PORTABLE VEGETABLES HYBRID SOLAR DRYER FOR RURAL AREA

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ABSTRACT

In many countries of the world, the use of solar thermal systems in the agricultural area to conserve vegetables, fruits, coffee and other crops has shown to be practical, economical and the responsible approach environmentally. Solar heating systems to dry food and other crops can improve the quality of the product, while reducing wasted produce. Under the module of Advance topics in mechanical engineering projects, we were assigned to design the low cost vegetable dryer. The design of dryer consists of several steps and sequence procedure.

A systematic approach for the classifcation of solar-energy dryers has been evolved. Two generic groups of solar-energy dryers can be identifed, viz passive or natural-circulation solar-energy dryers and active or forced-convection solar-energy dryers (often referred to as hybrid solar dryers). Three sub-groups of these can also be identifed integral-type (direct mode), distributed-type (indirect mode) and the mixed-mode type. The appropriateness of each design type for application by rural farmers in developing countries is discussed. Some very recent developments in solar drying technology are highlighted.

Keywords: Solar, Exergy, Direct, Indirect, Mixed Mode, Dryer.

I. INTRODUCTION

Food is a basic need for all human beings along with air and water. Food problem arises in most developing countries mainly due to the inability to preserve food surpluses rather than due to low production. Agricultural yields are usually more than the immediate consumption needs, resulting in wastage of food surpluses during the short harvest periods and scarcity during post-harvest period. Hence, a reduction in the post-harvest losses of food products should have considerable effect on the economy of these countries. More than 80% of food is being produced by small farmers in developing countries. Fruits and vegetables constitute a major part of the food crops in developing countries. From the limited data available on post-harvest losses in fruits and vegetables, it is understood that the actual losses are much higher. The minimum reported loss is 21%, while some references indicate estimates of above 40–50%. The most notable feature is that many varieties of fruits are seasonal and many of them are consumed in their dried form to a large extent which has been made possible by the process of drying. Preservation of fruits, vegetables, and food are essential for keeping them for a long time without further deterioration in the quality of the product.

Several process technologies have been employed on an industrial scale to preserve food products; the major ones are canning, freezing, and dehydration. Farmers dry food products by natural sun drying, an advantage being that solar energy is available free of cost, but there are several disadvantages which are responsible for degradation and poor quality of the end product. Certain variety of food products are not supposed to be dried by natural sun drying because they lose certain basic desirable characteristics. Experiments carried out in various countries have clearly shown that solar dryers can be effectively used for drying agricultural produce. It is a question of adopting it and designing the right type of solar dryer

Among these, drying is especially suited for developing countries with poorly established low temperature and thermal processing facilities. It offers a highly effective and practical means of preservation to reduce post- harvest losses and offset the shortages in supply. Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. The prime objective of drying apart from extended storage life can also be quality enhancement, ease of handling, further processing and sanitation and is probably the oldest method of food preservation practiced by humankind. Drying involves the application of heat to vaporize moisture and some means of removing water vapor after its separation from the food products. It is thus a combined and simultaneous heat and mass transfer operation for which energy must be supplied. The removal of moisture prevents the growth and reproduction of microorganisms like bacteria, yeasts and molds causing decay and minimizes many of the moisture-mediated deteriorative reactions. It brings about substantial reduction in weight and volume, minimizing packing, storage, and transportation costs and enables storability of the product under ambient temperatures. These features are especially important for developing countries, in military feeding and space food formulations.

At the same time continuous increasing pressure of energy demand, the degradation of environment through greenhouse gas emissions and the rise in fuel prices are the main driving forces behind the efforts for more effectively utilizing various sources of renewable energy. Renewable technologies are considered as clean energy sources and optimal use of these resources minimizes environmental impacts and produces minimum secondary wastes, and such resources are sustainable based on current and future economic and social societal needs. Energy in various forms has been playing an increasingly important role in worldwide economic progress and industrialization. The growth of world population coupled with rising material needs has escalated the rate of energy usage. Rapid increase in energy usage characteristic of the past 50–100 years cannot continue indefinitely as finite energy resources of earth are exhaustible. Therefore, there is a need to explore the renewable energy sources to meet out the energy demand in present context.

II. PROBLEM STATEMENT

Energy is limited but energy demand is unlimited. All our activities such as transportation and communication need to use energy. We use mostly fossil fuel energy. The use of fossil fuel energy causes world energy will deplete and cause greenhouse effect, it is causes many of effect for living beings include more extreme weather incident, rising sea level. This project deals with the design and construction of a solar dryer so that we can use energy from the sun to dry agricultural products and to reduce air pollution.

