International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 03 | Mar -2017 www.irjet.net p-ISSN: 2395-0072

Design and Construction of Solar Dryer for Drying Agricultural Products.

Prof. Pravin M. Gupta[1], Amit S. Das[2], Ranjit C. Barai[3], Sagar C. Pusadkar[4], Vishal G. Pawar[5].

[1]Assistant Professor,Dept. of Mechanical Engineering, J.D.C.O.E.M, Nagpur.
[2345]Students, Dept. of Mechanical Engineering, J.D.C.O.E.M, Nagpur.

Abstract-*The solar drying system utilizes the solar energy to heat up a air and to dry any food substance which is loaded, which is not only beneficial but also it reduces wastage of agricultural products and helps in preservation of agricultural products, but it also makes transportation of such dried product easily and promotes the health and welfare of the people. This paper presents the design and construction of a solar dryer for drying a agriculture product. The dryer is composed of solar collector (air heater) with the baffles and a solar drying chamber containing rack of four net trays both being assimilated together. The air allowed in through air inlet is heated up in the solar collector chamber and channeled through the drying chamber where it is utilized in drying (removing of the moisture content from the food substances or agricultural product which is loaded in it). The design was based on the geographical location which is Nagpur and meteorological data were obtained for proper design specification. Locally materials were used for the construction are wood, glass, aluminium metal sheet and net for the trays.*

Introduction

Drying is an excellent way to preserve foods. Drying was probably the first ever food preserving method used by mans. It involves the removal of moisture from agricultural product so as to provide a product that can be safely stored for longer period of time.

"Sun drying" is the earliest method of drying farm produce ever known to man and it involves simply laying the agricultural products in the sun on mats, roofs or drying floors. This has several disadvantage since the farm produce are laid in the open sky and there is greater risk of spoilage due to adverse climatic situation like wind, rain, moist and dust, loss of product to insects, birds and rodents; totally dependent on good weather and very slow drying rate with danger of mould growth thereby causing deterioration and decomposition of the product. The process also requires large area of land, takes time and highly labour intensive.

In solar drying, solar dryers are specialized devices that control the drying process and protect agricultural product from damage by insect, dust and rain. In addition, it takes up less space, takes less time and relatively inexpensive compared to artificial mechanical drying.The solar dryer can be seen as one of the solutions to the world's food and energy crises. With drying, most agricultural product can be preserved and this can be achieved more efficiently through the use of solar dryer.

Some Background to the Concept

Attempts to Harness Solar Energy

The idea of using solar energy to produce high temperature dates back to classical times. The solar radiation has been used by man since the starting of time for heating his domicile, for agricultural purposes and for personal uses. Reports abound in literature on the 18th century works of Archimedes on applying the sun's rays with flat mirrors; Antoine Lavoisier on solar furnace; Joseph Priestly on applying rays using lens. In the 19th century, improvement of solar distillation unit covering 4750sq meters of land, operated for 40 years and, generating 22712.47 liters of water from salt water per day has been reported. Also, John Ericson's work on conversion of solar energy into mechanical energy through a device, which produced 1hp (746 W) for each 9.3m^2 of collecting surface has also been reported.

Modern research on the use of solar energy started during the 20th century. Improveent include the invention of a solar boiler, small powered steam engines and solar battery, but it is hard to market them in competition with engines running on inexpensive gasoline. During the mid 1970's shortages of oil and natural gas, increase in the cost of fossil fuels and the reduction of other resources energize efforts in the United States to develop solar energy into a practical power source. Thus, interest was rekindled in the comparison to natural "sun drying", solar dryers generate higher temperatures, lower relative humidity, lower product moisture content and reduced spoilage during the drying process. Thus, solar drying is a better alternative solution to trapping of solar energy for heating and cooling, the generation of electricity and other purposes.

Capturing Solar Energy

Solar radiation can be transfer either into thermal energy or into electrical energy. This can be done by useing of thermal collectors for conversion into heat energy or photovoltaic collectors for conversion into electrical energy. Two main collectors are used to save solar energy and convert it to thermal energy, these are flat plate collectors and concentrating collectors. In this paper, significance is laid much on the flat plate collectors which are also known as non-focusing collectors.

Importance of Solar Dried Food

For centuries, people of different nations have been preserving fruits, other crops, meat and fishes by drying. Drying is also useful for hay, copra, tea and other income producing non-food crops. With solar drying being available everywhere, the presentability of all these farm produce can be greatly rising. It is worth noting that until around the end of the 18th century when canning was developed, drying was essentially the only method of food preservation.

