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Performance of Box Type Solar Dryer for Drying Potato Chips

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Abstract: Large amount of food is wasted every year due to lack of proper storage and preservation. Amount of moisture in food affects growth and activities microbial such as bacteria and fungi. Basis of drying is reduction of moisture from food and preventing growth and activity of microbial. Here solar drying was performed for potato chips in simple box type of solar dryer at Pune, India (18.58N, 74E) in first week of June 2022. The potato is the third most important food crop in the world after rice and wheat in terms of human consumption. Study was conducted for passive mode. Temperature inside box and loss of moisture was studied. Maximum temperature achieved was 74.3 ºC.

***Index Terms* - Solar energy, solar Dryer, box type dryer, passive dryer, potato drying.**

I. INTRODUCTION

Around 15% of the world population is undernourished. The increase in world population will further disturb existing population-food imbalance. Reduction in the food losses occurring throughout food production, harvest, post-harvest, and sell is one of solutions to fight food shortage [1].

A food is source of energy for human and animals. Content of food like water, fat, carbohydrates, protein etc are also food for microbial. To prevent growth of microbial, various preservation methods are used for different food depending on their properties. Food preservation methods are used to retain food quality and prevent them from deteriorating. The preservation process will prevent the development of microbial such as bacteria and fungi. Drying is one of method of food preservation since ancient time. In absence of sufficient moisture, growth and activity of microorganism is reduced. Drying reduces weight of product thus transportation cost is reduced [2].

In absence of proper food preservation huge amount food is wasted. Open Sun drying of vegetable, animal products and fruits is the most widespread method of food preservation in Asian and African countries due solar irradiance being very high for the most of the year. There are some drawbacks relating to the traditional open drying method i.e., spreading the crop in thin layers on mats, trays or paved grounds and exposing the product to the sun and wind. These include poorer quality of food caused by contamination by dust, insect attack, enzymatic reactions and infection by micro-organisms. Non-uniform and insufficient drying also leads to deterioration of the crop during storage. Close drying using solar energy is called solar drying. In solar drying higher temperature is achieved due to green house effect than open sun drying. Thus solar drying is faster. Food is enclosed in the dryer and therefore protected from dust, insects, birds and animals, and chances of food contamination get reduced. The dryers are water proof and the food does not therefore need to be moved when it rains. [3]

Drying contains two steps, i) heating of the product from the heating source ii) mass transfer of moisture from the interior of the product to its surface and from the surface to the surrounding air. Drying consist of the extraction of moisture from the product by heating and the stream of the air around it to carry away the released vapour. The objective of a dryer is to supply the product with more heat than is available under ambient conditions, thereby increasing sufficiently the vapour pressure of the moisture held within the crop and decreasing significantly the relative humidity of the drying air and thereby increasing its moisture carrying capacity and ensuring sufficiently low equilibrium moisture content. In solar drying, solar-energy is used as either the sole source of the required heat or as a supplemental source. The air flow can be generated by either natural or forced-convection. The heating procedure could involve the passage of preheated air through the product or by directly exposing the product to solar radiation or a combination of both. Water starts to vapourise from the surface of the moist product when the absorbed energy has increased its temperature sufficiently for the water vapour pressure of the product moisture to exceed the vapour pressure of the surrounding air. Loss of moisture from the surface is replenished by diffusion from the interior. Solar-energy drying systems are classified as i) active solar-energy drying systems (forced-circulation solar drying systems); and ii) passive solar-energy drying systems (natural-circulation solar drying systems).[4]

Potato also known as Solanum tuberosum is an important crop. Potatoes are used as whole or as ingredients in various foods, for starch extractions and other industrial purposes. The demand and use of such crops has increased since recent past due to changing food habits. More than half of the potatoes grown in developed countries are used as processed

products. Potatoes are cooked, dried, fried, smoked or used as snacks and other products. Recent years have witnessed the expansion of markets for processed potato products. However, shorter shelf life as a result of deterioration with changes in temperature, humidity and microbial growth makes potatoes unacceptable to consumers. Drying provides an alternative to increase the shelf life of potatoes.[5]

Benefits of drying are, i) it permits the long-time storage of food without deterioration ii) it helps to continuous supply of the product throughout the year and advantage of higher price after harvesting season can be taken. iii)it reduces transportation cost. [7]

