# Review of Solar Dryer for Drying Agricultural Products

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*Abstract*— In many countries of the world, the use of solar thermal systems in the agricultural area to dry vegetables, fruits, coffee and other crops has shown to be practical, economical and the responsible approach environmentally. Solar drying systems to dry food and other crops can improve the quality of the product, while reducing wasted produce. Under the module of Advance topics in mechanical engineering projects, we were assigned to design the low cost vegetable dryer. The aim of our project is to determine the drying curve and the change rate of drying by solar energy by taking green beans or peas using an indirect solar dryer operating in forced convection. Solar dryer is not only a process, but it is a technology that helps to obtain products that are better in color, flavor and nutrient content than the open sun dried products. Using this technology farmer can take better price for their products, because the solar dried products are the international standard of market in quality.

***Key words:*** Drying Agricultural Products, Solar Dryer

## I. INTRODUCTION

Solar dryers are devices that use solar energy to dry substances, especially food. In solar dryers, the black surface heats incoming air. This heating air is then passed over the substance and exits through a chimney, taking moisture from the substance with it.

It has been used for drying grains, meat and other agricultural products for consumption in the long term. Much of the world's production in dried fruits and vegetables continues to be dried by conventional methods such as outdoors. However, large-scale production limits the use of outdoor drying because it suffers from several drawbacks, among them, the inability to control the drying process properly, uncertainties of weather cost of labor need for large areas, infection by insects and other foreign matter. Solutions involving proposed solar devices such as solar dryers. A properly designed solar dryer can alleviate the disadvantages of open sun drying and makes the industry and the quality of the final product can be improved. Under the module of Advance topics in mechanical engineering projects, we were assigned to design the low cost vegetable dryer. The design of dryer Consists of several steps and sequence procedure. This report consists of back ground about project .This project report gives a great guideline about designing of low cost vegetable dryer compare with the other competitive industrial food processing technique.

In a working principle of solar dryer the sunlight is falls on a black heat absorbing metal sheet and large amount of heat is generated. Then atmospheric air comes into the solar dryer and the generated heat heats the air and this heating air then passed over the substance and substance dry quickly. After this heating air flow into atmosphere through chimney.

In indirect solar dryers, the black surface heats incoming air, rather than directly heating the substance to be dried. This heated air is then passed over the substance and exits upwards often through a chimney, taking moisture released from the substance with it. They can be very simple, just a tilted cold frame with black cloth to an insulated brick building with active ventilation and a back-up heating system. One of the advantages of the indirect system is that it is easier to protect the food, or other substance, from contamination whether wind-blown or by birds, insects, or animals. Also, direct sun can chemically alter some foods making them less appetizing. Drying of crops can change this trend and is useful in most areas of the world, especially those without a high humidity during the harvesting season. If drying of produce were widely implemented, significant savings to farmers would be achieved. These savings could help strengthen the economic situation of numerous developing governments as well as change the nutritional condition in these same countries.

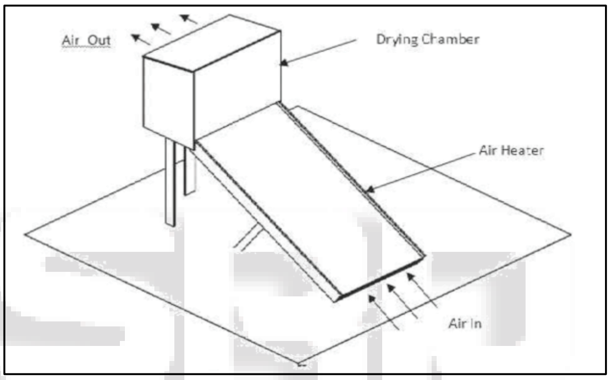


Fig. 1: Indirect Solar Dryer.

Drying generally refers to the removal of moisture by evaporation rather than by pressure or other physical means. The factures that are affecting the drying can be identified as the temperature, humidity, pressure, velocity of air and the size and the shape of the wet surface and the air moment with respect to it. There are various mechanical drying methods that are available at present. Some of these are operating utilize fans for air circulation, and electric or gas heater for heating of drying air. But they are very expensive drying methods so we have introduced a high efficiency low cost vegetable dryer for our advance topic in mechanical engineering module.

