Design and Fabrication of Efficient Solar Dryer

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Abstract - *Crop drying is the most time consuming and energy-efficient process of all agricultural processes. The drying purpose is to remove moisture from the agricultural product so that it can be safely processed and stored for longer periods of time. In order to prevent decomposition by inhibiting fermentation, crops are dried before storage or during storage. Because of inefficient handling and poor implementation of post-harvest technology, two hundredths of the world's grain production are lost once harvest. Grains and seeds are usually harvested at a level of humidity.*

Depending on application and market requirements, these must be dried to a higher level. After harvesting a cereal crop, it may need to be stored for a while before it can be sold or used in the form of feed. This work is aimed at developing an efficient solar dryer in which grains are dried by means of solar radiation via transparent walls and the cabinet roof, controlling the heat required to be dried for a given product. If the solar dryer is designed to overcome the restrictions of the direct and indirect kind of solar dryer, the problems of low and medium scale dryer can be corrected.

This work will therefore be based on the importance of a reliable and economical mixed - mode efficient solar dryer. The work's objective is to build a solar dryer with efficiency in a mixed mode using local materials and to evaluate the solar dryer's performance.

***Key Words*: Agriculture, Moisture, Efficient, Foldable, Portable, Heat, Economical.**

1. INTRODUCTION

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1.1 Literature survey:

Solar energy is a renewable, non-conventional and a free energy resource. It is one of the most reliable, efficient and effective non-conventional energy resource alternatives available. This resource if used in a large scale can be used to preserve non-renewable energy resources and can cut down the cost that is included in systems that run on non-renewable fuels. The major disadvantage of solar energy is the lack of its availability at all times i.e., unavailability during night; it is seasonal and varies from region to region. However, these problems can be solved by storing the energy when available excessively and utilizing it when the resource is not available.

Solar energy in solar thermal or solar photovoltaic mode is environmentally friendly. Numerous solar thermal uses of solar energy are available; the drying process is one of the biggest uses of solar thermal energy. Drying involves reducing the moisture of a product so that a product with different characteristics than the first one is obtained.

Dehydration is one of the oldest techniques for the storage of foods or agricultural products. About 20% of the total product is lost in our country due to inefficient storage. Once a crop is harvested, it cannot be immediately marketed so that the crop must be kept for a given amount of time.

The storage span depends mostly on the post processing and storage facility. The major losses in pulses and certain seeds are mainly due to the presence of moisture content after harvest. Some of these crops contain up to about 40% moisture content and to store these crops the moisture content must be reduced up to 11% depending on the application.

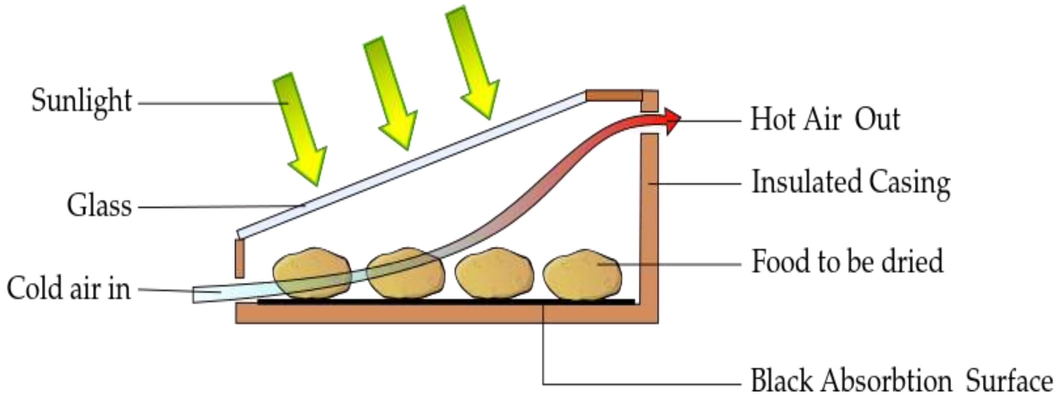
Today, thanks to their energy and cost saving properties, solar drying systems are widely used in many countries around the world. They are highly suitable for agricultural crop processing with low cost and stable performance by the use of the free and available renewable energies. The drying rate in solar drying depends on external factors that are not controlled, such as solar radiation, environmental air temperature, wind velocity and relative humidity. It also depends on the characteristics of the substrate, such as the initial moisture, physical properties and the exposed surface of the drying air. Direct exposure to sun is a very simple drying technique for open-air drying or direct solar drying, but it does not allow weather conditions to be administered, and thus does not produce homogeneous and good quality products.

