Design and Construction of Solar Food Dryer

Experimental Setup for drying Bombay Duck

Mr. Vinit V. Nair
Assistant Professor, Department of Mechanical Engineering
Don Bosco Institute of Technology, Kurla (W)
Mumbai, Maharashtra, India.
vinit.v.nair@gmail.com

Valency Colaco
Student, Department of Electronics & Telecommunication
Don Bosco Institute of Technology, Kurla (W)
Mumbai, Maharashtra, India.
valencycolaco@yahoo.in

Rahul Fernandes
Student, Department of Electronics & Telecommunication
Don Bosco Institute of Technology, Kurla (W)
Mumbai, Maharashtra, India.
rahul_ralf@yahoo.com

Jacqlyn Monteiro
Student, Department of Information Technology
Don Bosco Institute of Technology, Kurla (W)
Mumbai, Maharashtra, India.
jacqlyn.monteiro@gmail.com

Amit Inamdar
Student, Department of Computer Engineering
Don Bosco Institute of Technology, Kurla (W)
Mumbai, Maharashtra, India.
inamdar44@gmail.com

Anjaneya Shetty
Student, Department of Computer Engineering
Don Bosco Institute of Technology, Kurla (W)
Mumbai, Maharashtra, India.
shettyanjaneya@gmail.com

Siddharth Singh
Student, Department of Computer Engineering
Don Bosco Institute of Technology, Kurla (W)
Mumbai, Maharashtra, India.
sidthakur955@gmail.com

***Abstract*—A solar dryer is a device which makes use of solar heat energy to dry foodstuff like fruits, fish, etc. more effectively and in a controlled fashion. Keeping in mind the energy crisis faced by mankind and issues of climatic change, need for alternative sources of energy is recognized. India's high solar insolation promises alternative energy source for the future. Of the various solar appliances, solar dryer has been opted to harness the solar energy for food drying. In the traditional method of drying open in sun, the food normally gets contaminated by insects and dust. A solar dryer ensures quick drying and keeps the food contamination-free.**

Keywords—moisture content, drying efficiency, solar collector area, thermosiphon, dryer, dehydrator.

I. INTRODUCTION

As per the data of year 2005, India's electricity production as contributed by fossil fuels was nearly 66.3 percent. Small yet significant contribution to electricity production in India is now being done by nuclear power and renewable sources. The sun's power on earth read is $1.8 * 10^{11}$ MW which if intercepted can trapped can curb future energy crisis [3]. Thus solar power is the most promising unconventional energy source.

Drying of food products helps in removing moisture and preserves it for longer duration of time. The issue with the conventional methods of food dehydration is that it needs more space to dry in open sun. Also, the open air drying leads to contamination of food by insects and also by dust [4]. This reduces the food quality and thus the rate. This is why open sun drying of commercial food products in large quantities is not easily possible as the quality check then becomes an important parameter. In contrast to open air drying, the solar dehydration method uses air heated by solar energy. The principle of the solar drying technique is to concentrate solar radiation by heating up the incoming air in solar collectors and transfer the hot air to an enclosed food drying section. Also, at times, the food may appear properly dried, but may still be moist inside. This type of half dried food will get degraded over time. Thus the food item should be properly dried in the optimum possible time. This trade-off between moisture and moisture clogging with respect to time must be taken into account while designing any such system. Thus the dryer designed for a particular food product may not hold good for other food products as the moisture content and ease with it gets removed may vary from one food product to other.

In the example of drying fish like Bombay duck; during the initial drying process, the fish may appear perfectly dried, i.e., the outer surface may have a perfect glossy finish, but the inside may still be moist. This internal moisture may spoil the fish. A solar drier can deliver perfectly dried food with the optimum drying time.

II. DESIGN FACTORS

The following points have to be taken into account for designing of a forced/natural convection solar drier, (considering good amount of sunlight per day)

- The amount of moisture loss
- Total solar exposure during daytime (time factor).
- Quantity/Volume of air needed for drying.
- Solar radiation per day to determine solar energy.
- Wind speed for the air inlet vent dimensions.
- Dimensions of the Dryer
- Cost Factor
- Automation (Advanced Levels)

III. WORKING PRINCIPLE

The commonly seen dryer types are cabinet shaped (wood boxes with glass/plastic cover). For the design, the thermosiphon and greenhouse phenomenon have to be taken into account. There is an air inlet/vent to the collector where the incoming air enters, gets heated, the hot air is transferred to the food drying chamber, dehydrating it and exiting from the air outlet mostly placed near the top. The heated air acts as the main drying factor as it extracts the moisture from the food item. The moist air flows out of the air outlets. If the process has no mechanical device to control the air flow, it is called natural convection, else it is called forced convection. The solar dehydrator consists of two compartments being integrated together,

- The solar collector.
- The drying chamber, to accommodate the food item.