This dryer has been designed to construct from material available in the market at low cost. This especially to overcome the problems encountered in the sun drying such as over drying occurs, low drying rate, risk of spoilage, contaminating with impurities. It uses solar energy for heat generation. Evaluation of a prototype of this dryer is important to reduce the drying losses and optimize the utilization. This dryer consists of main parts namely the body of the dryer, the cabinet, chimney, and solar unit.

### A. Working Principle

Solar energy dryers can broadly be classified into direct, indirect and hybrid solar dryers. The working principle of these dryers mainly depends upon the method of solar energy collection and its conversion to useful thermal energy for drying.

*1) Open Sun Drying (OSD)*

The crops are generally spread on the ground, mat, cement floor where they receive short wavelength solar energy during a major part of the day and also natural air circulation. A part of the energy is reflected back and the remaining is absorbed by the surface depending upon the colour of the crops. The absorbed radiation is converted into thermal energy and the temperature of the material starts to increase. However there are losses like the long wavelength radiation loss from the surface of crop to ambient air through moist air and also convective heat loss due to the blowing wind through moist air over the crop surface.

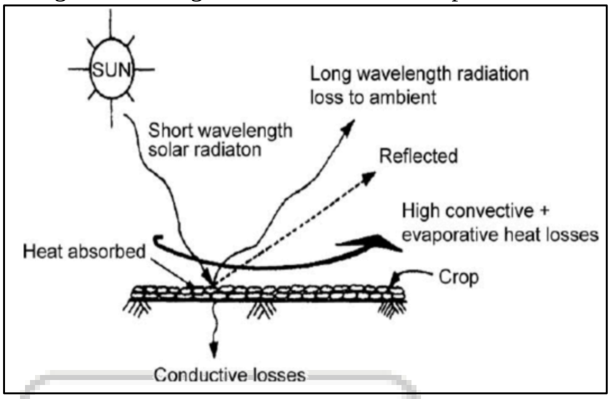


Fig. 2: Open Solar Dryer

*2) Direct Solar Drying (DSD)*

The working principle of direct solar crop drying is shown in figure also known as a solar cabinet dryer. Here the moisture is taken away by the air entering into the cabinet from below and escaping through at the top exit as shown in Figure. In the cabinet dryer, of the total solar radiation impinging on the glass cover, a part is reflected back to atmosphere and the remaining is transmitted inside the cabinet. A part of the transmitted radiation is then reflected back from the crop surface and the rest is absorbed by the surface of the crop which causes its temperature to increase and thereby emit long wavelength radiations which are not allowed to escape to atmosphere due to the glass cover.

The overall phenomena cause the temperature above the crop inside the cabinet to be higher. The glass cover in the cabinet dryer thus serves in reducing direct convective losses to the ambient which plays an important role in increasing the crop and cabinet temperature.

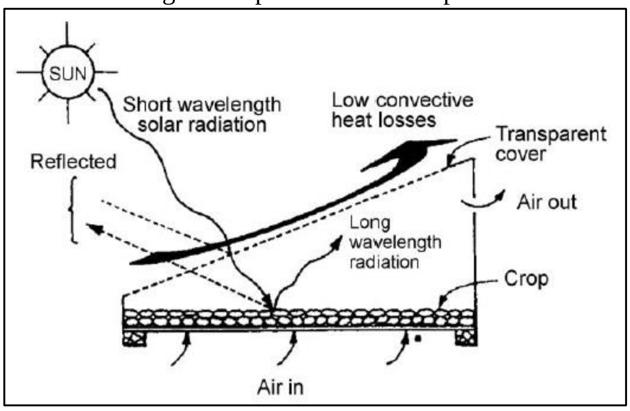


Fig. 3: Direct Solar Dryer

*3) Indirect Solar Drying (ISD)*

These differ from direct dryers with respect to heat transfer and vapour removal. The crops in these indirect solar dryers are located in trays or shelves inside an opaque drying cabinet and a separate unit termed as solar collector is used for heating of the entering air into the cabinet. The heated air is allowed to flow through/over the wet crop that provides the heat for moisture evaporation by convective heat transfer between the hot air and the wet crop. Drying takes place due to the difference in moisture concentration between the drying air and the air in the vicinity of crop surface.