Furthermore, as food is exposed to radiation without protection, insect, dust and microorganism contamination is frequent. With indirect solar driers, some of these disadvantages can be prevented. There are more benefits in indirect solar dryers where air is heated by passing the solar panel and entering a drying chamber such as drying capacity, effectiveness, preventing the colorations of crops because of direct exposure to sunlight, better humidity, etc. In this indirect solar dryer. The impediment remains, however, to changes in solar radiation.

There are two types of solar dryers in controlled drying or indirect solar dryers, free convection solar dryer and forced convection solar dryer. In free convention solar dryers, the air flow takes place naturally where as in forced convection solar dryer there is an electric fan that forces air flow. It is observed that forced convection dryers are more efficient than free convention dryers but forced convection dryers require electric supply which is not always available in rural areas. This problem can be solved by providing power to fan through solar panels.

Accumulation or storage of thermal energy enables the use of the solar energy during low or null periods of radiation. Sensitive storage and/or phase change heat can accumulate this energy. Due to its high heat density and a minimum variation of temperature during loading and discharge periods, heat changes have advantages. The use of PCMs in recent years to store solar energy in industrial and home applications has received considerable attention.

The latent thermal system heat stores energy during melting and transmits it when PCM is solidified. These materials are categorized as PCM organic and inorganic. Organic PCM has the benefit of maintaining its properties regardless of how many times they are melted or solidified. A new chamber geometrical structure needs to be redesigned to upgrade the drying system for high-value drying products to a higher quality. In addition, variations in the solar event, the moisture and temperature of the environment have a strong impact on the drying state.



1.2 Objectives:

All the solar dryers designed and fabricated were not investigated further for its actual work and efficiency. It is also clearly revealed that it requires a new approach and modified design so that it can be used efficiently and will be made use full in all rural as well as the urban usage in common. With this as the main objective the present work will be carried out with following objectives:

1. Improvement in design and quality.
2. Improvement in material selection.
3. Improvement in hygiene.
4. Variety of ingredients drying options.
5. Economical and Portable.
6. Improved storage capability.
7. Controlled drying compared to the existing dryers.

2. MATERIALS AND METHODOLOGY

2.1 Material consideration factors

In selecting engineering materials for the production of equipment, the factors considered were:

I-Manufacturing cost.

II - Mechanical properties (i.e. stress, creep, fatigue etc.) of materials.

III - Robustness to corrosion.

IV - Easy to manufacture (for example forming, nailing, bending, cutting, etc.).

V - Requirements for service.

Solar dryer is a device that uses a naturally available conventional form of energy to undertake some useful work. To attain maximum efficiency, one must be able to attain best physical conditions possible to be attained which demands the use of high-quality parts to be used for the production process. Although this process increases the initial cost considerably the cost is justified by the improvement in efficiency and the useful work developed. The capital invested in the process is well justified after a period of time as the effectiveness of the process is improved and the durability of the materials used ensures a prolonged lifespan of the product.

Conventional solar dryers also pose the problem of immobility and bulk. To overcome the posing problem the chassis of the structure is built with the help of aluminum. Aluminum along with its light weight also carries certain useful properties such as non-corrosiveness which is very essential in a solar dryer, as the frame is often exposed to high humidity conditions and the use of oxidizable metals can cause critical damage and also the failure of the structure. Aluminum is also a great conductor of heat; this property of aluminum is extremely helpful as the frame is in contact with either the product that needs to be dried or other parts of the dryer that can accumulate heat. Along with these properties aluminum is also durable and long lasting which promises the products long lasting life. To overcome the problem of immobility the frame is made portable but if the transparent materials used in the product are made of glass or other fragile materials chances of damage to the products are high, so transparent polymers such as polythene, hilum sheets and acrylic sheets are used in the production of this structure. These polymer sheets other than providing transparency equal to glass sheets are also quite flexible which promises it to be extremely durable and its flexibility also contributes to the ease of transport. Polythene sheets are used instead of glass cover to reduce the weight of the product and naturally the polythene sheet can be easily unzipped and removed before transporting the product from one point to another and also the shelves are made detachable to avail mobility.