The potato is the third most important food crop in the world after rice and wheat in terms of human consumption. More than a billion people worldwide eat potato, and global total crop production exceeds 300 million metric tons. Potato is vegetatively propagated, meaning that a new plant can be grown from a potato or piece of potato, called a "seed". The new plant can produce 5-20 new tubers, which will be genetic clones of the mother seed plant. Potatoes can grow from sea level up to 5000 meters above sea level. Potatoes produce more food per unit of water than any other major crop and are up to seven times more efficient in using water than cereals. They are produced in over 100 countries worldwide. Potato is a good source of zinc, iron, potassium, and vitamin C. [8]

Higher the air temperature, faster is drying observed in potato similar to other products. [9]

II. SOLAR DRYER

Solar dryers use the heat from sun to remove the moisture content of food substances. Main components of dryer are a) solar air heater, b) drying chamber and c) chimney. The schematic of indirect solar dryer is shown in Figure 1. In indirect solar dryer food article is not directly heated, but first air is heated and air then in turn heats food article. In passive case, natural draft is created using chimney circulated naturally by buoyancy force. Present system uses passive system.

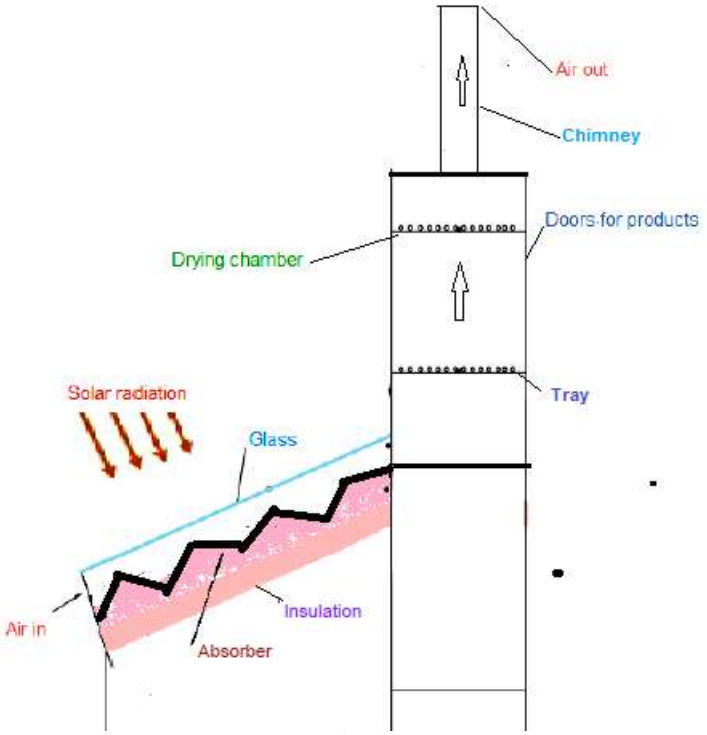

Fig. 1 Indirect solar dryer [11]

Solar air heater:- Here the solar radiation is absorbed in absorber plate of aluminum which is painted black and heat is transferred to air flowing between glass and collector plate. At bottom side of corrected is insulated. To promote turbulence collector surface in step form.

Drying chamber:- Here trays containing food article are kept for drying. Here baffle is provided to create turbulence. Tray having mesh to allow movement of air is provided. Figure 1 shows view of drying chamber.

Chimney: - This is part in located on the top of the drying chamber to increase the air flow in the system by natural draft.

Photograph of system is shown in figure 1.

Present study use box type solar dryer which very simple design. box-type solar dryer has been widely used for small scale food drying. It consists of a wooden box with a hinged transparent lid. The inside is painted black and the food supported on a mesh tray above the dryer floor. Air flows into the chamber through holes in the front and exits from vents at the top of the back wall. Box type solar dryer is shown in Figure 2. Here chimney is absent. These dryers can achieve higher temperatures, and thus shorter drying times, than tent dryers. Drying temperatures in excess of about 80 °C were reported for the dryer.[3]