In India, 50–80% of agricultural product currently goes to waste during production periods due to their perishability and an inability to adequately preserve them with local technologies. We propose to develop a solar food dryer that will use concentrated solar power to quickly and safely dry fresh food, particularly fruits and vegetables, in hazy environments. The unit will be constructed with locally available materials and technology

- To design and fabricate the solar dryer system for drying the vegetables, fruits, etc. in ruler region.

OBJECTIVE:

- To study about solar energy.
- To design the component for solar dryer.
- To identify the amount of solar energy required for drying.
- To design electronics devices for solar dryer.
- To fabricate solar dryer.
- Determination of Moisture Loss, Moisture Content and Drying Rate.
- To study variation of moisture content (dry basis) versus time.
- To study variation of moisture loss (% basis) versus time (h).
- Variation of moisture content with respect to drying time for different air velocity flow rates.
- To find out the result of solar dryer on green vegetables or fruits.
- To estimate the overall cost for ruler and low economy people.

III.METHODOLOGY

In the present project the methodology adopted includes the design and analysis of the solar dryer After design the solar dryer we are practically perform on vegetable or fruits and then graph will be draw moisture content v/s time. And finally we get result and conclusion.

IV.LITERATURE REVIEW

RICHARD JOHN MONGI

“Fruits and Vegetables solar dryer”

Fruits are defined in several ways. Botanically, fruits are the mature ovaries of the plant with their seeds. Therefore, this definition included all grains, legume, nuts and seeds, and common vegetables-fruits such as cucumbers, olives, peppers, and tomatoes. When defined and considered in culinary role fruit refers to the flesh edible part of a plant, tree, bushy or vine that, usually eaten alone or served as a dessert and has sweet or tart taste. Fruits are high in organic acids and sugar, higher than vegetables (Vaclavik and Christian, 2008). They are used as breakfast beverage or side-dish (e.g., orange juice, berries, grape fruit, and melon), lunch side-dish or dessert, snack food between meals or dinner dessert. Raw and canned fruits are also used as appetizers, salads ingredients and side-dishes (IARC, 2003). Vegetables are the edible usually succulent part(s) of plant or portion of it consumed raw or cooked, generally with a main dish, in a mixed dish, as appetizer or in a salad (Vaclavik and Christian, 2008). Vegetables include edible stems and stalks, roots, tubers, bulb, leaves, flowers, some fruits, pulses (mature beans and peas), fungi (mushrooms, tuffles), algae (sea-weeds) and sweet corn and horminy (cereal grains used as vegetables) (IARC, 2003). Since any definition of vegetable generally centers on its use, a plant may be a vegetable in one country but a fruit, weed, an ornamental or medicinal plant in another country, depending on the crop. For example, tomato is a vegetable in Asia but a fruit in Europe (AVRDC, 1990). Vegetables may be processed into beverages or vegetable starches, eaten fresh or lightly processed, dried, pickled, or frozen. They impart their own characteristics flavor, color, and texture to the diets and undergo changes during storage and cooking (Vaclavik and Christian, 2008). Tanzania’s climatic growing conditions can accommodate the production of a wide range of fruits and vegetables (Ngereza et al., 2007). The most important fruits include pineapples, passion fruits, citrus fruits, mangoes, peaches, pears and bananas. Vegetables include tomatoes, spinach cabbages and okra (MAFC, 2009). This study however, concentrated on three selected fruits banana, mango and pineapple and one vegetable, tomato.

2.2 Chandrakumar B Pardhi and Jiwanlal L Bhagoria

"Development and performance evaluation of mixed-mode solar dryer with forced convection"

