Paper ID: NITETMECH38

DESIGN AND FABRICATION OF A SOLAR DRYING SYSTEM FOR FOOD PRESERVATION

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ABSTRACT

Drying crops by solar energy is of great economic importance the world over, especially in India where most of the crops and grain harvests are lost to fungal and microbial attacks. Proper drying could easily prevent these wastages, which enhances storage of crops and grains over long periods. India is blessed with abundant solar energy all the year round. Drying is one of the important and most energy consuming processes in the food-processing, chemical, printing, fabric dying industries, etc. In farmer level drying is being done on open yards without any good hygienic conditions. Generally thermal energy, maintained between 45 0C to 25 0 C depending on the products and production methods. A conventional fuel like electricity, firewood, diesel, furnace oil, kerosene, etc is producing that energy. The objective of this project is to modify design of a forced convection indirect solar dryer and its performance test on Grapes. The system consists of an air heating section. The solar dryer consists of different components such as solar panel, battery, heating element and blower. The blower is used to passing the hot air to the required place, so that the moisture contents in the place was removed. It offers a better control over drying and the product obtained is of better quality than sun drying. Solar Dryer Can be operated at higher temperature, recommended for deep layer drying.

KEY WORDS: Solar energy, Solar dryer, Grape drying, Agriculture produce, Optimum temperature.

INTRODUCTION

Energy is the most important need of today's society and economy. Our work, leisure, and our economic, social and physical welfare all depend on the sufficient, uninterrupted supply of energy. The energy demand continues to grow, year after year. Drying is one of the methods used to preserve food products for longer periods. The heat from the sun coupled with the wind has been used to dry food for preservation for several thousand years.

Sun drying is still the most common method used to preserve agricultural products in most tropical and subtropical countries. However, being unprotected from rain, wind-borne dirt and dust, infestation by insects, rodents and other animal, products may be seriously degraded to the extent that sometimes become inedible and the resulted loss of food quality in the dried Products may have adverse economic effects on domestics and international markets.

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. Solar air heaters are simple devices to heat air by utilizing solar energy and it is employed in many applications requiring low to moderate temperature below 80°C, such as crop drying and space heating.

In ancient times, the sun and wind would have naturally dried foods. Evidence shows that Middle East and oriental cultures actively dried foods as early as 12,000 B.C. in the hot sun. Later cultures left more evidence and each would have methods and materials to reflect their food supplies—fish, wild game, domestic animals, etc.

Vegetables and fruits were also dried from the earliest times. The Romans were particularly fond of any dried fruit they could make. In the Middle Ages purposely built "still houses" were created to dry fruits, vegetables and herbs in areas that did not have enough strong sunlight for drying. A fire was used to create the heat needed to dry foods and in some cases smoking them as well. [1]

The importance of food drying is likely to increase. The global population is predicted to exceed eight billion by the year 2025 (Cliquet and Thienpont, 1995). Food production must therefore be increased to meet the rising demand but this is unlikely to come from simply growing crops on previously uncultivated land (Dyson, 1996). One strategy to increase food supplies is to minimize crop wastage. In developing countries alone, the minimum estimates of post-harvest losses, including those from poor drying, vary between 10-20% (Pariser, 1987). A 1978 report by the National Research Council of the National Academy of Sciences in Washington, D.C., cited by Salunkhe and Kadam (1998), puts post-harvest losses as high as 30-40% in both industrialized and developing countries.

In addition to foods for human consumption, many other products require Drying. These include organic crops like timber and rubber and inorganic materials like this has focused our attention on energy intensive processes like drying where fossil fuels can often be replaced by renewable and non-polluting sources of energy. Drying paint. All of the above arguments emphasize the importance of drying in people's lives.

However, according to Mujumdar (1990), "drying is the most energy-consuming industrial process". It requires approximately 2.4 MJ to evaporate one liter of water. To dry one metric ton of most fruits in a conventional dehydrator to the safe moisture, content for long-term storage requires approximately 100 liters of oil. The shortage of energy is an issue in many countries, particularly those in the developing world. Even where conventional energy is plentiful, there is pressure to reduce the amount of fossil fuels used. Concern over global warming is universal and one metric ton of fruit in a conventional dehydrator produces approximately 300 kg of carbon dioxide. Technology the growers dry many crops at the point of production themselves so there is usually adequate land area available for the solar drying system.

