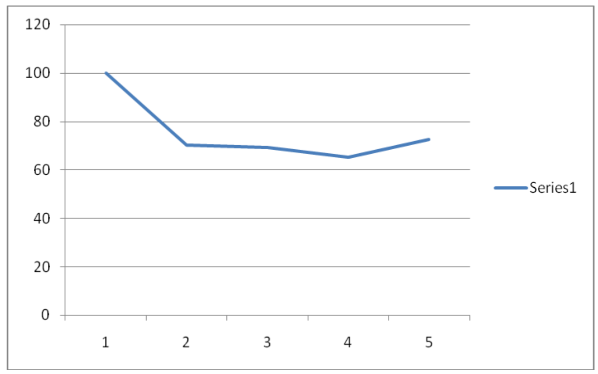

Figure 4: Drying Rate of Green Chilli

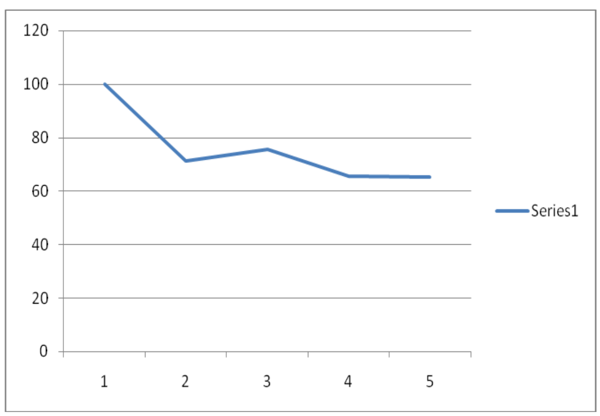

Figure 5: Drying rate of Mint

Conclusion

Thus the drying process of vegetables was carried out in the solar tunnel drying and it may be superior in maintaining the shelf life of agricultural products. The increased rate of drying during subsequent hours is showed through graph and it may be very efficient compare to other drying process. Hence the adoption of solar drying would recommend for high quality product and it fetches more market prices for all agricultural farmers.

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