The performance of the solar drying system is highly influenced by the performance of the collector. Therefore, several studies have been conducted in order to improve the performance of the solar drying system is highly performance of the solar dryer Belhamristudied a simple efficient and inexpensive solar batch dryer for agriculture products. During periods of low sunshine, a heater is used. Onion was chosen as the dried product because obits swift deterioration characteristic. The results showed that drying is affected by the surface of the collector, the air temperature, and the product characteristics. Muller et al. Designed and constructed a dryer with a collector area of 16.8 m2 which is expected to dry 195.2 kg of freshman go (100 kg of sliced mango) from 81.4% to 10% wet basis in 2 days under ambient conditions during harvesting period from April to June. Ismail et al. Designed and constructed a solar dryer based on preliminary investigations for mango slices drying under controlled conditions. The designed dryer with a collector area of 16.8 m2 was expected to dry 195.2 kg of fresh mango (100 kg of sliced mango) from 81.4% moisture level to 10% on wet basis in 2 days under ambient conditions during harvesting period from April to June. Mujumdar et al. studied briefly the emerging drying methods and selected recent developments applicable to postharvest processing. In their study, they included the heat pump-assisted drying with multimode and time-varying heat inputs, low and atmospheric pressure superheated steam drying, modified atmosphere drying, intermittent batch drying, osmotic pretreatments, microwave-vacuum drying etc. Bolaji et al. Developed a simple and inexpensive mixed-mode dryer from locally sourced materials. Bukola et al. Experimentally mixed-mode solar dryer for food preservation. The temperature increase inside the drying cabinet was up to 74% for about found out the performance evaluation of a 3 h immediately after 12noon. The drying rate and system efficiency were 0.62 kg/h and 57.5%, respectively. Sarsavadia developed a solar-assisted forced convection dryer to study the effect of airflow rate (2.43,5.25, 8.09 kg/min), air temperature (55°C, 65°C, 75°C), and fraction of air recycled (up to 90%) on the total energy requirement in drying of onion slices. Kumar et al. Used a natural convection mixed-mode solar dryer in performing the experiments on potato cylinders and slices of the same thickness of 0.01 m with respective length and diameter of 0.05 m to investigate the convective heat transfer coefficient. Sreekumar et al. Developed a new type of efficient solar dryer with an arrangement to absorb maximum solar radiation by the absorber plate.Abene et al. Studied experimentally to improve the efficiency-temperature rise couple of the flat plate solar collector by considering several types of obstacles disposed in rows in the dynamic air vein of the flat collector. Ramana Murthy studied various aspects of solar driers applied to drying of food products at a small scale. Karim et al. Studied experimentally the effect of different operating variables on drying potential and drying time. Smitabhindu et al. A simulation and optimization model to minimize the drying cost per unit of dried banana.

2.3 J.T Liberty, W.I Okonkwo, S.A Ngabea

"Solar Crop Drying-A Viable Tool for Agricultural Sustainability and Food Security"

Preservation of fruits, vegetables, and food are essential for keeping them for a long time without further deterioration in the quality of the product. Several process technologies have been employed on an industrial scale to preserve food products; the major ones are canning, freezing, and dehydration. Among these, drying is especially suited for developing countries with poorly established low-temperature and thermal processing facilities. It offers a highly effective and practical means of preservation to reduce postharvest losses and offset the shortages in supply. Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. The prime objective of drying apart from extended storage life can also be quality enhancement, ease of handling, further processing and sanitation and is probably the oldest method of food preservation practiced by humankind drying involves the application of heat to vaporize moisture and some means of removing water vapor after its separation from the food products. It is thus a combined and simultaneous heat and mass transfer operation for which energy must be supplied. The removal of moisture prevents the growth and reproduction of microorganisms like bacteria, yeasts and molds causing decay and minimizes many of the moisture-mediated deteriorative reactions. It brings about substantial reduction in weight and volume, minimizing packing, storage, and transportation costs and enables storability of the product under ambient temperatures. These features are especially important for developing countries. The drying process takes place in two stages. The first stage happens at the surface of the drying material at constant drying rate and is similar to the vaporization of water into the ambient. The second stage takes place with decreasing (falling) drying rate. The condition of the second stage determined by the properties of the material being dried. Open sun drying is the most commonly used method to preserve agricultural products like grains, fruits and vegetables in most developing countries. Such drying under hostile climate conditions leads to severe losses in the quantity and quality of the dried product. These losses related to contamination by dirt, dust and infestation by insects, rodents and animals. Therefore, the introduction of solar dryers in developing countries can reduce crop losses and improve the quality of the dried product significantly when compared to the traditional methods of drying such as sun or shade drying. Solar drying methods are usually classified to four categories according to the mechanism by which the energy, used to remove moisture, is transferred to the product:

(1) Sun or natural dryers: The material to be dried is placed directly under hostile climate conditions like solar radiation, ambient air temperature, relative humidity and wind speed to achieve drying.

(2) Direct solar dryers: In these dryers, the material to be dried is placed in an enclosure, with transparent covers or side panels. Heat is generated by absorption of solar radiation on the product itself as well as the internal surfaces of the drying chamber. This heat evaporates the moisture from the drying product and promotes the natural circulation of drying air.

(3) Indirect solar dryers: In these dryers, air is first heated in a solar air heater and then ducted to the drying chamber.

(4) Mixed-type solar dryers: The combined action of the solar radiation incident directly on the material to be dried and the air pre-heated in the solar air heater furnishes the energy required for the drying process.