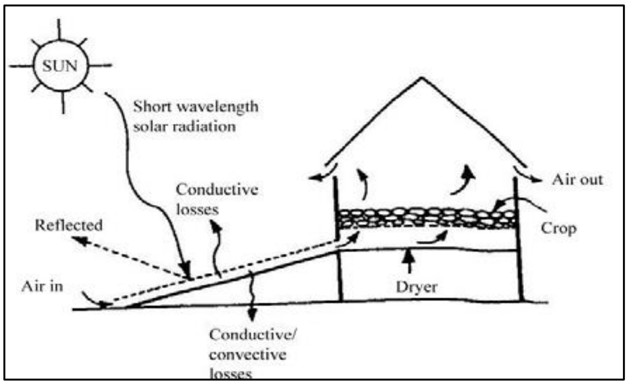


Fig. 4: Indirect Solar Dryer.

*4) Hybrid Solar Drying (HBD)*

The hybrid solar dryers combine the features of the direct and indirect type solar energy dryers. Here the combined action of incident direct solar radiation on the product to be dried and air pre-heated in a solar collector heater produces the necessary heat required for the drying process.

## II. LITERATURE SURVEY

### *A. Y.I. Sallam, M.H. Aly, A.F. Nassar and E.A. Mohamed – 'Solar Drying of Whole Mint Plant under Natural and Forced Convection' [1] (2015)*

Two identical prototype solar dryers (direct and indirect) having the same dimensions was used to dry whole mint. Both prototypes were operated under natural and forced convection modes. In the case of the later one the ambient air was entered the dryer with the velocity of 4.2 m s. The effect of flow mode and the type of solar dryers on the drying kinetics of whole mint were investigated. Ten empirical models were used to fit the drying curves; nine of them represented well the solar drying behaviour of mint. The results indicated that drying of mint under different operating conditions occurred in the falling rate period, where no constant rate period of drying was observed. Also, the obtained data revealed that the drying rate of mint under forced convection was higher than that of mint under natural convection, especially during first hours of drying (first day).

Open air sun drying is the dominant method that is used to preserve agricultural products, in which agriculture plants are directly exposed to solar radiations in an open environment. However, the contamination with dust, soil, sand particles and insects are some problems associated with this method.

To overcome previous problems, solar drying method could be used to dry agriculture products instead of traditional sun drying method as the drying process takes place in enclosed structures. Utilization of solar energy as a reliable energy source to dry foods in Egypt has a great potential, as, the annual daily average solar radiation on a horizontal plane in Egypt is 8 kW m_2 day_1 and the measured annual average daily sunshine duration is approximately 11 h. Mint is a genus of the Labiates family, which comprises a wide number of species, varieties and hybrids. It helps in colds, flu, fever, poor digestion, motion sickness, food poisoning and for throat and sinus ailments. Mint as flavouring agent is coming after vanilla and citrus flavours over the world. Several researches have investigated the drying kinetics of mint leaves and evaluated various mathematical models to describe thin layer drying characteristics. The best drying models to explain thin layer drying behaviour of mint leaves under different drying methods were Wang and Singh model, logarithmic model and Madill and Kuku model.

Drying experiments - Fresh mint was purchased at a local market in Giza, Egypt. Before drying, the foreign materials, as weeds, spoiled and discoloured plants were removed. Drying experiments were carried out using direct and indirect prototype solar dryers. The two prototypes are constructed from wood frames and have the same dimensions. The direct prototype solar dryer was covered by transparent polyethylene film; while black polyethylene film was used to cover the indirect prototype solar dryer. Each dryer has six perforated galvanized steel trays with the dimension of 1.00 · 0.90 · 0.04 m, and the spacing between them was 0.12 m. Each tray was loaded with 1.2 kg of fresh whole mint, which was spread as a single thin layer. The two prototypes were installed on the roof of the Department of Food Science and Technology building, Faculty of Agriculture, Cairo University and Giza. [1]

*B. N. Srisittipokakuna, K. Kirdsiria and J. Kaewkhaoa – 'Solar Drying of Andrographis Paniculata Using A Parabolic Shaped Solar Tunnel Dryer' [2] (2011)*

Thailand is an agricultural country, and its products range from world famous jasmine rice to various vegetables, fruits and herbs. Most of the products need some kind of preservation to enhance their shelf life since the production usually exceeds market demand at the harvest season. Drying is one of the most used methods for product preservation, and as a result, it adds higher value to the products. A dryer can achieve this purpose by supplying more heat which in turn increases the vapour pressure of the moisture in the product, reduces relative humidity of the air, then increases its moisture loading capacity and ensures sufficiently low equilibrium moisture content. Solar energy can be used as an important and environmental compatible source of renewable energy. The use of solar energy for drying effectively reduces the problems arising from generating energy by convention method. This is because the use of the Conventional energy source for drying purposes is costly and hazardous to environment. Solar drying system may be classified into direct, indirect and mixed modes. In direct solar dryers, the air heater contains the product and solar energy passes through a transparent cover and is absorbed by the product.