The energy input for drying is less than what is required to freeze or can, and the storage space is minimal compared with that required for canning jars and freezer containers. It was further stated that the nutritional value of food is only nominal affected by drying. Also, food scientists have found that by decreasing the moisture content of food to 10 to 20%, bacteria, yeast, mold and enzymes are all protected from spoiling it. Microorganisms are effectively killed when the internal temperature of food reaches 150°F. The flavour and most of the nutritional value of dried food is protected and concentrated. Dried foods do not require any special storage equipment and are easy to transporting. Dehydration of vegetables and other food crop by general methods of open-air sun drying is not satisfactory, because the products deteriorate fastly.

Studies showed that food items dried in a solar dryer were exclusive to those which are sun dried when evaluated in terms of taste, colour and mould counts. Solar dried food are quality products that can be stored for extended periods, easily transported at minimum cost while still providing excellent nutritive value. This paper therefore presents the design nd construction of solar food dryer for drying agricultural product.

Material and Method

General Description of the Solar Dryer

The most commonly seen design types are of cabinet form (wooden boxes with glass cover), some types are even modified making use of cardboard boxes and non reflecting nylon or polythene.

For the design being considered, the greenhouse effect and thermosiphon principles are the theoretical basis. There is an air vent (or inlet) to the solar collector where air goes inside and is heated up by the greenhouse effect, the hot air rises through the drying chamber going through the trays and around the food, removing all moisture content and exits through the exhust fan at the top of cabinet.

The solar food dryer consists of two major compartment or chambers being integrated together:

1. The solar collector compartment, which can also be referred to as the air heater of system.
2. The drying chamber, designed to accommodate four layers of drying trays made of net (cheese cloth) on which the product (or food) are placed for drying.

Materials Used

The following materials were used for the construction of the domestic solar dryer:

1. Wood – wood was selected for for entire casing, because it is light in weight, easily available and cheaper in cost then other material.
2. Glass – we choose the glass for upper covering of the air heater chamber because it is easily allow the rays to go inside and heat the sheet and it resist the heat to go out side.
3. Aluminium sheet of 1mm thickness use to increase the temperature of air passing through the air chamber painted black with tar for absorption of solar radiation.
4. Net used for constructing the trays for placing the product in the drying chamber.
5. Nails,glue and silicon glue as fasteners and adhesives.
6. Insect net at air inlet and outlet to restrict the insect to enter inside the chamber.
7. Hinges and handle for the dryer's door and reflector.
8. Paint (black and brown).
9. Plan Reflecting mirrors (two).

Design Consideration

1. Temperature - The minimum temperature for drying food is 35°C and the maximum temperature is 65°C, therefore. 50°C and above is considered average and normal for drying fruits, vegetables, roots and tuber crop chips, crop seeds,etc.

2. The design was made for the optimum temperature for the dryer. T_0 of 65°C and the air inlet temperature or the ambient temperature of dryer was T1 = 35°C (approximately outdoor temperature).

3. Efficiency - This is defined as the ratio of the useful output of a product to the input of the product.

4. Air gap - It is suggested that for hot climate passive solar dryers, a gap of 10 cm should be created as air vent (inlet) and air passage.

5. Glass and flat plate solar collector – It suggested that the glass covering should be 4-5mm thickness. In this work, 5mm thick transparent glass was used. It also suggested that the metal sheet thickness should be of 0.8 – 1.0mm thickness; here a aluminium of 1.0mm thickness was used.

6. Dimension – It is recommended that a constant exchange of air and a roomy drying chamber should be attained in solar food dryer design, thus the design of the drying chamber was made as spacious as possible of average dimension of 50 × 47 × 45cm with air passage (air vent) out of the cabinet of 50 × 5cm^2.

7. Dryer Trays – Net(metal) was selected as the dryer screen or trays to aid air circulation within the drying chamber. Three trays were made of metal net. The tray dimension is 48 × 48cm.

8. Exhust fan of 12v is used to remove the air from the drying chamber.

The design of the dry chamber making use of wooden wall sides and a top protects the food to be placed on the trays from direct sunlight since this is undesirable and tends to bleach colour, removes flavour and causes the food to dry unevenly.