2.3.1 Agricultural Products Drying Mechanism

Almost all agricultural products can be preserved by drying. Products like fruits such as apple, vegetable grains beverage crops, fish; meat, timber etc can be dried and preserved for years. In most developing nations, agricultural products are dried by the convectional open-air drying, where the product intended to be dried is exposed directly to sun allowing the solar radiation to be absorbed by the product sprayed on mat, concrete or on clear soil. It was reported that this method of drying has many shortcomings consisting of poor quality yield, soiling, and contamination etc.

The mechanized form of dryer is a container designed to house product to be dried which is powered by electricity or fuel as a source of heat and/or air to dry the product. This form of drying is faster than open-air drying but the equipment is very expensive and requires a substantial quantity of fuel to operate. As such, the evolution of solar dryer is opted to be the positive alternative technology to agricultural product drying. This is large because of lower operating cost and it's environmentally friendliness when compared with the mechanized dryer. Other reasons are largely connected to fossil fuel limitation and cost, depleting of the resources and its negative environmental effects such as air pollution, global warming etc.

2.4 E. KavakAkpinar*

"Mathematical modeling and experimental investigation on sun and solar drying of white mulberry"

Drying is widely used in a variety of thermal energy applications ranging from food drying to wood drying. It can either be done by traditional sun drying or industrially through the use of solar dryers or hot air drying. The solar dryers could be an alternative to the hot air and open sun drying methods, especially in locations with good sunshine during the harvest season. However, large-scale production limits the use of the open sun drying. Among these are lack of ability to control the drying process properly, weather uncertainties, high labor costs, large area requirement, insect infestation, mixing with dust and other foreign materials and so on [4]. Solar drying is essential for preserving agricultural products. Using a solar dryer, the drying time can be shortened by about 65% compared to sun drying because it is warmer inside the dryer than outside; the quality of the dried products can be improved in terms of hygiene, cleanliness, safe moisture content, color and taste; the product is also completely protected from rain, dust, insects; and its payback period ranges from 2 to 4 years depending on the rate of utilization. The most important feature of solar dryers is that the product does not include any kind of preservatives or other added chemical stuffs, which allows its use for people suffering from various allergic reactions from chemical preservatives and other added stuffs. Furthermore, the product is not exposed to any kind of harmful electromagnetic radiation or electromagnetic poles Simulation models are helpful in designing new or in improving existing drying systems or for the control of the drying operation. The drying kinetics of materials may be described completely by using their transport properties (thermal conductivity, thermal diffusivity, moisture diffusivity, and interface heat and mass transfer coefficients) together with those of the drying medium. In the case of food drying, the drying constant K is used instead of transport properties. The drying constant combines all the transport properties and may be defined by the thin layer equation. Thin layer equations describe the drying phenomena in a united way, regardless of the controlling mechanism. They have been used to estimate drying times of several products and to generalize drying curves. In the development of thin layer drying models for agricultural products, generally the moisture content of the material at any time after it has been subjected to a constant relative humidity and temperature conditions is measured and correlated to the drying parameters. Although there are many studies of solar and open sun on thin layer drying of fruits such as grapes, apricots, grapes, plums, apples, prickly pear peel, Stanley plums, no studies were found about the thin layer

Drying process in solar dryer with forced convection and under open sun with natural convection of mulberry in the literature.

The main objectives of this study are to:

(i) Study and compare the thin-layer drying characteristics

Of mulberry by using the open sun and solar

Drying methods,

(ii) Fit the experimental data obtained to semi theoretical

Models widely used to describe thin layer

Drying kinetics of mulberry, and

(iii) Calculate the effective moisture diffusivity.

2.5 R. VidyaSagar Raju, R. Meenakshi Reddy,

"Design and Fabrication of Efficient Solar Dryer"

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. Some of the problems associated with open-air sun drying can be solved through the use of a solar dryer who comprises of collector, a drying chamber and sometimes a chimney. The conditions in tropical countries make the use of solar energy for drying food practically attractive and environmentally sound. Dryers have been developed and used to dry agricultural products in order to improve shelf life. Most of these either use an expensive source of energy such as electricity or a combination of solar energy and some other form of energy. Most projects of these natures have not been adopted by the small farmers, either because the final design and data collection procedures are frequently inappropriate or the cost has remained inaccessible and the subsequent transfer of technology from researcher to the end user has been anything but effective. Drying may be an interesting method in order to prevent fresh fruit deterioration. There is spoilage of fruits and other fresh foods that could be preserved using drying techniques in India and other developing countries. Seasonal fruits like

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mangoes are not presently dried for export, or for local consumption during period of scarcity.