The beading is preferred to be wood, as polymer materials are used for shelves and usage of metal as beading can cause formation of creases and can eventually cause damage to the shelves. The interior of the structure is painted black to absorb heat. The most economical materials that meet both the mechanical and the process requirements have also been taken into consideration during the working life of the solar dryer, making loosening, maintenance and replacement easy. Finally, adequate strength was guaranteed and simply worked with the materials chosen.

2.2 - Design and development of solar dryer

A solar dryer is a device that uses solar radiation as a source of heating the product and the air surrounding the product and there by achieving moisture removal by the process of convection. The process of moisture absorption mainly depends on the temperature of the air and the moisture content already present in the air per unit mass viz. absolute humidity of air. Dryers already available in the market are of several types based on the methods which are used to dry the products such as electric dryers, fuel-based dryers, solar dryers etc. Solar dryers are mostly used where lesser amounts of heat is required for drying they are used for large scale drying however the dryers in use face certain challenges trying to solve which stands the current design of the project.

A solar dryer consists of a transparent layer enclosing a closed chamber where heat is trapped due to the energy transfer from the solar radiations and a solution for the maintenance of low humidity of air. There are two solutions to the humidity problem which are:

1. Chemical method
2. Mechanical method

Chemical method includes equipping the solar dryer with deliquescent chemicals such as silica gel. Although this process is efficient and can enable high cooling rates it also requires constant changing of the chemical to ensure faster cooling of the product. Therefore, the mechanical solution is incorporated in most of the solar dryers. Which may include providing vents for the circulation of air, or forced and controlled circulation of air with the help of exhaust fans which not only helps in circulation of air but also in regulation of temperature in case of excess heating conditions.

If a body encloses a larger volume it also means that there is a larger space for the heat to escape but if there is lesser space then the objective of bulk drying is not achieved. The dryer must contain a smaller volume with greater surface area for the products to be placed within the confined space hence the dryer is incorporated with transparent shelves at various elevations which not only help in bulk drying but also provide transparency which contributes in improving the overall thermal efficiency.

Solar dryers in spite of all the advantages over conventional open sun drying is not widely used mainly because it occupies a lot of floor space and mostly is a permanent setup and cannot be moved around easily to overcome this problem the dryer must be designed to be smaller in size and portable. Current solar dryers are not portable because they are very large in size and require a lot of effort to setup and made of materials that are heavy and fragile.

To achieve this portable solar dryer that is ideal for bulk drying with detachable or foldable or the combination of both and must be easy to assemble is fabricated. This can be achieved by the use of light, durable, rugged materials which are not affected by moisture and a design which enables easy setup of the product. The dryer designed contains exhaust fans at the absolute bottom walls which causes cooling effect at the bottom layers of the dryer whereas the heated air trapped at the upper layers cause a higher temperature at the top shelves which produces various temperatures at various shelves within the same dryer this enables the user to dry different products on different shelves based on their temperature requirements.