Design Calculations[7]

1. Solar Collector/Air Heater Angle of Tilt (β).

It states that the angle of tilt (β) of the air heater should be

$\beta = 10^0 + \text{lat } \phi$ ………………… (1)

were lat ϕ is the latitude of the collector location, the latitude of Nagpur where the dryer was designed is latitude 21.15^{0}N. Hence, the suitable value of β use for the collector:

$\beta = 10^0 + 21.15^0 = 31.15^0$

2. Insulation on the Collector Surface Area.

A research obtained the value of insolation for Nagpur i.e. average daily radiation H on horizontal surface as;

$H = 657 W/m^2$
and average effective ratio of solar energy on tilted surface to that on the horizontal surface R as;
R = 1.017
Thus, insulation on the collector surface was obtained as
$I_c = H_T = HR = 657 \times 1.017 = 668.17 W/m^2$ ………. (2)

3. Determination of Collector Area and Dimension.

The mass flow rate of air M_a was determined by taking the average air speed $V_a = 0.2 m/s$.
The air gap height was taken as 5cm = 0.05m and the width of the collection assumed to be 50cm = 0.5m.
Thus, volumetric flow rate of air
$V'_a = V_a \times 0.05 \times 0.6$
$V'_a = 0.2 \times 0.05 \times 0.5 = 5 \times 10^{-3} m^3/s$

Thus mass flow rate of air
$M_a = v_a \rho_a$ ……………………… (3)

Density of air ρ_a is taken as $1.28 kg/m^3$
$M_a = 5 \times 10^{-3} \times 1.28 = 6.4 \times 10^{-3} kg/s$
Therefore, area of the collector A_C
$A_C = (6.4 \times 10^{-3} \times 1005 \times 30)/(0.5 \times 668.17) = 0.57 m^2$

The length of the solar collector (L) was taken as;
$L = A_c/B = 0.57/0.6 = 0.95m$
Thus, the length of the solar collector was taken approximately as 1m.
Therefore, collector area was taken as $(1 \times 0.6) = 0.6 m^2$

4. Determination of the Base Insulator Thickness for the Collector.

The rate of heat loss from air is equal to rate of heat conduction through the insulation. The following equation hold for the purpose of the design.

$F m_a C_p (T_0 - T_i) = K_a A_c (T_0 - T_a)/t_b$ ……… (4)

$K = 0.04 Wm^{-1}K^{-1}$ which is the approximate thermal conductivity for glass wool insulation.
F = 10% = 0.1
$T_0 = 65^{\circ}C$ and $T_i = T_a = 35^{\circ}C$ approximately
$m_a = 6.4 \times 10^{-3} Kgs^{-1}$
$C_p = 1005 JKg^{-1}K^{-1}$
and $A_c = 0.57 m^2$

$t_b = [0.04 \times 0.57 \times (60-30)]/[0.1 \times 6.4 \times 10^{-3} \times 1005 \times (60-30)] = 0.0354 = 3.54cm$

For the design, the thickness of the insulator was taken as 7cm. The side of the collector was made of wood, the loss through the side of the collector was considered negligible.

5. Calculation of Heat Losses from the Solar Collector (Air Heater).

Total energy transmitted and absorbed is given by

$I_cA_c\tau_\alpha = Q_u + Q_L + Q_s$ .... (5)

where Q_s is the energy stored which is considered negligible therefore,

$I_cA_c\tau_\alpha = Q_u + Q_L$ .... (6)

Thus Q_L the heat energy losses

$Q_L = I_cA_c\tau_\alpha - Q_u$ .... (7)

Since

$Q_u = m_aC_p (T_0 - T_i) = m_aC_p\Delta T$ .... (8)

and

$Q_L = U_LA_c\Delta T$ .... (9)

then

$U_LA_c\Delta T = I_cA_c\tau_\alpha - m_aC_p\Delta T$ .... (10)

$U_L = (I_cA_c\tau_\alpha - m_aC_p\Delta T)/(A_c\Delta T)$ .... (11)

α was taken as 0.9 and τ = 0.86

$T_a = 0.774$

$U_L = (668.17\times0.57\times0.774 - 6.4\times10^{-3}\times1005\times30)/(0.57\times30) = (294.78 - 192.96)/17.1$

$U_L = 5.9 W/m^2{}^\circ C$

Therefore,

$Q_L = 5.9 \times 0.57 \times 30 = 100.8W$

This heat loss includes the heat loss through the insulation from the sides and the cover glass.

Construction

The solar food dryer was generally constructed by wood because it is easily available and light in weight and cost. Since the entire casing of wood only the top of air heater chamber is made of two 5mm glasses, the major construction works of project is carpentry works.