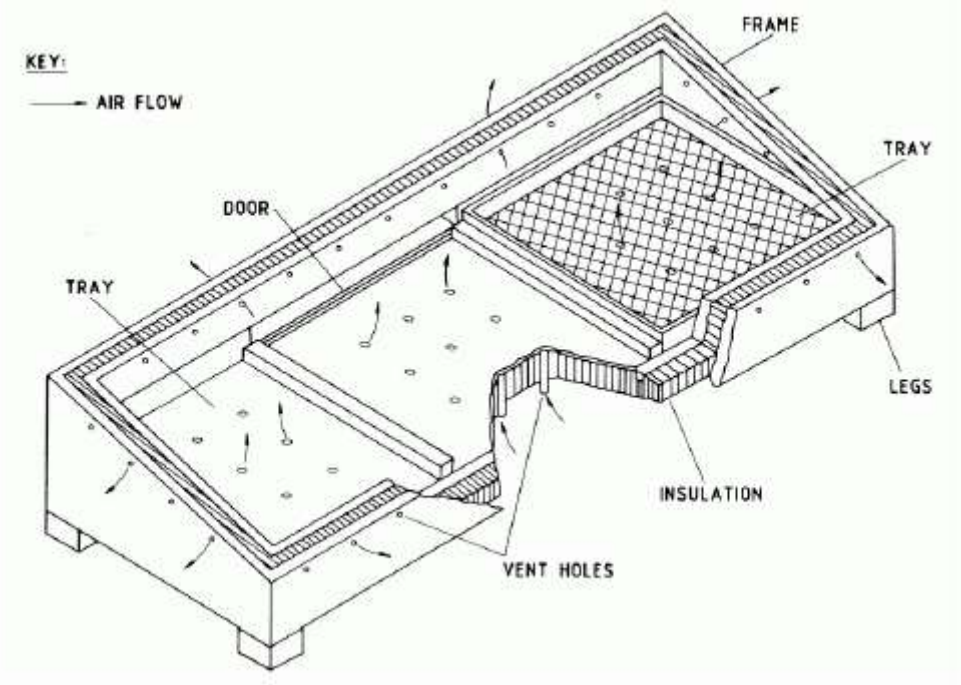

Fig. 2 Schematic diagram of box type solar dryer

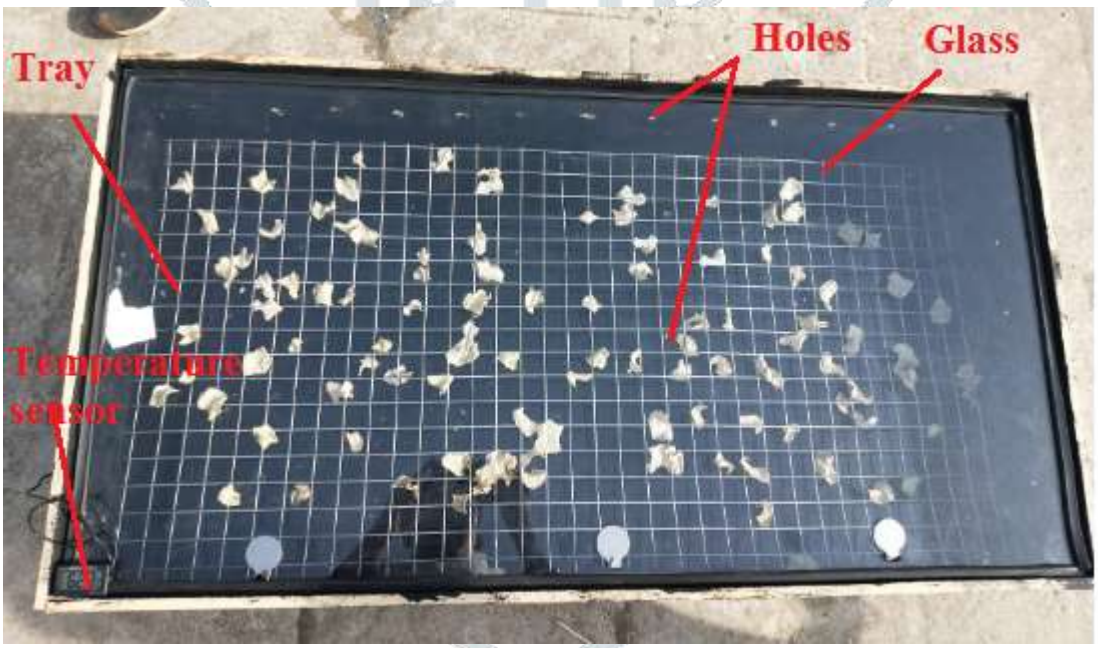

Fig. 3 Box type solar dryer fabricated and tested

Here in present study, box type solar dryer is made from plywood. Aluminum sheet 0.5mm thick is fitted inside box at bottom. All walls inside of box are painted black. Holes of 8mm diameter are made at bottom and top side of top walls as shown in Figure 3. Top transparent glass was inclined at 18.5° with horizontal equal to local latitude. It also shows digital temperature sensor. Tray is mesh of galvanized steel wires as shown in figure 3.

