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SOLAR DRYING: AN ALTERNATIVE IN FISH DRYING–A REVIEW.

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ABSTRACT

Energy is one of the main concerns for the future development of any nation. It is by far the largest merchandise in the world and an enormous amount of it is extracted, distributed, converted and consumed in our global society daily .One major problem regarding agricultural produce is related to the product storage in the harvesting season, and identifying an alternative to marketing fresh produce. A useful option is to prevent wastage of produce by drying, using solar energy. In this regard, solar dryer for domestic as well as industrial usage could be an effective alternative of saving conventional energy. Utilization of solar thermal energy through solar dryer is relatively in a nascent state in our country. This paper gives a description of the efforts made under several researches to design and develop some types of solar dryers.

KEY WORDS: Solar drying, dryers, Drying methods, drying systems,

INTRODUCTION

In many parts of the world, there is a growing awareness that renewable energy (solar energy) has an important role to play in extending technology to the farmers in developing countries in order to increase their productivity (Waewsak *et al*., 2006). Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting (Akinola and Fapetu, 2006; Akinola *et al*., 2006). The application of solar dryers in developing countries can reduce post harvest losses and significantly contribute to the availability of food in these countries. Estimations of these losses are generally cited to be of the order of 40% but they can, under very adverse conditions, be nearly as high as 80%. A significant percentage of these losses are related to improper and/or untimely drying of foodstuffs such as cereal grains, pulses, tubers, meat, fish, etc. (Togrul and Pehlivan, 2004). The only alternative available is solar drying (Senadeera *et al*., 2003).

Drying methods

Usage of renewable energy technologies has received considerable attention within the past five years for their potential to help meet basic needs in many countries (Banerjee, 2005). Also, use of renewable energy today is much more desirable because most of the other alternative sources of energy have adverse effect on the environment and are in most cases more expensive (Basunia and Abe, 2001).

As the sun is the cheapest source of renewable energy and sun drying is still the most common method used to preserve agricultural products in most tropical and sub tropical countries despite the problems and the risk of contamination involved; high food losses ensue from inadequate drying, fungal attacks, insects, birds and rodents encroachment, unexpected down pour of rain and other weathering effects (Ong, 1999). In such conditions, solar-energy dryers appear to be increasingly attractive as commercial propositions (Ekechukwu, 1998).

Classification of drying systems

All drying systems can be classified primarily according to their operating temperature ranges into two main groups of high temperature dryers and low temperature dryers. However, dryers are more commonly classified broadly according to their heating sources into fossil fuel dryers (more commonly known as conventional dryers) and solar energy dryers. Further, solar-energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized (El-Sebaii *et al*., 2002).

passive solar-energy drying systems (conventionally termed natural-convection solar drying systems); and

Active solar-energy drying systems (most types of which are often termed hybrid solar dryers).

Although, for commercial production of dried agricultural products, forced

Convection solar dryer might provide a better control of drying air; natural convection solar dryer does not require any other energy during drying operation. Hence, natural convection solar dryer is highly preferred for drying food products especially when in thin layers of drying (Pangavhane *et al*, 2002).

Solar drying

Due to the current trends towards higher cost of fossil fuels and uncertainty regarding future cost and availability, use of solar energy in food processing will probably increase and become more economically feasible in the near future (Boits,2010).

Solar food drying can be used in most areas but how quickly the food dries is affected by many variables, especially the amount of sunlight and relative humidity. Typical drying times in solar dryers range from 1 to 3 days depending on sun, air movement, humidity and the type of food to be dried (Danith, 2009).

Solar dryers

Various investigations have shown that solar drying can be an effective means of food preservation since the product is completely protected during drying against rain, dust, insects and animals (El-Sebaii *et al.*, 2002: Farkas, 2004). But still some obstacles have to be overcome that solar drying will become a technology with a broad dissemination. 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 (Ekechukwu and Norton, 1998). The major requirement is the transfer of heat to the moist product by convection and conduction from the surrounding air mass at temperatures above that of the product or by radiation.

Categories of Solar Dryers

The major two categories of the dryers are natural convection solar dryers and forced convection solar dryers. In the natural convection solar dryers the airflow is established by buoyancy induced airflow.