Solar energy is an obvious energy source for drying various products, particularly food crops. Many crops are harvested in the summer months and are usually dried at temperatures below 70^0C - a temperature which can be readily attained by solar [2]

Some of the problems associated with open-air sun drying can be solved using a solar dryer, which comprises of collector, a drying chamber and sometimes a chimney.

Solar drying may be classified into direct, indirect and mixed-modes. In direct solar dryers the air heater contains the grains and solar energy passes through a transparent cover and is absorbed by the grains. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the grain bed.

In indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the grain bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or roof.

In our project, the solar food air dryer consists of four main parts such as solar panel, cabinet and blower. The blower is used to passing the hot air forcedly to the drying cabinet.

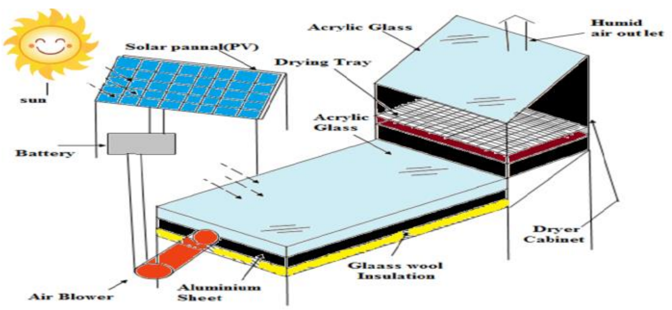


Fig 1.1 over view of solar dryer

MATERIALS USED

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

- Wood - as the casing (housing) of the entire system; wood was selected being a good insulator and relatively cheaper than metals.

- Glass - as the solar collector cover and the cover for the drying chamber. It permits the solar radiation into the system but resists the flow of heat energy out of the systems.
- Mild steel sheet of 1mm thickness (dimension 115cm × 65cm) painted black with tar – for absorption of solar radiation.
- Net cloth (cheesecloth) and wooden frames for constructing the trays.
- Nails and glue as fasteners and adhesives.
- Glass wool insulation.
- Paint (black).

LITERATURE REVIEW

Crop drying is the most energy consuming process in all processes on the farm. The purpose of drying is to remove moisture from the agricultural produce so that it can be processed safely and stored for increased periods. Crops can also dry before storage or, during storage, by forced circulation of air, to prevent spontaneous combustion by inhibiting fermentation. It is estimated that 20% of the world‘s grain production is lost after harvest because of inefficient handling and poor implementation of post-harvest technology, says Hartman‘s (1991). Grains and seeds are normally harvested at a moisture level between 18% and 40% depending on the nature of crop. These must be dried to a level of 7% to 11% depending on application and market need. Once a cereal crop is harvested, it may have to be stored for a period before it can be marketed or used as feed. The length of time a cereal can be safely stored will depend on the condition it was harvested and the type of storage facility being utilized. Grains stored at low temperature and moisture contents can be kept in storage for longer period before its quality will deteriorate. Some of the cereals that are normally stored include maize, rice, beans.
Figure 2.1 show that two types, active and passive mode, can classify solar dryers. Passive dryers can be further divided into direct and indirect models A direct solar dryer is a system in which the food is directly exposed to the solar radiations only in which the material to be dried are placed in a transparent enclosure of glass or plastic or with reflected radiations such as box dryer. Reflected radiations are used to increase the temperature in the box dryer. In direct solar dryers, the air heater contains the grains and solar energy, which passes through a transparent cover and is absorbed by the grains. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the grain bed. However, in an indirect solar dryer, solar radiation do not falls directly onto the product being dried, but collector is used to raise the hot air temperature in the dryer chamber. in indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the grain bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or the roof.
Energy is important for the existence and development of human kind and is a key issue in international politics, the economy, military preparedness, and diplomacy. To reduce the impact of conventional energy sources on the environment, much attention should be paid to the development of new energy and renewable energy resources. Solar energy, which is environment friendly, is renewable and can serve as a sustainable energy source.