2.6 Ahmed Abed Gatea

"Performance evaluation of a mixed-mode solar dryer for evaporating moisture in beans" Drying crops by solar energy is of great economic importance the world over, especially in Iraq where most of the crops and grain harvests are lost to fungal and microbial attacks. These wastages could be easily prevented by proper drying, which enhances storage of crops and grains over long periods of time. Iraq lies within the equator and is blessed with abundant solar energy all the year round. This solar energy can easily be harnessed by a proper design of solar dryers for crop drying. This method of drying requires the transfer of both heat and water vapor (Forson et al., 2007). Most of our crops and grain are harvested during the peak period of rainy season and so preservation proves difficult and most of these grains and crops get spoilt. This results in the crops not lasting the year, resulting in subsequent hunger and malnutrition. 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 (Gatea, 2010). These crops can be preserved and stored, so that they can be of economic importance both to the farmers and the entire populace.

Rural farmers do this by open-air drying. This practice in the rural areas has some obvious disadvantages (Henry et al., 1999). This method is unhygienic since the crops are easily contaminated by animal droppings and consequent infestation by fungi and bacteria. Human health is thus endangered as a result of food poisoning. This method also prolongs drying and may result in the deterioration of the quality of the crops. Moreover, more labor is involved as the crops are being moved frequently in and out during the day and night and from rain. They are also watched in order to prevent physical attacks birds and other animals. It is a well-known fact that in rural areas, conventional sources of energy like petrol and electricity are either totally absent or are not readily available to develop active dryers, which have higher rate of performance. A low temperature passive solar dryer has therefore been developed, which will be appropriate for crops and grains during the low temperature and high relative humidity periods of the year. The obvious advantage of low temperature drying is that, it enables crops to be dried without cracking and hence minimizes the exposure of the crops to fungal and bacterial infestation and wastage; this is also suitable for bulk drying for long-term storage (Forson et al., 2007). The objective of this research was to fabricate the solar dryer using indigenous materials to assess their efficacy in drying beans. The fabricated driers utilized no chimney and both direct and indirect modes in the same unit.

V. DESIGN AND DEVELOPMENT OF SOLAR DRYER

This chapter deals with design considerations and calculations for developed low cost solar dryer. Additionally, it includes the subsystem design and manufacturing of dryer cabinet, flat plate collector and drying chamber.

4.1 Overview of solar dryer designed:

The developed solar dryer consists of the different components like flat plate collector based solar air heater, thermal energy storage system, dryer cabinet and blower. On the basis of the criteria mentioned, the design of the individual component was prepared and corresponding parameter (i.e. relative dimensions and material for solar flat plate collector, dryer cabinet and drying chamber) were calculated. The procedure of design and calculations for each component is mentioned below.

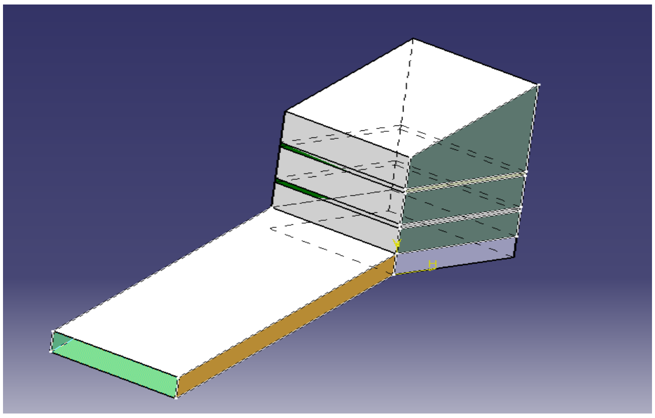


Fig. 4.1 Overall view of solar dryer

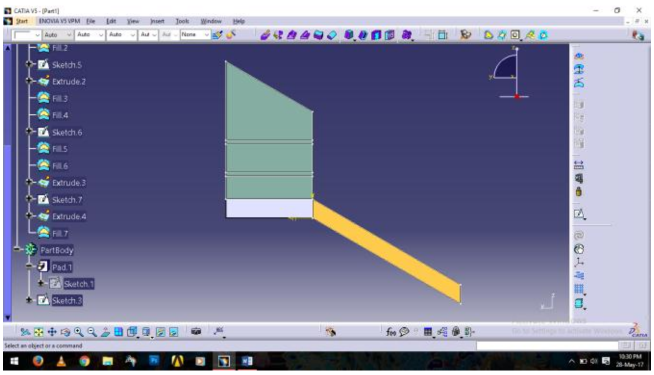


Fig 4.2 Overall view of solar dryer (Side View)

The overall project is designed for drying of 2kg of vegetables. Taking into consideration the drying area required for 1kg of vegetable the drying chamber is designed. Then from the calculations carried out the total energy required for drying is calculated based on the desired final and initial moisture content of grapes. Then the design of drying chamber was calculated.