The following tools were used in measuring and marking out on the wooden planks:

- Carpenter's pencil.
- Steel tapes (push-pull rule type).
- Steel meter rule.
- Vernier caliper.
- Steel square.
- Angle plate.
- Scriber.

The following tools were also used during the other construction;

- Hand saws (crosscut saw and ripsaw).
- Jack plane.
- Wood chisel.
- Hammer.
- Mallet.
- Pinch bar and pincers.
- Electric cutter machine.

The construction was generally made with simple butt joints using nails as grapnel and glue (adhesive) where necessary. The construction was sequenced as follows for the wood work.

- Marking out on the planks to cut into desired shape size.
- Cutting out the already marked out parts properly.
- Planning of cut out parts to smoothen the surfaces.

Combining and fastening of the cut out parts with nails and glues.

The metal sheet used was Aluminium of 1mm thickness. It was cut to the size of 100×50cm to minimize the top heat loss. It was painted black color for maximum absorption and radiation of heat energy. The aluminium sheet, together with the insulator of 5mm thickness, was placed inside the air heater (solar collector) compartment.

The glass was cut into size of 100 × 50cm size and two of these were required. One as the solar collector's cover. The glass used was clear glass with 5 mm thickness.

The trays were made of steel net and steel net to permit free flow of air within the drying cabinet chamber and also geeting heatup. Three trays were used with average of 7cm spacing arranged vertically one on top of the other, the tray size was 48 × 48cm.

The interior of the solar food dryer was insulated by heatlon sheet on this aluminium casing was placed and sheet was painted black with tar to promote adsorption of heat energy while the exterior was painted brown to minimize the adverse effects of weather and insect attack on the wood and also for aesthetic appeal.

Two reflecting mirrors are used to reflect the sun rays on the glass properly on 135° and 120° angles for proper reflation, the thickness of mirrors are 3.5mm they are sticked by silicon glue. Exhust fan of 6inch diameter and 12v was used to remove the moist aire from the chamber properly.

IMAGES OF SOLAR DRYER

1.1 Side view of Solar Dryer

1.2 Front view of Solar Dryer

1.3 Back view Of Solar Dryer

1.4 Drying Chamber with Trays

Conclusion

Solar radiation can be highly effective and utilized for drying of agricultural product in our environment if proper design is carried out. This was demonstrated and the solar dryer designed and constructed expressed sufficient ability to dry agricultural produce most especially food items to an appreciably reduced moisture level.

Locally available cheap materials were used in manufacturing of solar dryer making it available and affordable to all and specially for farmers. This will go a long way in reducing food wastage and at the same time food shortages, since it can be used extensively for majority of the agricultural food crops. Apart from this, solar energy is required for its operation which is readily available in the tropics, and it is also a clean type of energy. It protects the environment and consume cost and time spent on open sun drying of agricultural produce since it dries food items faster. The food items are also well protected in the solar dryer than in the open sun, thus reducing the case of pest and insect attack and also contamination.

However, the performance of existing solar food dryers can still be improved upon especially in the aspect of reducing the drying time and probably storage of heat energy within the system. Also, meteorological data should be easily available to users of solar products to ensure maximum efficiency and effectiveness of the system. Such information will probably guide a local farmer on when to dry his agricultural product and when not to dry them.

References

[1]. Scalin D., *The Design, Construction and Use of an Indirect, Through-pass, Solar Food Dryer,* Home Power Magazine, 1997, 57, p. 62-72.

[2]. Whitfield D.E., *Solar Dryer Systems and the Internet: Important Resources to Improve Food Preparation,* 2000, Proceedings of International Conference on Solar Cooking, Kimberly, South Africa.

[3]. Nandi P., *Solar Thermal Energy Utilization in Food Processing Industry in India,* Pacific Journal of Science and Technology, 2009, 10(1), p. 123-131.

[4]. Ayensu A., *Dehydration of Food Crops Using Solar Dryer with Convective Heat Flow*, 2000, Research of Department of Physics, University of Cape Coast, Ghana.

[5]. Sukhatme S.P., *Solar-Energy-Principles of Thermal Collection and Storage,* Tata McGraw Hill Publishing Company Limited, 1996.

[6]. Olaleye D.O., *The Design and Construction of a Solar Incubator,* 2008, Project Report, submitted to Department of Mechanical Engineering, University of Agriculture, Abeokuta.

[7]. Olayinka ADUNOLA, *Design and construction of a Domestic Passive Solar Food Dryer,*2014, department of mechanical, Nigeria