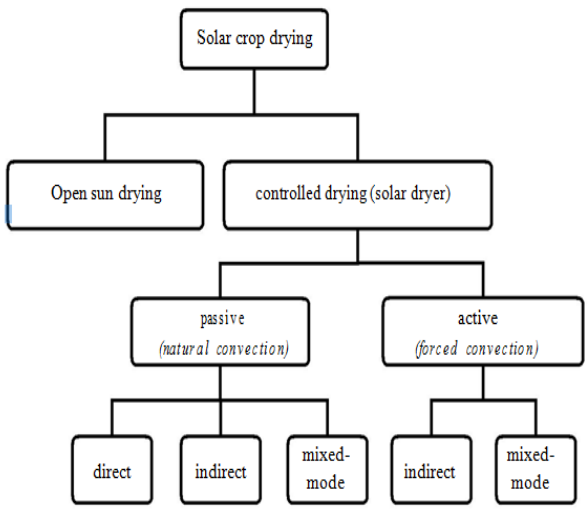


Figure 2.1: Classification of crop drying using solar energy

Hence, it will certainly become an important part of the future energy structure with the increasingly drying up of the terrestrial fossil fuel. However, the lower energy density and seasonal doing with geographical dependence are the major challenges in identifying suitable applications using solar energy as the heat source. Consequently, exploring high efficiency solar energy concentration technology is necessary and realistic [3].
Solar energy is free, environmentally clean, and therefore is recognized as one of the most promising alternative energy recourses options. In near future, the large-scale introduction of solar energy systems, directly converting solar radiation into heat, can be looked forward. However, solar energy is intermittent by its nature; there is no sun at night. Its total available value is seasonal and is dependent on the meteorological conditions of the location. Unreliability is the biggest retarding factor for extensive solar energy utilization. Of course, reliability of solar energy can be increased by storing its portion when it is in excess of the load and using the stored energy whenever needed.
Solar drying is a potential decentralized thermal application of solar energy particularly in developing countries [4]. However, so far, there has been very little field penetration of solar drying technology. In the initial phase of dissemination, identification of suitable areas for using solar dryers would be extremely helpful towards their market penetration.
Solar drying is often differentiated from sun drying‖ by the use of equipment to collect the sun‘s radiation in order to harness the radiative energy for drying applications. Sun drying is a common farming and agricultural process in many countries, particularly where the outdoor temperature reaches 30ºC or higher. In many parts of South East Asia, spice s and herbs are routinely dried. However, weather conditions often preclude the use of sun drying because of spoilage due to rehydration during unexpected rainy days. Furthermore, any direct exposure to the sun during high temperature days might cause case hardening, where a hard shell develops on the outside of the agricultural products, trapping moisture inside. Therefore, the employment of solar dryer taps on the freely available sun energy while ensuring good product quality via judicious control of the radiative heat. Solar energy has been used throughout the world to dry products. Such is the diversity of solar dryers that commonly solar-dried products include grains, fruits, meat, vegetables and fish. A typical solar dryer improves upon the traditional open-air sun system in five important ways [4]

PROBLEM IDENTIFICATION

Solar air dryer is old concept, but in modern world many different parameters are been considered during its manufacturing. The design of solar dyer which gives some advantages as well as disadvantages such as friction losses ,vibration, expansion of acrylic glass due to heat and air flow, friction losses at the reducing cross-sections and leakages of air at small portions which cannot be identified . By considering all factors, we have taken decision to make solar food dryer, which is less costly, more efficient to poor people.
The objective of this study is to develop a mixed-mode solar dryer in which the grains are dried simultaneously by indirect radiation through the transparent walls and roof of the cabinet and by the heated air from the solar collector. The problems of low and medium scale processor could be alleviated, if the solar dryer is designed and constructed with the consideration of overcoming the limitations of indirect type of solar dryer. So therefore, this work will be based on the importance of a mixed mode solar dryer which is reliable and economically, design and construct a mixed mode solar dryer using locally available materials and to evaluate the performance of this solar dryer.

SCOPE OF WORK

In order to reach the project’s objective, the following scopes are identified:

- Designed a solar dryer according to the information obtained from the literature.
- Acquire materials needed is suitable for fabrication.
- Performance of solar dryer for collector efficiency, drying air temperature and weight loss will be compared with different types of drying method.