4.2. Specifications of developed solar dryer

The developed solar dryer consists of the following parts:

1. Dryer Cabinet
2. Drying Chamber
3. Flat plate collector
4. Fan and Host pipe

The components specifications are mentioned below:

4.2.1. Dryer Chamber:

The dryer chamber is designed for the mixed mode method purpose. The overall dimensions of dryer chamber are:

Length* Width * Height = 900mm * 600mm * 100mm

4.2.2. Flat Plate Collector:

The Flat Plate collector is used for air heating purpose which further is supplied to the chamber using Fan.

Specifications of the Flat Plate collector are:

- Reflecting material used = aluminum
- Dimensions of collector=900mm*600mm
- Effective aperture area = 884mm*584mm
- Aperture width =0.3m

4.2.3. Fan:

Fan is implemented for carrying out forced convection.

The specifications of the fan are:

- Speed: 1000RPM
- Dc Voltage Range (volts): 12 V DC
- Rated current: 0.13A

4.3. Solar Dryer Design Considerations:

The following points were considered in the design of the forced convection solar dryer system:

- Capacity of solar dryer.
- The amount of moisture to be removed from the given quantity of tomato.
- The drying time required and optimization.
- The daily sunshine hours for the selection of the total drying time.
- Drying temperature for the selection of phase change material.
- The quantity of air needed for drying.
- Daily solar radiation intensity to determine energy received by dryer per day.

4.4. Design of drying chamber:

The design of the drying chamber is carried out on basis of quantity of product to be dried, drying area required for the mentioned quantity of product.

Fig. 4.3(a).Drying Chamber

Fig. 4.3. (b) Drying Chamber

4.5Testing Methodologies:

The experiment was carried out using different method. The mass flow rate of air was varied and the subsequent effects on the drying time were calculated. Also study of effect of use of thermal energy storage on the drying time is studied by carrying out the experiment with thermal energy storage and without thermal energy storage.

The mass flow rates of air were varied from 0.0148kg/sec to 0.01726kg/sec. Study on pretreatment analysis showed considerable decrease in the drying time of fruits. Hence, the fruits were pretreated by dipping in the chemical solution effecting in skin cracking of the fruits and helping the cause of moisture removal.

4.6 Electronic Weighing machine:

The initial, instantaneous and final masses of sample figs are measured by digital portable weighing machine during testing. The specifications of said weighing machine are described below.

Fig.4.4. Portable Electronic weighing machine

In accordance with the above conditions the design and calculation procedure was carried as below:

Dryer Chamber Design calculations: -

Amount of vegetable =2 kg

Number of trays to be kept = 2 for 300g

Per tray loading = 300/2 = 150g

Characteristics of Vegetable dried:

Vegetable type: Potato, chili, karalla, onion,

Per tray load = 250g

Tray area =600*459= 275400 mm2

Now, the overall dimensions of the chamber are calculated from the number of trays implemented, spacing between the trays in horizontal as well as vertical direction.

Length of the drying chamber = Length of the tray =459mm.

Now, for the length of the drying chamber,

Width of chamber = Width of tray + Deflector Length

=584+ 16

Length of chamber = 600mm

Now, for height consideration of the chamber,

Height = (Ground clearance + required height for chamber)

Height = 450 + 820 =1270mm

Overall dimensions of the drying chamber are:

Length* Width * Height = 459mm * 600mm * 820mm

4.5. Design of drying chamber:

The energy required to dry the food is the function of the moisture content to be removed. So, the testing report of the wet (raw) vegetable and the market purchased dried vegetable were taken from the labs for moisture contents. The reports resulted in the initial and the final moisture as 80g/110g and 20g/100g respectively. Using this data obtained the energy calculations were done. Capacity of solar Dryer:-25kg

Considering amount of moisture content: 93% for ripped tomatoes

Amount of moisture to be removed from given quantity of grapes to be dried

Amount of moisture mn= ((Mw-Md)) / Mw)*100 (4.1)

Here, Mn = Moisture content(% of material)

Mw= Wet mass of sample

Md= Mass of sample after drying

Amount of heat required to evaporate water = Q = Mw * hfg (4.2)

hfgw = 4186 (597-0.56 * Tp) = 2.42MJ/kg (4.3)

Tp = Initial temperature of the product=30

Amount of heat required to evaporate water = Q = mw * hfg= 12.1 MJ

Assume 10 % loss of heat in drying chamber

Amount of heat required to be supply = 12.1* 1.1 = 13.31MJ

Amount of heat required to be supply = 13.31MJ

Total energy to be supplied for drying of fruit = 13.31MJ.

