International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 21-07-2025, Accepted: 21-08-2025, Published: 05-09-2025
Volume 10, Issue 5, 2025, Page No. 60-62

Farmers friendly solar tunnel dryer for vegetables dehydration

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Abstract
A solar heating system is used to increase the thermal energy storage inside the solar drier during the day or to transfer excess heat from inside the drier to the heat storage area. Dehydration is a common technique for preservation of agricultural and other products, including fruits and vegetables Narinesingh and Mohammed (1988) [2]. Depending on weather conditions, the solar tunnel dryer was found to be more efficient than the open sun drying and resulted in saving to the extent of about 17.4% of drying time. Samples dried in the solar tunnel dryer were completely protected from insects, rain and dusts and the dried samples were high quality in terms of colour and hygienic. The present new type solar tunnel dryer designed manufactured consisted of an air collector, drying chamber and an air circulation system. During the drying period, drying air temperature, relative humidity, solar radiation, and lose of moisture were measured continuously in different parts of the dryer. The portable solar tunnel dryer for the drying of fruits & vegetables, mushroom and greens. The system was designed as a portable system for decentralized applications at various sites to satisfy the drying requirements of small farmers. The cross-sectional area of the solar tunnel dryer was trapezoidal in shape having 0.254 m2 face area, with length and width of three meters and one meter respectively. It comprises a collector section 1.35 m long and a drying section 1.65 m long and two PV powered DC fans to provide the required air flow rate over the perishable agricultural products to be dried. Transparent polythene cover was used to close the dryer on top side to maintain the steady state air flow within the dryer. It has been observed that the drying air temperature was easily raised by some 8-14°C above the ambient temperature at air velocity ranges 0-1 m s-1. The efficiency of the solar tunnel dryer was found to be 40-45%. Psychrometric analysis was also carried out within the dryer and the process curves were drawn. The process curves were found similar to a conventional dryer showing that this dryer can be successfully utilized for the drying of agricultural products using solar energy. Now it is possible to design solar dryers by keeping in view the needs of the farming community and end-users. Industrial and commercial applications can easily be met by using forced circulation solar drying systems because these technologies provide good control of temperature and air distribution system within the dryer unit. These systems also facilitate to couple with the existing drying systems. Roof space available in small-scale industries would normally permit installation of systems of one to two tons per day capacity. This is not only an efficient method of drying but also produces better quality products (Naween, 2009) [9]. Keeping all facts in view, the study objectives were to design and fabricate, evaluate the performance of solar tunnel dryer and to develop psychometric curves for drying of various agricultural products.

Keywords: Solar tunnel dryer, relative humidity, dehydration, relative humidity, solar radiation

Introduction

Solar tunnel dryers give faster drying rates by heating the air to 10-30°C above ambient, which causes the air to move faster through the dryer, reduces its humidity. Drying process is the most common form of food preservation and extends the food shelf life. It is a simultaneous heat and mass transfer operation in which moisture is removed from food material and carried away by hot air (Boiln and Salunkhe, 1982) [1]. A solar heating system is used to increase the thermal energy storage inside the solar drier during the day or to transfer excess heat from inside the drier to the heat storage area. The faster drying reduces the risk of spoilage, improves quality of the product and gives a higher output. It requires less drying area. How ever care is needed when drying vegetables that too rapid drying will prevent complete drying and would result in hardening and subsequent mould growth. Solar dryers also protect foods from dust, insects, birds and animals (Rossello *et al*., 1990; Fellows, 1997) [4, 6]. They can be constructed from locally available materials at a relatively low capital cost and there are no fuel costs. Drying process plays a crucial role in post-harvest technology for preservation of agricultural products. Due to the increasing cost of electricity and fossil fuels, application of solar energy for drying of various agricultural products has become the need of the time. It is not only economical but also ceases the gas emissions. 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) [7]. By solar drying, huge amount of national revenue can be saved by avoiding the spoilage of agricultural products due to non- availability of conventional processing facilities. In the drying process, food material is preserved by evaporating a significant amount of water to prevent it from decay and spoilage. In different agricultural products, moisture contents can be up to 85%. Solar drying is a clean and hygienic way to process the products according to international standards without any expenditure on energy costs. Although solar energy occupies larger area comparatively yet it also improves product quality like conventional high tech. In the present scenario, solar energy is successfully being utilized for complete drying of agricultural products, as well as it can be used as a supplement to artificial drying systems (Muhlbauer, 1986) [8].