OBJECTIVES

The main objectives to achieve in this research that are:

- To study a characteristics and performance of the solar dryer system.
- To select and evaluate the optimum design of solar dryer.
- To test dynamically for its performance and suitability of campus use.

DESIGN CONSIDERATION

1. Temperature - The minimum temperature for drying food is 30°C and the maximum temperature is 60°C, therefore. 45°C and above is considered average and normal for drying vegetables, fruits, roots and tuber crop chips, crop seeds and some other crops [5].
2. The design is made for the optimum temperature for the dryer. T_0 of 60°C and the air inlet temperature or the ambient temperature T_a = 30°C (approximately outdoor temperature).
3. Efficiency – It is defined as the ratio of the useful output of a device to the input of the device.
4. Air gap - It is suggested that for hot climate passive solar dryers, a gap of 7 cm should be created as air vent (inlet) and air passage.
5. Glass and flat plate collector – In this work, 4mm thick transparent glass is used. Here we also suggested that the metal sheet thickness should be of 0.8 – 1.0 m thickness; here a mild steel of 1.0mm thickness is used. The glass used as cover for the collector was 115 × 65cm^2.
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 60 × 57 × 55cm with air passage (air vent) out of the cabinet of 60 × 7cm^2. The drying chamber has roofed with glass of 65 × 60 cm tilted at the same angle with that of the solar collector (27.11°).
7. Dryer Trays - Net cloth has selected as the dryer screen or trays to aid air circulation within the drying chamber. Two trays are made having wooden edges. The tray dimension are 50 × 50cm of 2.5cm × 2.5cm and wooden sticks used as frame.

The design of the dry chamber making use of wooden wall sides and a glass top (tilted) protects the food is 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 [5].

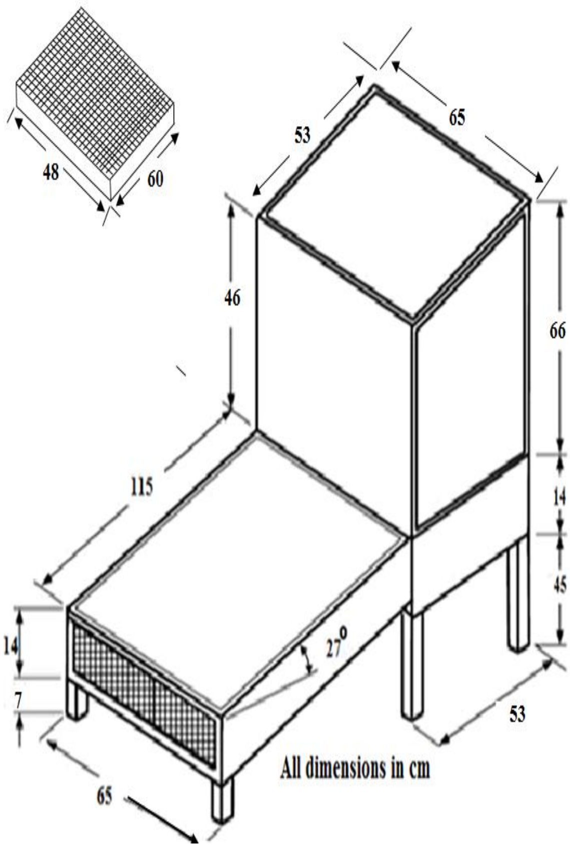


Fig 6.1: Isometric drawing of the mixed-mode solar dryer

DESIGN CALCULATION

NOMENCLATURE

m_w	Mass of water vapor (kg)
m_p	Mass of product (kg)
m_i	Initial moisture content in product (%)
m_f	Final moisture content in product (%)
E_p	Energy required to evaporate water vapor (joule)
L_v	Latent heat of vaporization of water (kJ/kg)
E_a	Energy gain from air (joule)
I_c	Solar intensity (W/m^2)
A_c	Area of collector (m^2)
η	Efficiency of collector (%)
t_d	Drying time (hour)
M_{dr}	Average drying rate (kg/hour)
T_i	Inlet air temperature (K)
T_0	Outlet air temperature (K)
T_a	Ambient air temperature (K)
m_a	Mass flow rate of air (kg/sec)
Cp_a	Specific heat of air (kJ/kgK)
ΔT	Temperature difference (K)
ρ_a	Density of air (kg/m^3)
V_a	Volume flow rate of air (m^3/sec)
v_a	Velocity of air (m/sec)
A	Area of inlet air section (m^2)
T	Transmissivity
α	Absorptivity
Q_u	Heat gain (W)
Q_L	Heat loss by convection (W)
K	Thermal conductivity of insulation (W/mK)
t_b	Thickness of base insulator (mm)
F_R	Heat removal factor (0.1)