Natural Convection Solar Dryers

Natural convection solar drying has advantages over forced convection solar drying in that it requires lower investment though it is difficult to control drying temperature and the drying rate may be limited. Due to low cost and simple operation and maintenance, natural convection solar drier appears to be the obvious option and popular choice for drying of agricultural products. It is the oldest type of solar dryer and consists of a solar collector with a transparent cover on the top and a drying unit with an opaque cover on the top. These are connected in series. Natural convection solar dryers do not require power from the electrical grid or fossil fuels. Hence the obvious option for drying would be the natural convection solar dryers. Several designs are available and these are (i) cabinet type solar drier (Sheana *et al*, 2010). (ii) Indirect natural convection solar drier (Oak, 2007) (iii) mixed mode drier. (iv) Solar chimney dryer. These dryers have been widely tested in the tropical and subtropical countries.

Cabinet Type Solar Dryer

Direct-solar cabinet-type driers are used to dry small quantities of food substances, and provide moderate drying temperatures (37-58°C) and airflow rates (Sheana *et al*, 2010). Both the 1 m^2 and 2 m^2 model dryers have been tested for fish drying. The 1 m^2 model can dry about 15- 20 kg of fresh fish over a period of two or three days while the 2 m^2 model can dry double this quantity. The dryer consists of four main parts: a base frame, drying chamber, drying trays, and loading door. The rectangular base frame has six supporting legs on which rest a drying chamber. A solar collector, supported by another three legs, is attached to the drying chamber. The drying chamber of the 1 m 2 model measures 1 m length x 1 m width x 0.75 m height, and contains 4 trays of 1m x 0.495 m to provide a total drying area of 2 m^2. The drying chamber of the 2 m^2 model measures 1 m length x 2 m width x 0.75 m height, and contains 8 trays of 1m x 0.495 m to provide a total drying area of 4 m^2.The base frame is built with softwood. Within the frame, a mat made from papyrus is laid and covered over with black plastic sheet to form the base of the drying chamber. Along the back of the frame, a ventilation slot is made to form the air inlet vent to let the air enter the collector and the chamber. The roof of the collector is parallel to the roof of the chamber. The vent is covered plastic mosquito mesh to keep out insects. The dryer has a solar collector attached at the other side of the drying chamber. The solar collector heats the ambient air, which then passes through the products to be dried (loaded on trays) by natural convection. The drying chamber is built with hardwood for strength and durability. The front of the chamber has two hinged doors to provide access for loading and unloading the drying trays, on which the products to be dried are spread. Wooden rails are provided in the cabinet frame, on which the trays slide through. The tray has a hardwood frame, and plastic mosquito mesh is stapled to it. An air outlet vent is provided at the top front side, for exit of the warm moist air through natural convection; the vent is covered with mesh to keep the insects and flies out. Both the 1 m^2 and 2 m^2 model dryers have been tested for fish drying. The 1 m^2 model can dry about 15-20 kg of fresh fish over a period of two or three days while the 2 m^2 model can dry double this quantity (Bala, and Janjai, 2009).

Solar Box Dryer

The solar box dryer has been designed to be suitable for household drying of agricultural products. The dryer can dry about 4-5 kg of fish, fruits and vegetables in a single batch, at a drying air temperature of about 40-50°C. The dryer design was based on thermal performance and product quality optimization. The dryer consists of a rectangular inner box made of GI sheet, with an open top. It is insulated at the outside with a layer of glass wool at the bottom and sides, and clad with GI sheet. A 3 mm thick window glass is used as cover glazing. The glass is fixed at the top of the box, and is hinged to the box at the left edge. This facilitates opening and closing of the cover glass, allowing access inside the box for loading and unloading the products spread on trays. The dryer box is fixed on a mild steel stand with a tilt of 20°, and placed facing south, to maximize the incident solar radiation (Phoeun *et al*, 2005).

Mixed-mode Solar Dryer

The mixed-mode solar dryer consists of a separate solar collector and a drying unit, both having a transparent cover on the top. Solar radiation is received in the collector as well as in the dryer box. The dryer is fixed with a solar collector consists of a matt-black substance spread on the ground and provided with transparent top and side covers. The dryer was initially designed with a bed of burnt rice husk às the absorber and clear UV stabilized polyethylene plastic sheet as transparent cover. However, these materials could be substituted with locally available materials (Bala, and Janjai, 2009).