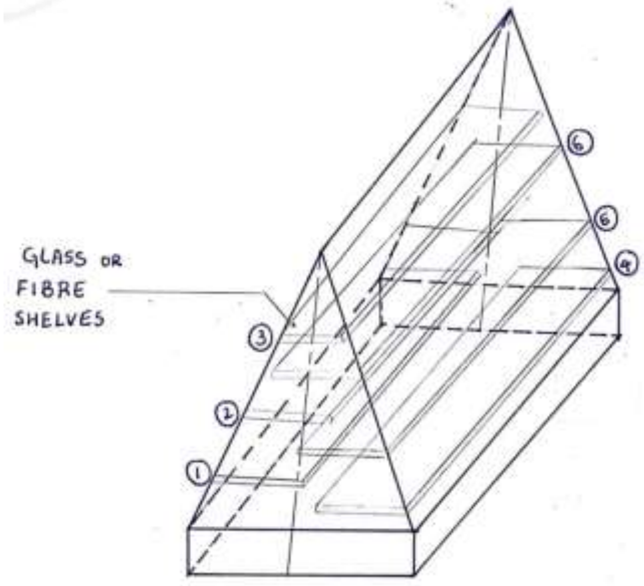


Figure-2: Drawing of solar dryer

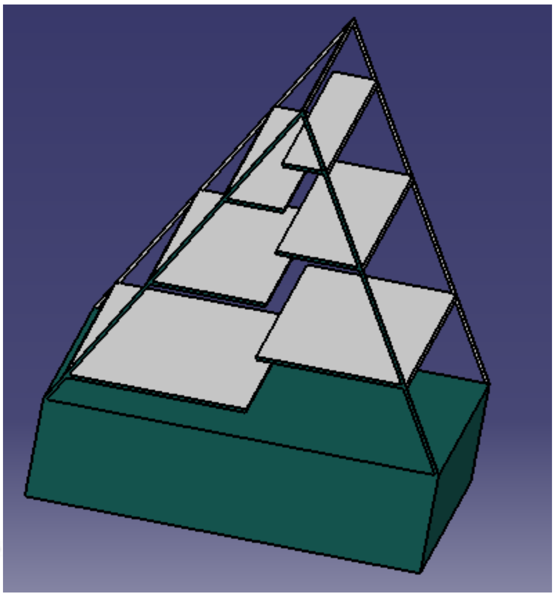


Figure 3: Solar Dryer CAD Model

3. Fabrication Procedure

- The Dryers available are either fixed at one place or portable from one place to another by help of large vehicles.
- Our main objective is to fabricate a dryer which is easier to transport. Hence, According to the developmental design the dryer is made foldable.
- The foldable chassis and outer frame of the dryer was fabricated using aluminium pipe.
- Appropriate angles were maintained to increase the efficiency i.e., maximum solar energy is being utilized by all the shelves.
- Side panels are fabricated by using aluminium sheets for the required length of the frame.
- The shelves were made and heat resistant Acrylic sheets as per the design.
- The whole assembly is covered using the polythene sheets to increase the heat flow inside the chamber.
- The inner part of is coloured black to increase the inner temperature.
- Each shelf temperature is monitored by the temperature sensors and can be controlled effectively.

4. WORKING OF THE INSTRUMENT AND TEMPERATURE OBTAINED

- It is observed from the table that the maximum temperature is attained during the time period of 02:00 pm to 04:00 pm.
- Ingredients kept for drying from the morning can attain zero moisture level if the same temperature is maintained for 2 to 3 hours depending upon the objects used for drying.
- Betel leaves, jackfruit seeds, papads were dried within a span of 2 hours.
- Ingredients kept for drying weren't affected by rain due to the covering of polythene sheet.

Table 1: Variation in temperature at different shelves at different times.

SL.NO	TIME	SHELF 1	SHELF 2	SHELF 3	SHELF 4	SHELF 5
1	07:00 am	33.48	34.56	34.23	33.17	34.11
2	08:00 am	39.23	38.24	38.10	41.66	40.28
3	09:00 am	47.85	43.96	43.58	42.97	41.50
4	10:00 am	47.88	46.39	46.53	44.92	45.90
5	11:00 am	52.32	50.06	50.27	51.47	49.73
6	12:00 pm	55.67	53.51	54.03	55.92	52.18
7	01:00 pm	60.55	58.11	59.77	63.96	54.69
8	02:00 pm	**65.72**	**62.39**	**63.88**	**64.77**	**61.66**
9	03:00 pm	**72.84**	**69.59**	**70.25**	**72.96**	**70.09**
10	04:00 pm	**82.56**	**83.05**	**83.00**	**83.02**	**79.59**
11	05:00pm	45.90	44.92	44.52	46.39	46.02
12	06:00 pm	32.52	31.06	31.78	32.63	30.41

The graphical representation of the variation in temperature at various shelves is as shown in the graphs in Fig: 13 and 14