Materials and Methods

In this study, solar tunnel dryer with 0.75 m 2 base area and 0.6 m height was used for small scale for drying of vegetables and herbals. The dryer was oriented in an east-west direction to make the incident solar radiation more efficient on the solar tunnel dryer. A corrugated galvanized iron sheet pointed black was used as an absorber plate for absorbing the solar radiation. Agro products are highly hygroscopic and drying is a method of an approved method of improving their shelf life. The drying of food stuffs like vegetables and greens for dehydration in open air is not only labour consuming and but involves expenditure. The agro products contain more than 37% moisture initially which has to be brought down to 11% by drying. This is a critical process and it depends on monosomic variations. Hence, it is proposed to integrate small poly cover in tunnel shaped structure designed as tunnel shaped semi cylindrical prototype model for drying agro-industrial product. Tunnel shaped Semi cylindrical prototype model solar drier in the size of 3'x 2 was fabricated for drying of fruits and vegetables. It is a metallic frame structure of tunnel shape dryer covered by UV stabilized semi-transparent polythene sheet of 200-micron thickness. No post is used inside the green house, allowing a better use of inside space. A slope of 10-15 degree 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.

Pretreatment procedure for Vegetables and greens

Tomatoes: Due to the increasing demand for dried tomatoes from the industry, especially from the soup manufacturers, interest is focused on producing high quality dried tomatoes. Therefore, it is important to establish a drying method, which yields products with higher sensory and sanitary quality in a shorter drying time compared to the conventional sun-drying method. 2% citric acid pretreatments can be used to protect the bright, red colour of tomatoes. However, citric acid did not prevent the growth of moulds and yeasts effectively. Therefore, dipping into sodium metabisulfite solution for 3-minute pretreatment was done following drying of tomatoes at 55°C in solar tunnel dryer without darkening. At this temperature the drying takes 4-5 days to reach a final moisture content of 11 %.

Onion: A large part of the dehydrated onion is used for production of ketchup, chilli sauce and other snack items. Food service outlets also use dehydrated onions because of its convenience in storage, preparation and use. Before drying, onions are peeled and sliced into desired shapes. Onions can be dried at 45-50°C for 2-3 days to a final moisture content of 15 % in solar tunnel dryers. Sodium metabisulfite dipping can be used to preserve colour. Drying temperatures of onions should not exceed 50°C in order to prevent browning of the product.

Carrot: Before loading into the dryer, carrots were peeled, washed, cut into small cubes and treated with 2% sodium metabisulfite solution for 3- 5 minute. Carrots can be dried at 50-55°C for 1-1.5 days to a final moisture content of 7.5 %. Naturally dried carrots lose their bright orange colour. The sodium metabisulfite treated ones preserve their colour to the largest extent.

Bitter gourd: Bitter gourd is one of the most popular vegetables. Before loading into solar dryer, potato is washed and its seeds are removed. The following treatments can be applied to bitter gourd prior to solar drying steam blanching dipping in the water containing 1 tea spoon of sodium bisulphate per cup of water for 4-6 min followed by rinsed with water as a pretreatment and drying of bitter gourd at 50-55°C in the solar dryer was done.

Cluster bean: Before loading into the dryer, cluster bean was washed, cut into small pieces and blanched for 5 to 8 minutes. Cluster bean can be dried at 50-55°C for 1-2 days to a final moisture content of 7.5 %.

Coriander leaves: Before loading into the dryer, coriander were cleaned, washed, cut and steam blanched for 2 minutes. It can be dried at 40-45°C to the final moisture content.