Mass of water to be evaporate from product,

$$m_w = m_p [(m_i - m_f) / (100 - m_f)] \qquad ....(1)$$

Energy required for evaporating water from product,

$$E_P = m_w \times L_v \qquad ....(2)$$

Energy gain by air from Radiation,

$$E_a = I_c A_c \eta_c \qquad .... (3)$$

Energy required evaporating = Energy gain by air x time

$$E_p = E_p \times t_d \qquad .... (4)$$

Heat gain by air,

$$E_a = I_c A_c \eta_c = m_a Cp_a \Delta T \qquad ....(5)$$

Calculating mass flow rate of air,

$$m_a = I_c A_c \eta_c / Cp_a \Delta T \qquad ....(6)$$

Now calculating velocity of air required,

$$m_a = V_a \rho_a \qquad ....(7)$$

But, $V_a = A \times v_a$

$$V_a = m_a / \rho_a$$

Calculating air velocity,

$$v_a = V_a / A$$

$$A = h \times w$$

Average drying rate,

$$M_{dr} = m_w / t_d \qquad \text{............ (8)}$$

Determination of heat losses from the solar air collector
Total energy transmitting and absorbing is given by,

$$I_c A_c \tau\alpha = Q_u + Q_L \qquad \text{.......... (9)}$$

$$Q_u = m_a Cp_a \Delta T$$

$$Q_L = U_L A_c \Delta T$$

Determination of the Base Insulation Thickness for the collector

$$F_R m_a Cp_a (T_0 - T_a) = K A_a (T_0 - T_a) / t_b$$

$$t_b = K A_a / F_R m_a Cp_a \qquad \text{....(10)}$$

ADVANTAGES & LIMITATIONS

A.) ADVANTAGES

1. Much less time is required for drying as compared to direct drying because of black body.
2. Protection of the drying products from insects but also from birds, dogs, especially for drying meat and fish.
3. The product is hygienic because microorganisms, insects and flies are killed
4. Protection of rain.
5. Protection of pollution by dust etc.
6. Protection of the wind which can blow away the food

B.) LIMITATION

1. Not workable at night.
2. Efficiency decreases to a large extent on cloudy days.
3. Overheating may occur if regular attention is not paid.
4. Due to overheating, it can decrease the quality of food.
5. Change in taste and flavour of food may occur if regular monitoring is not done.
6. We cannot get the accurate amount of sun rays and heat.