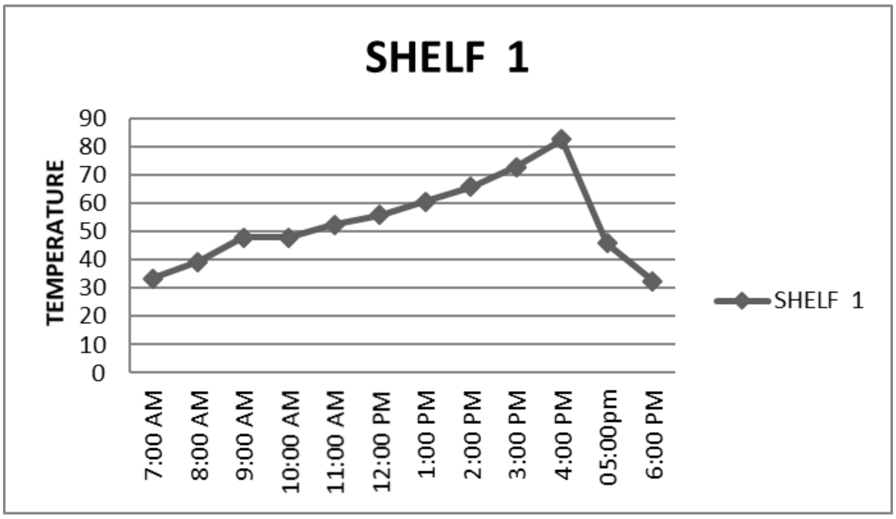


Figure-13

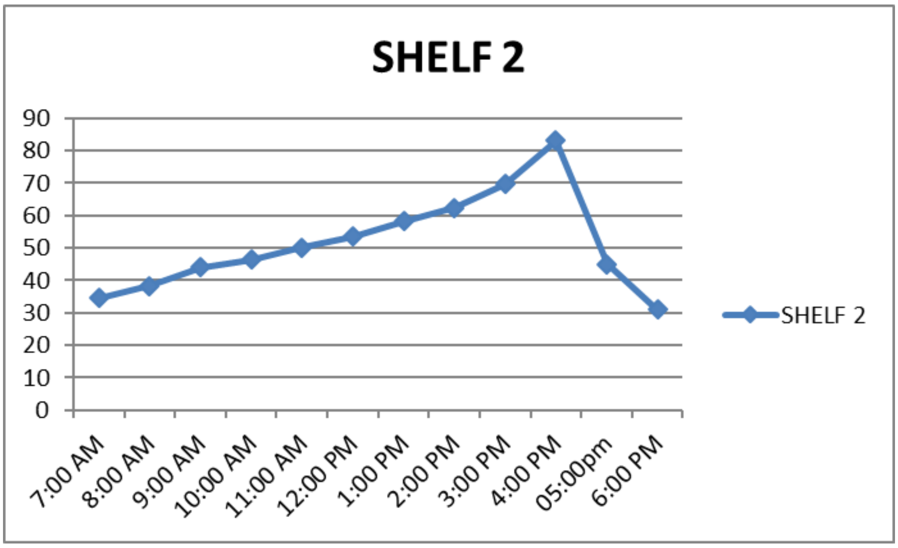


Figure-14

CALCULATIONS

Basic Theory (Formulations):

The total water mass evaporated from the food product can be calculated as,

$$W = \frac{m_p - m_s}{m_p} 100\%$$

Where:

W = percentage of moisture content lost;

Mp = initial mass of the food item;

Ms = mass of food item after drying;

Table 1: Typical results of a day of Papad humidity loss

The analysis consists of readings of weight of a single papad measured before and after drying it in the dryer and as follows,

Time	Item Initial Mass (g)	Item Dried Mass(g)	% Moisture Loss
9 hours	25	10	60

5. RESULTS AND DISCUSSION

- The equipment can be used to dry all types of agricultural produce and increases the shelf life of agricultural produce.
- Equipment can also be used by small home industries effectively for drying the food stuff etc. before marketing.
- The dryer is foldable and hence easily portable.
- According to the testing of the equipment, ingredients kept inside dried faster compared to the open air drying and the temperature attained is as given in table 1.
- 60% moisture level is lost during a span of 9 hours whereas it takes up to 2 days in open air drying condition.

6. CONCLUSIONS

- Efficient solar dryer is designed and fabricated.
- Ingredients dried are more hygienic than open air drying.
- The equipment is capable of drying the ingredients in almost half the time taken to dry in open space.

- More than double the atmospheric temperature is achieved to dry the ingredients.

ACKNOWLEDGEMENT

The authors can acknowledge any person/authorities in this section. This is not mandatory.

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