Results and Discussion

The drying time for solar tunnel dryer is less with 20% time saving when compared to open sun method. This tunnel dryer can also be useful for drying of vegetables and fruits. Simple in fabrication and installation. Maximum mean temperature obtained inside the dryer is 57° C ±0.19 while the ambient temperature was 33.5 °C±0.28. Due to the increasing demand for dried tomatoes from the industry, especially from the soup manufacturers, interest is focused on producing high quality dried tomatoes. Therefore, it is important to establish a drying method, which yields products with higher sensory and sanitary quality in a shorter drying time compared to the conventional sun-drying method. Pretreatments can be used to protect the bright, red colour of tomatoes. However, citric acid did not prevent the growth of moulds and yeasts effectively. Therefore, dipping into sodium metabisulfite solution for 3-minute pretreatment was done following drying of tomatoes at 55°C in solar tunnel dryer without darkening. At this temperature the drying takes 4-5 days to reach a final moisture content of 11 %. Before loading into the dryer, greens were cleaned, washed, cut and steam blanched for 2 minutes. It can be dried at 40-45°C to the final moisture content. The studies on optimization of drying process for vegetables and herbals were carried out in two drying pattern namely solar tunnel drier and open sun drying. Solar tunnel drier was designed as prototype model fabricated with 1.2 m length and 0.6m wide. This system has superior drying efficiency in terms of increased rate of drying and also the quality product which helps improved shelf life.

The solar drying was found to be superior in maintaining the shelf life of the agricultural produce and recorded to retain higher lipid content than open sun drying (Oparaku, 2012) [5]. There was a significant increase in lipid contents in the solar drying which suggests and supports the results of the present findings that the nutritional qualities of perishable food stuffs like fish could well be maintained and retained as reported by the authors. The sensory evaluation reports (Enein, 2000) [3] supported solar tunnel dryer rather than open sun dryer in retaining the quality of the produce tested and gained good acceptance for its colour, aroma and texture. Average moisture content of produce was reduced from 52% to 8% after 60 hr under full load in solar tunnel drier. 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 compared to the sides of it. Solar tunnel drier is to be found to produce high quality compared to open sun drying, possibly due to less humid drying environment provided by the solar tunnel drier in the absence of microbial activity. High quality product produced in solar tunnel drier fetches more market prices for all agricultural farmers.

Weight in grams of vegetable products under drying process

S.No	Product	Solar drying				Sun drying			
		Initial	I hour	2 hour	4 hour	Initial	I hour	2 hour	4 hour
1	Tomato	50	21	10	4.5	50	34	26.5	13
2	Onion	70	26.5	18	10.5	70	35	22.5	15
3	Coriander	15	3	1.5	1.0	15	4.0	1.0	1.0
4	Cluster bean	50	24	13.5	9	50	34.5	28	20
5	Carrot	65	36	22.5	16	65	46.5	38.5	23.5
6	Bitter gourd	50	25	13.5	6.5	50	32.5	22.5	17

In sun drying method, the average removal of moisture % for vegetables including the fish was found to be 39.6 % at the end of first hour, 14.7 % for the second hour and 15.45% for the period of drying from second to 4th hour. Whereas in solar drying the average removal of moisture % for vegetables including the fish was found to be 53.85 % at the end of first hour, 18.92 % for the second hour and 10% for the period of drying from second to 4th hour. Hence the comparison shows that 36% increased rate of drying during first hour followed by 28% during the second hour in the solar drying.

Conclusion

The solar tunnel dryer was operated by a photovoltaic module independent of electric grid. The photovoltaic has the advantage that the temperature of drying air is automatically controlled by the solar radiation. The photovoltaic driven solar tunnel dryer must be optimized for efficient operation. Psychrometric chart can be successfully utilized for solar tunnel dryer by plotting a process curve. The process curve can be used to evaluate the dryer performance during the dehydration process. The dried products are protected from dirt, insects and climatic conditions due to its perfect sealing. The air leaving the dryer was found to have still greater potential for drying more products. However, this should also be considered for other products, as this dryer is designed for multi-products use. The solar based renewable technology is free from operating cost and can play a vital role in promoting the field of post-harvest technology using solar energy. The optimization of drying process for vegetables and greens was carried out in two drying pattern namely solar tunnel drier and open sun drying. The solar drying was found to be superior in maintaining the shelf life of the agricultural produce tested in terms of relative rapid drying and maintaining shelf life. The comparison showed that 36% increased rate of drying during first hour followed by 28% during the second hour in the solar drying. Hence the adoption of solar drying would recommend for high quality product. Thus, the products dried in solar tunnel drier fetches more market prices for all Agricultural farmers.

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