COST ESTIMATION

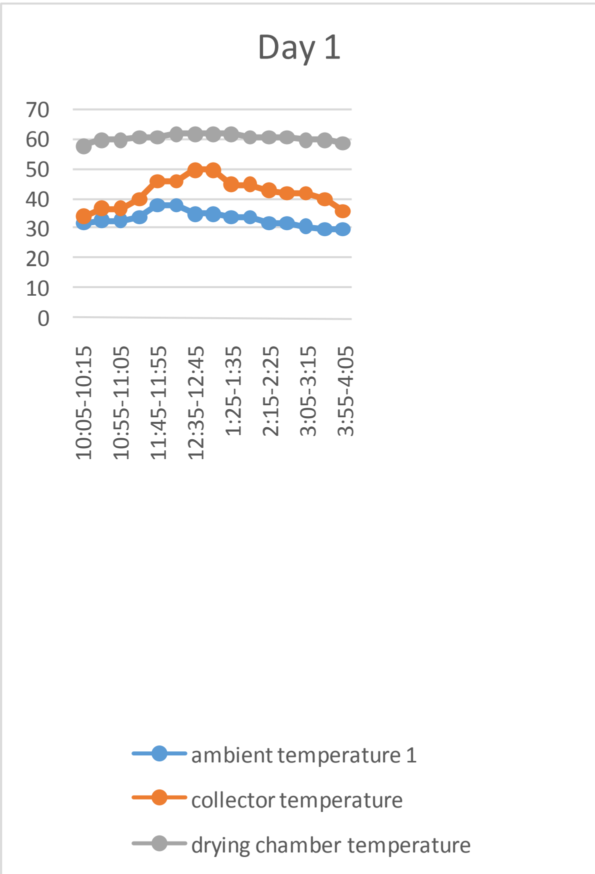
Sr. No	**Component**	**Rs. Per Qty**	**Quantity Used**	**Total Price In(Rs)**
1	Plywood	1500	1	1500
2	Glass wool	400	1	400
3	Aluminum sheet	1500	1	1500
4	Nylon net sheet	100	2	200
5	Acrylic glass	1100	1	1100
6	Angles rods	1200	-	1200
7	Hinges ,pins ,welding ,nails	200	-	200
8	Colour paint	150	1	150
9	Solar panale	2500/	2(18v)	2500
10	Battery	700/-	2(12v)	700
11	Exhaust fan	50	1	50
12	Blower	1300/-	1	1300
13	Other expenses	1550	-	1550
14	Total Expenditure.	12250	13	**12350**

RESULT & DISCUSSION

To dry 2.5 kg of grapes minimum 0.60 m/sec air velocity is requires where the ambient temperature is 30 ^{0}C and average solar radiation is 450 W/m^2 (assumed), grapes having 80% initial and 18 % final moisture content. The collector area is 0.75 m^2 (1.15 m x 0.65m) is assumed. From 2.5 kg of grapes 1.9 kg of water to be evaporate, the latent heat of vaporization of water is 2257000 J/kg from which the total energy required to evaporate water is 4288300 joule. The energy gain by air from radiations is 168.75 J/second when the collector efficiency assumed 50% from this the time required to dry 2.5 kg grapes is 7.08 hour is calculated. The average drying rate is 0.35 kg/hour. The convective losses are 92.49 J/second and the thickness of base insulator polyurethane material which is having thermal conductivity of 0.05 W/mK is 1.1 cm.

The following table shows the typical day results of the diurnal variation of temperatures in the solar dryer.

Time	Ambient temperature	Collector temperature	Drying chamber temperature
10:05-10:15	32	34	58
10:30-10:40	33	37	60
10:55-11:05	33	37	60
11:20-11:30	34	40	61
11:45-11:55	38	46	61
12:10-12:20	38	46	62
12:35-12:45	35	50	62
1:00-1:10	35	50	62
1:25-1:35	34	45	62
1:50-2:00	34	45	61
2:15-2:25	32	43	61
2:40-2:50	32	42	61
3:05-3:15	31	42	60
3:30-3:40	30	40	60
3:55-4:05	30	36	59



From the above graph, it is observed that the charging time varies as intensity of sun light. In addition, the distance travelled by hot air is depending upon time of charging. It is observed from graph that it will cover maximum drying capacity there is more sunshine.

Analysis of dried Samples at various stages during grapes drying

Fresh Grapes During Solar drying Dried Raisins

CONCLUSION

- Solar food dryer can operated by charging the battery by solar or electricity.
- In a country like India where 300 days out of 365 days are sunny have a huge asset of solar energy. Government is also promoting the use of renewable sources of energy like solar energy by providing subsidies on solar pumps, solar water heater, solar panels, solar lights etc. son we should take advantage of these schemes.
- Use of solar energy costs us nothing just only solar panel, sunlight is free of cost and sun is a non-finishing source of energy.
- Almost every year there are news of rotten food grains in newspaper, which causes a huge loss to farmers but if we design those go downs on the concept of black body then such condition will occurs.

FUTURE SCOPE

This 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 minimizing shortcomings associated with than low efficiency, cost not portable solar dryer.

Estimating the Size Solar Food Dryer

The original design of our solar food dryer is for daytime only. In future we will try to make it that, it can be for night time by adding air heater and also because of solar panel mounting fabrication the dryer size becomes bigger, so in future we will try to make it.

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