Total collector Area required;

Assuming the efficiency of collector (η) = 30%

(Generally efficiency of flat plate collector is 25-28%. But by Using Reflector Surfaces we can enhance the Flat Plate Collector Efficiency up to 30%)

Intensity of radiation (I) = 800 W/m2

According to Solar Radiation Hand Book data by Solar Energy Centre, MNRE Indian Metrological Department it gives the 25.12MJm-2per day.

Let's assume area of flat plate collector 0.52 m2

Energy retracted from FPC=η* 25.12*Area

=3.92 MJ per Day

Total Energy supplied from FPC =3.92*5 = 19.6 MJ

The Flat Plate collector area required for supplying the essential heat energy is 0.54m2.

Fig. 4.6 Flat Plate Collector

Physical parameters of solar air heating systems

Overall Size of the collector = Length * Width* Height=900mm*600mm*100mm

Tilt angle 300 (south facing)

Glass area 0.52 m2

Collector glazing Window glass with 5 mm thickness

Absorber plate Width: 584 mm, length: 884 mm

VI. RESULT AND DISCUSSIONS

From results of the experiments, the diurnal variation of temperatures of the solar collector outlet air, absorber, ambient, and solar radiation were plotted. One typical day of June is shown in Figure 5. It is observed that the rise in air temperature due to the generated air flow rate in the collector is sufficient for the purpose of most agricultural products drying. The daily solar radiation was relatively high with an average of 600 W/m2. For the inlet air temperature of 38°C, the maximum air temperature at the dryer inlet was recorded as 56°C at a solar irradiance level of 700 W/m2. The mass flow rate of the drying air in the thermo-sphere mode of the collector depends on the prevailing wind conditions, ambient air temperature, incident solar radiation and the collector design. It was observed that, when the wind velocity was more or less uniform throughout the day, the air velocity in the collector shows definite dependence on the stack temperature difference between ambient and collector outlet air.

Performance of solar dryer

The performance of the solar dryer depends on several factors, the solar radiation, inlet air temperature of solar dryer and the dryer design factors (Figure 6) note that access to the highest temperature required for drying when tray 4 is from 61°C and is at the highest intensity of the radiation 700 W/m2 at 11. There were no significant differences in temperature at the trays (1, 2 and 3) with the differences ranging from (2 to 5°C).

Moisture content variation

As shown in Figure 7, the moisture content was reduced from 60% on dry basis to 8% on dry basis through 6 h. Been delivering moisture content of the beans on (trays1, 2, 3 and 4) to (8, 11, 14 and 18%) respectively.

Solar collector efficiency

The efficiency of the solar collector depends on the airflow rate and the difference in temperature (to- ti) and radiation intensity as in the Equation 3 of Figure 8, was obtained at the highest efficiency of the solar collector the amount of 61.82% at midday, and less efficient were obtained from 45.4% at 9 am.

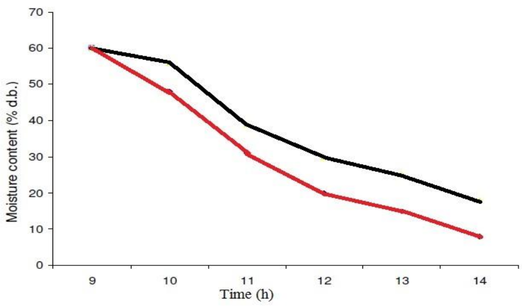
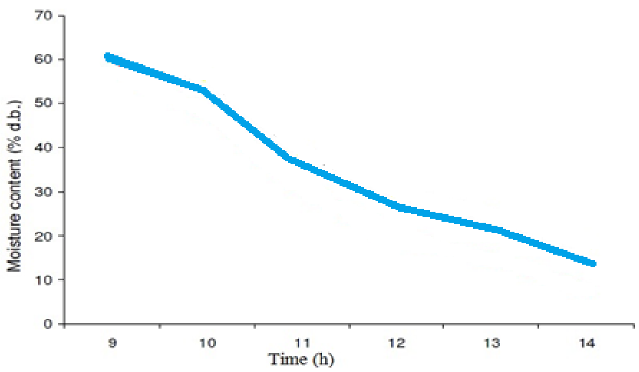


Fig: 5.1 Decreasing of moisture content of broad – Potato for each tray of the Dryer



Graph: 5.4. Moisture content vs. Time

VII. SCOPE FOR FUTURE WORK

Developed solar dryer with thermal energy storage have been successfully tested and results are quite promising, still there are some areas on which the same work can be further extended so that solar drying technology can be applied to vegetables drying successfully. The details of which are follows,