Essentially, the heat required for drying is provided by radiation to the upper layers and then conducted to the product bed. In indirect drying system, solar energy is collected in separate equipment, called solar air heater, and the heated air then passes through the product bed. Andrographis paniculata is an annual plant with characteristic white-purple or spotted purple flowers that flourishes in South-East Asia, China and India. It has been valued for centuries by herbalists as a treatment for upper respiratory infections, fever, sore throat and herpes. Other reported applications include its use in cases of malaria, dysentery and even snakebites. Now, important new research has confirmed a host of pharmacological benefits for this herb, including potent anti-inflammatory, antibacterial and anti-viral effects. In addition, scientists have discovered that Andrographis paniculata helps boost the immune system, protects against cancer, prevents blood clots and maintains efficient digestive functioning. The purpose of this paper is to present the developments and potentials of solar drying technologies for drying Andrographis paniculata.

*1) Characteristics of the dryer*

The solar tunnel dryer, is 12.20 meter long and 1.22 meter wide. The solar tunnel dryer consists of a solar collector, drying tunnel, and three radial flow fans to drive the moist air out of the drier. The product to be dried is placed as a single layer inside the drying tunnel. Air entering the solar collector is heated and is forced on the products placed in the drying tunnel using three fans at the air inlet of the solar collector. For experiments with DC power from solar PV panels could be used. Metal plates are curved to be S-shaped and used as side walls. Moreover, top of the dryer is covered by transparent materials. [2]

*C. J. Kaewkiew, S. Nabnean , S. Janjai – 'Experimental Investigation of The Performance of A Large-Scale Greenhouse Type Solar Dryer for Drying Chilli In Thailand' [3] (2011)*

Chilli is an important ingredient in daily cuisine in Thailand. It is consumed both as fresh and dried products. A natural sun drying method is generally used to dry chilli in Thailand. With this method, substantial losses of chilli due to insects, animals and rain usually occur during drying. To overcome this problem, well-performed dryers are needed to dry chilli. Although mechanical dryers using fossil fuel based energy are available, the drying cost is relatively high due to the high price of the fuel. In addition, the use of such dryers creates an environmental problem caused by carbon dioxide emission. [3]

*D. Adolfo G. Finck-Pastrana – 'Nopal Drying Using an Indirect Solar Dryer' (4) (2014)*

Water contained in foods allows the proliferation of microorganisms and the development of chemical reactions that deteriorate. When required preserve food for a time, a dry or dehydrate alternative is removing the water contained therein. There are several ways to achieve this issue; the simplest is to expose the food into a stream of air with certain conditions of temperature, humidity and velocity. There are several types of solar dryers to achieve proper product treatment. The two basic elements of a solar dryer are manifold where solar radiation heats the air and the drying chamber where the product is dried by the air passing through it, these elements can be designed to integrate the team in different forms. In an indirect solar dryer the two elements are separated, the air is heated in the manifold so that no solar radiation incident on the product placed inside the opaque drying chamber, in this type of dryers the process control drying is simpler. Having a separate drying chamber manifolds facilitates handling of the product and the work of loading and unloading. Since the drying chamber is opaque, this system conveniently dries products that can be damaged by direct sunlight.

This project works with an indirect solar dryer having a solar air heater built into its structure with plywood wood 1cm thick, both the base and sides, with dimensions of 140 cm long and 60 cm width, a cover glass thickness of 3 mm and an inclination of 17.5° to the horizontal. The main element is a coil of copper foil matt black painted placed inside the structure, isolated base and on all four sides with fibreglass wool, has thirteen channels 10 cm x 10 cm x 10 cm, which means a final length of 5 m in the warm air path, giving a conservative 0.01 m3/s flow and a 1 m/s natural convection speed. The drying chamber is constructed of plywood wood ½" thickness and dimensions of 60 cm long, 40 cm wide and 55 cm high with four nylon mesh trays, allowing initial drying mass about 2 kg. The connection between the solar air heater and the drying chamber is performed by means of a neoprene hose with a very low thermal conductivity in its wall. Thermal efficiency is calculated by evaluating the productivity of the dryer measuring temperature, air flow, solar radiation and loss of product mass. [4]