For advanced upgrades, heat distribution can be controlled by using fans, Food quality can be maintained by using a sensor network, all these powered by a microcontroller. The controller can be powered by solar panels to make the product more eco-friendly.

IV. DESIGN CONSIDERATIONS

- **Temperature** - Here, we must consider the minimum and maximum drying temperature of the food item. An average of those temperatures would be the ideal drying temperature. The internal temperature of the air vent/inlet is taken as the ambient temperature, i.e., 27°C to 30°C

- **Product/Device Efficiency** - Defined as the ratio of the device output parameters to the device input parameters keeping some predetermined parameters constant.

- **Air gap** - For hot climate solar dryers, a gap of 10-20 cm is recommended for the air inlet/vent.

- **Flat plate solar collector** – The glass covering should be 4-5 mm thick (Check the reflective properties of the glass material). The metal sheet must have a thickness of about 1.0 – 1.2 mm. The metal sheet is painted black to absorb maximum solar radiation and heat up the incoming air. The glass area depends on the collector area and is calculated as the product of length * breadth.

- **Dimension** – For the continuous exchange of air, the design of the food drying compartment should be made as spacious considering the requirement. The drying compartment was covered with glass/plastic tilted at the same angle with that of the collector. This is useful to keep the internal temperature within the drying compartment constant due to the greenhouse phenomenon.

- **Dryer Trays** - Cloth/Metal mesh should be used as the food tray material to help in the circulation of air within the drying compartment.

V. DESIGN CALCULATIONS

- **Angle of Tilt (β):** The angle of tilt (β) of the collector is given by the following expression,

$$\beta = 10^0 + \text{lat}\ \phi$$

Where lat ϕ is the latitude where the dehydrator will be designed and tested.

- **Collector Solar Insolation:**

The values of insolation for a particular location i.e. average daily radiation (H) on a horizontal surface and the average effective ratio of solar energy on a tilted surface to that on the horizontal surface (R) should be determined. Therefore, the solar radiation energy (insolation) on the collector surface is given by the following expression,

$$I_c = H_T = H*R$$

- **Collector Area with Dimensions**: The mass rate of flow of air M_a was determined using the average air speed value (V_a). The air gap was taken as 10-20 cm and the width of the collector is assumed as a suitable value. Thus, volumetric flow rate of air is given by,

  $$V'_a = V_a \text{ x (air gap area) x (collector area)}$$

  Thus mass rate of flow of air: $\mathbf{Ma = v_a \rho_a}$. The density of air ρ_a is usually taken as 1.28 kg/m^3

  Therefore, area of the collector (A_C) which is a function of Volume of air, Pressure, Specific Heat Capacity Ambient Temperature, Solar Insolation and Food tray size.

  $$A_C = (M_a \times C_p \times \text{Temperature})/(\text{Air Inlet Dimension} \times I_c)$$

Therefore, length of the collector (L) was taken as, $L = A_c/B$
And, collector area was taken as, $A = L^2$

Collector Heat Loss Determination:

- Total transmitted and absorbed energy is given by
  $I_cA_c\tau_\alpha = Q_u + Q_L + Q_s$

  where Q_s is the stored energy(negligible). Therefore,
  $I_cA_c\tau_\alpha = Q_u + Q_L$

- Thus Q_L the heat energy losses, $Q_L = I_cA_c\tau_\alpha - Q_u$

- Since, $Q_u = m_aC_p (T_0 – T_i) = m_aC_p\Delta T$ and $Q_L = U_LA_c\Delta T$
  then , $U_LA_c\Delta T = I_cA_c\tau_\alpha - m_aC_p\Delta T$

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

- This loss equations cover the insulation heat loss from the side plates and the glass[1-2].

ACKNOWLEDGMENT

We extend our gratitude to Fr. Adolf for his sincere support in the completion of our project. Our very sincere thanks to our project guide, Dr. Prasanna Nambiar and Mr. Vinit Nair Sir for motivating, co-operating and guiding us throughout the project work with their effective skills and huge knowledge base. We would like to thank Mr. Royal D'sousa, Head of NSS and Dr. Amiya Kumar Tripathy, Conference Chair for their continuous valuable guidance, support, suggestions and their precious time in every way throughout the project activity.

CONCLUSION

Solar radiation can be efficiently used for dehydration of food products in our environment if proper design is in place. The food items are well protected inside the dryer compared to the open air, reducing insect attacks, theft and also direct contamination. It should be duly noted that the action of existing solar food dehydrators can still be optimized depending on the aspect of time required for drying and accumulation of heat energy in the system. Also, climatic data should be easily available to designers of any solar products to ensure optimum efficiency of the system/product.

REFERENCES

[1] Fisk M.J., Anderson H.C., "*Introduction to Solar Technology",* Massachusetts, Addison-Wesley Publishing Company Inc., 1982

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

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

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