Solar Chimney Dryer

This is a natural convection dryer with a separate collector of 6.45 m^2 area, a drying chamber, and a chimney to assist the airflow. The drying chamber is also covered by a polyethylene sheet. The air collector has an absorber plate fabricated from corrugated galvanized iron sheets riveted together and painted with black paint. A sheet of plastic cover is placed above the absorber plate. The airflow in the air heater is below the absorber plate, and the air gap between the absorber plate and the plastic cover is sealed and made stagnant to reduce losses. A wooden flap is hinged at the inlet of the air heater to control the inlet opening. The brick frame built to support to absorber plate divides the airflow passage through the air heater into the channel to provide the smooth passage for the air along the length. Experiments in the rainy season showed that the maximum ambient temperature was 39°C and the temperature inside the dryer was 51°C at noon.

Solar Tent Dryer

A simple solar dryer can be constructed in form of a tent with frames, of bamboo, sticks or wood, commonly called solar tent dryer. This equipment was developed first in bangladash and has been tested with variable results in many countries including Africa, Asia and Latin America (Olokor, 1997). The frame is covered with black or transparent plastic film (or both) to produce an enclosure with openings at the top and bottom. Fish is laid on racks inside the solar dryer. The black plastic film absorbs the heat energy from the sun while in the transparent type; the radiation comes directly into the tent and is absorbed by the black surfaces such as black zinc, black wood or black stones at the base. Cool air enters the dryer through the bottom openings, while the top opening allows the heated air to flow out after it had circulated around the fish.

Forced Convection Solar Drying

Solar Tunnel Dryer

Solar tunnel dryer was developed at the University of Hohenheim, Germany in the early eighties for small scale production of dried fruits, vegetables, spices, fish etc. This type of dryer has been widely tested and attained economic viability. A low cost version of this drier has been designed at Bangladesh Agricultural University, Mymensingh, Bangladesh and the pictorial view of the dryer under construction The design of the solar tunnel dryer has been further improved and tested by Janjai (2004) at Silpakorn University at Nakhon Pathom in Thailand. The dryer still consists of two parts, namely the solar collector part and the drying part similar to the original version. Instead of using PE plastic sheet, the roof of the new design dryer is made of polycarbonate plates fixed with the side walls of the dryer. The plate has an inclination angle of 5° for the drainage of rain. As loading of products to be dried cannot be done from the top of the dryer, rectangular windows were made at the side wall of the drying part for loading and unloading products. Back insulation was made of high density foam sand witched between two galvanized metal sheets. A 15 watt-solar cell module was used to power a dc fan for ventilating the dryer. The collector part and the drying part have the area of 1.2×4 m^2 and 1.2×5 m^2, respectively. In the solar collector the drying temperature is heated up to 60 ^0C which is the optimum drying temperature for most fruits. The standard size of the drier is 20 m^2 m with 20 m^2 of drying area. The capacity of the drier is mainly influenced by the size, shape and moisture content of the fruits/fish to be dried. The loading capacity ranges from 120 to 150 kg of fresh fruits/fish.

Greenhouse Solar Dryer

A pv-ventilated greenhouse solar dryer was developed at Silpakorn University (Janjai, 2004).The dryer essentially consists of a parabolic shape greenhouse with a black concrete floor with an area of 5.5×8.0 m^2. The parabolic shape can withstand well the tropical rain and storm. The roof of the dryer is covered with polycarbonate plates. The floor of the dryer is made of concrete mixed with black powder paint to serve as a basement of the dryer as well as solar radiation absorber. The loading capacity of the PV ventilated greenhouse solar dryer is 100-150 kg of fresh chillies. Drying in the PV ventilated greenhouse results in considerable reduction in drying time (50%) and the quality of the dry products is high quality dried products in terms of color and texture. The roof-integrated solar dryer consists of a roof integrated solar collector and a drying bin with an electric motor operated fan to provide the required air flow. The bin is connected to the middle of the collector through a T- type air duct connection. The roof-integrated collector consists of two arrays of collector: one facing the south and other facing the north with a total area of 108 m^2. These arrays of these collectors also serve as the roof of the building. The roof-integrated collector is essentially an insulated black painted roof serving as an absorber which is covered with a polycarbonate cover.