*E. David Gudiño-Ayala, Ángel Calderón-Topete– 'Pineapple Drying Using A New Solar Hybrid Dryer' (5) (2004)*

Studying these dryers, which worked only on solar radiation, it was evident that they had a very good performance; they were also practical, low cost and easy to handle. These are some of the reasons that they are still being studied and improved in order to provide better options to agro-alimentary producers, which require better ways to preserve their products year-round and have some type of added value.

Among the great diversity of papers and practical-theoretical studies related to solar drying worldwide, some have used dryers which incorporate thermal storage of solar energy using rocks or water. This stored energy is later used when there is no solar radiation available (night or cloudy days). Other studies use a photovoltaic cell to power up a fan which removes moist air inside the dryer. Finally, some have studied the possibility of hybrid dryers; their purpose is to complement solar energy with a conventional energy source (biomass, electricity, LP gas) with the intention of having a better drying process, making it continuous and even useful during nights and cloudy days where an unfinished drying test could be concluded or a new process begin. Both Benton and Fuller and Mahopac and Newalla studied the operation of an indirect integrated solar dryer which used biomass incineration energy as a backup for a pineapple drying process. These authors report that the system was able to maintain a continuous drying process, including nighttimes and days without solar radiation incidence; moisture removal efficiency and general performance proving satisfactory. [5]

*F. Elsamila Aritestya and Dyah Wulandani – 'Performance of the Rack Type-Greenhouse Effect Solar Dryer for Wild Ginger Drying' (6) (2013)*

Wild ginger is one of Indonesia's native plants. Nowadays, dried wild ginger are produced and processed as spices for cooking, healthy and tasty soft drink and herbal medicine with various nutritional values. It could treat liver disorder and malaria. Ethanol 70% extract of rhizome powder of wild ginger inhibited the growth of gram positive bacteria Staphylococcus aurous which causes a pimple. Conventional drying of wild ginger usually is carried out under the sun. However, it depends on the weather and the method contaminates to drying product by exposing it to dust, subjects it to destruction by animals and flies and it was not able to dry the product at rainy season.

Accordingly, greenhouse effect solar dryer rack type as artificial dryer is necessary to dry wild ginger in all of weather condition every day. Rack type greenhouse solar dryer was designed for thin layer drying of many kinds of product which could not be dried by deep bed dryer. Technically and economically the dryer have been used successfully for rosella pol. However it hasn't been tested yet for wild ginger drying. Therefore the objective of research is to obtain the performance of Greenhouse-effect solar dryer rack type to dried wild ginger. The study is expected to facilitate the drying process efficiently of slice wild ginger which could be applied for farmer and merchant of herbs (traditional medicine). **[**6]

*G. Varun, Sunil, Avdhesh Sharma and Naveen Sharma - 'Construction and Performance Analysis of an Indirect Solar Dryer Integrated with Solar Air Heater (7) (2011)*

Drying of agricultural products after harvesting had been of great importance for preservation of the products for longer period due to their increases shelf life. The process of drying removes the moisture from the product is stored for longer period. Solar drying is not only a process, but it is technology that helps to obtain products that better in color, flavor and nutrient content, because the solar dried products are at par with the international standard of market in quality. Drying bring about substantial reduction in mass and volume, minimizing packing, storage and transportation cost and enables storability of the product under ambient temperature. [7]

## III. FUTURE SCOPE

Scope for future work as suggested in above review is the project is carried out in order to get outside knowledge and involve in practical applications beyond in our day-to-day academic studies under in the module of "Advanced Topics in Mechanical Engineering". Designing of the solar dryer is high efficient in minimum cost. It is useful for farmer for improving quality of agriculture products and giving them best price for their product.

## IV. CONCLUSION

We studied about all types of solar dryer but we saw that indirect solar dryer is more efficient than other dryers and also give very good quality of product in minimum cost.

Designing of the solar dryer is high efficient in minimum cost. It is useful for farmer for improving quality of agriculture products and giving them best price for their product and it required very less space. It is also use for domestic purpose for drying seasoning products.

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