III. PARAMETERS AFFECTING DRYING

The factors affect the air heater efficiency such as collector dimensions, type and shape of absorber plate, glass cover, inlet temperature, wind speed, humidity, air path, and height of the channel. Among all, the glass cover collector, the absorber plate shape factor, and air path are the most important parameters in the design of any type of air heater. [6]

Drying process is non-linear. At starting of drying shows a linear trend and afterwards it decreases in a non-linear fashion. Initially, heat is taken by the sample to supply sensible heat and a few portions of the free moisture are evaporated and as the drying continues, the moisture moves out by diffusion. As the heat penetrates inside and moves moisture out leaving a product with decreased water content. In the beginning, drying rate increases owing to the availability of free moisture. As the water content decreases, due to evaporation, more and more moisture moves out to the surface by diffusion, and thereby further decreasing the amount of water to be evaporated which leads to the decline in the drying rate. At last, the water molecules which are strongly bound are to be removed by the heat supplied. At this point, the kinetic energy of molecules increases due to which the temperature of air and the substance equals, which decreases the drying rate and finally brings it to an end. With increase in the drying temperature, the drying time reduced and samples with more thickness required longer drying time. [5]

During the drying process, moisture content decrease was controlled by the diffusion mechanism described by Fick's second law.

Moisture Ratio, MR

$$MR = \frac{M_t - M_e}{M_i - M_e} = e^{-kt} \quad (1)$$

M_i and M_e are the initial and equilibrium moisture contents and M_t is the moisture content at any time t.

The drying rate constant k is a function of drying air temperature. Where (k) is the drying rate constant, min^{-1}, and (t) is the drying time, min [10]

The present study aims at studying drying of potato chips in box type solar dryer in passive mode. Potato chips were made to dip in salt solution before putting in dryer. Temperature of box and mass of potato chips were measured. For measurement digital sensors were used.

Fig. 4 i) Temperature sensor

IV. RESULTS AND DISCUSSION

Following readings were taken at Pune, Indian (18.58N, 74E). Slices of apples were made with thickness 2 mm. Slices were dipped in salt water for 15minuite before drying.

i) Temperatures

ii) Mass of sample

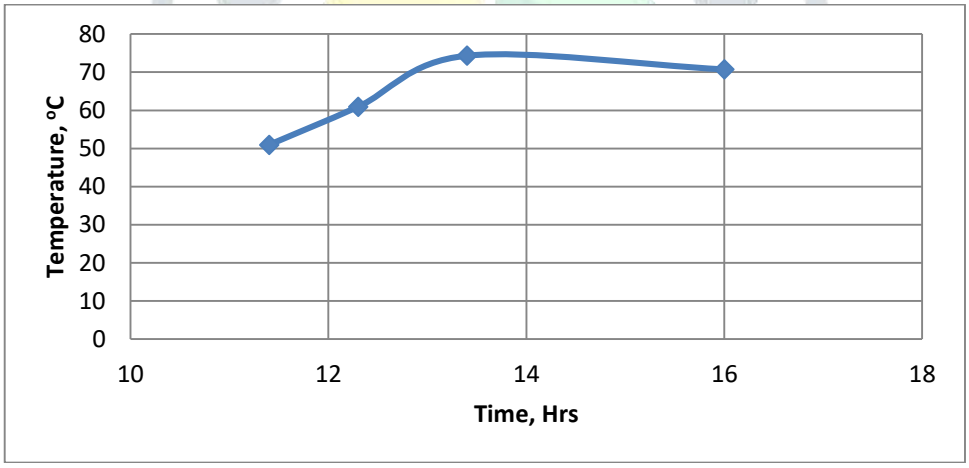

Fig. 5 Inlet and outlet temperature for Natural and Forced draft

Fig. 6 Drying of potato slices: (A) before drying; (B) after drying.

Table 4.1: Percentage moisture removed after drying potato slices

Variable	Day 1	Day 2	Day 3
Percentage moisture removed	81.0	81.3	81.4

Figure 5 shows variation of temperature for passive case inside box. Figure 6 shows photos slices before and after drying for a day. About 80% humidity is removed in a day from potatoes in sunny day. Table 4.1 shows percentage moisture removed from potato slices. Maximum temperature achieved was 74.3ºC.

IV. Conclusions

Following conclusion can be drawn from present study,
i) Potato slices can be dried using solar dryer.
ii) Large temperature of order 75ºC is developed inside box dryer.

V. Acknowledgment

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