REFERENCES

Akinola AO, Fapetu OP (2006). Exergetic Analysis of a Mixed-Mode Solar Dryer. J. Eng. Appl. Sci., 1: 205-210.

Akinola, OA, Akinyemi AA, Bolaji BO (2006). Evaluation of traditional and solar fish drying systems towards enhancing fish storage and preservation in *Nigeria. J. Fish. Int., Pak.,* 1(3-4): 44-49.

Banerjee, R. (2005). Capacity building for Renewable Energy in India. Proceedings of International congress on Renewable Energy (ICORE 2005), January, Pune India: 77-83.

Basunai, M.A. and Abe, T. (2001). Thin layer solar drying characteristics of rough rice under natural convection.Journal of Food Engineering(47)4:295-301 Biological Origin. ed. A.S.Mujumdar, 317-368. Science Publisher, Inc. Enfield.

Boits, E.D. (2010). Solar drying as an alternative to sundrying. 12(1-2):83-90 chimney for natural-circulation solar-energy dryers. *Renewable energy*; 10 (1): 22-25

B. K. Bala, Serm Janjai, (2009)"Solar drying of fruits, vegetables, spices, medicinal plants and fish: Developments and Potentials", in International Solar Food Processing Conference.

Danith, E.R. (2009).Factors affecting solar drying of Fish in the tropics. 9(3):20-24 *Development.Energy.*9(7): 545-55

Ekechukwa, O.V. and B.Norton. (1998). Review of solar energy drying systems II:an overview of solar drying technology,Energy Conservation and Management. 40:615-655.

Ekechukwu, O. V. (1998). Review of solar-energy drying systems I: An overview of drying principles and theory. *Energy Conversion and Management.* 40(6): 593-613

El-Sebaii, A. A., Aboul-Enein, S., Ramadan, M. R. I. and El-Gohary, H. G. (2002).Empirical correlations for drying kinetics of some fruits and vegetables.energy convention. Held on 1-3 December 1988, Hyderabad, India (Ed: V.V.N. Energy.27(9): 845-859

Farkas, I.(2004) Solar-drying of materials of biological origin. In: Dehydration of Products of biological origin. Ed. A.S. Mujumdar, 317-368 Sience publisher, inc. Enfield, USA.

Janjai, K.N. (2004) "Performance of a PV-ventilated Greenhouse Dryer for Drying Banana", *Asian Journal on Energy and Environment*, vol. 6(02), pp. 133-138.

Oak, T.K. (2007) "Opportunities to use renewable energy technology in rural korea", Department of Mechanical Engineering, korea.

Olokor, J.O., A.A. Eyo , M. Mdaihli, J.K. Okomoda and J.O. Ayanda (1997). Promotion of fish drying using solar energy in villages around Lake kainji In: proceedings of the 10th annual conference of the biotechnology society of Nigeria, Pp 221-229.

Ong, K.S. (1999). Solar dryers in the Asia-Pacific Region. Renewable Energy, 16: 779-780

Pangavhane, D. R., Sawhney, R.L and Sarsavadia, P.N. (2002). Design, development and performance testing of a new natural convection solar dryer. Energy, 27: 579-590.

Phoeun Sackona, Phol Norith, Romny Om, Pen Pornnareay, Bun(2005)

Proceedings of International congress on renewable Energy (ICORE), January, Pune India: 77-83.

Renewable and Sustainable Energy 2.

Senadeera W, Bhandari B, Young G, Wijesinghe B (2003) Influences of shapes of selected vegetable mater on drying kinetics duringfluidized bed drying, J. Food Eng. 58: 277-283

Sheana, N. S, Ratores T. and Jim N.M, (2010) "Performance evaluation of the semi cylindrical solar tunnel dryer for drying handmade paper", *Journal of Renewable and Sustainable Energy* 2.

Togrul I.T., Pehlivan D. (2004). Modelling of thin layer drying kinetics of under natural convection. *Journal of Food Engineering*, 47(4): 295-301.

Waewsak J, Chindaruksa S, Punlek C (2006). A mathematical modeling study of hot air drying for some agricultural products. *Thammasat Int. J. Sci. Technol.,* 11(1): 14-20.