- Efforts can be with modification in thermal energy storage system so that its use can be extended for longer period in drying process Controlled drying environment can be maintained in the dryer cabinet and its effect can be analyzed to improve the quality of the dried figs.
- In most of the literature it has been observed that the thermal energy storage system has been integrated with the collector only so that the incorporation of thermal energy storage below the collector surface can be done to study the variation in moisture content, moisture loss, drying time and dryer efficiency in grape drying.
- Phase change materials should be investigated in view of their chemical stability and compatibility with the containing materials before their integration within the drying system
- Cost benefit analysis of solar dryer can be carried out to make it cost effective for local farmers at the same time it can meet the requirements of lesser drying time and better quality.
- Furthermore, before using the drying systems on large scale, computer simulation models must be performed to simulate the short and long terms performance of the drying systems with and without the storage media to estimate the solar drying curves of the dried products.
- Same dryer can be modified for variety of agricultural products on a large scale so that it can be boon for small and marginal farmers.

VIII. CONCLUSION AND RECOMMENDATIONS

In this work mixed mode forced convection solar dryer for fig drying with thermal energy storage has been developed and tested experimentally. The sliced fig as well as whole fig with pretreatment has been dried with developed solar dryer. The designed dryer was integrated with a Phase Change Material to extend the use of dryer in the evening/night hours. The effect of air mass flow rate on moisture content, moisture ratio, drying rate, drying time and dryer efficiency has been evaluated for vegetables and fruits. At the same time effect of thermal energy storage on drying time on grapes also evaluated with and without incorporation of thermal energy storage with variation in mass flow rate of air.

The following conclusions have been arrived at, from the experimental investigation carried out in the present work on solar grape dryer.

- The drying experiment conducted with Potato and it was found that the complete drying process could be attained with 22 hours, which was much less than that of open sun drying
- Concentrating collector based air heating system, in the field of dryer technology can be successfully implemented in order to increase the capacity of solar dryer and drying time
- Dried products production is possible with developed solar dryer in shorter time which is commercially available in market.
- Incorporation of thermal energy storage system increases the dryer efficiency and reduces drying time remarkably. With implementation of thermal energy storage the drying time for particular day can be extended from sunshine hours to non-sunshine hours. Hence it increase the quantity of products dried (i.e. increase in number batches).
- The higher mass flow rate increases the higher heat transfer coefficient in the collector, which improves the collector efficiency.
- After all this work put forward extension of renewable energy based drying technology in the field of

drying so that small scale farmers can be economically benefited.

IX. REFERENCE

- R. VidyaSagar Raju, R. Meenakshi Reddy, E. Siva Reddy, Design and Fabrication of Efficient Solar Dryer

- Baloraj Basumatary1, Mrinmoy Roy 2, DhwrwmBasumatary3,Sanjaupu Narzary4, Uma Deuri5, Prakash K Nayak6 and Nitin Kumar7,Design, Construction and Calibration ofLow Cost Solar Cabinet Dryer

- Ahmed Abed Gatea, "Performance evaluation of a mixed-mode solar dryer for evaporating moisture in beans"

- J.T Liberty1, W.I Okonkwo2, S.A Ngabea3, "Solar Crop Drying-A Viable Tool for Agricultural Sustainability and Food Security"

- Chandrakumar B Pardhi1* and Jiwanlal L Bhagoria2, "Development and performance evaluation of mixed-mode solar dryer with forced convection"

- EL- Amin Omda Mohamed Akoy a, Mohamed Ayoub Ismail b, El-Fadil Adam hmed c and W. Luecke d. "Design and Construction of A Solar Dryer for Mango Slices"

- UmeshToshniwal and S.R Karale "1A review paper on Solar Dryer"

- Jain, D. and Tiwari, G.N. (2003) 'Thermal aspects of open sun drying of various crops', Energy, Vol. 28, pp.37–54.

- Mekhilefa, S., Saidurb, R., Safari, A., 2011, A review on solar energy use in industries Renewable and Sustainable Energy Reviews, 15, pp. 1777–1790.

- Xingxing, Z., Xudong, Z., Stefan, S., Jihuan, X., Xiaotong, Y., 2012, Review of R&D progress and practical application of the solar photovoltaic/thermal (PV/T) technologies, Renewable and Sustainable Energy Reviews, 16, pp. 599-617.

- Mekhilefa, S., Saidurb, R., Safari, A., 2011, A review on solar energy use in industries Renewable and Sustainable Energy Reviews, 15, pp. 1777–1790.

- Visavale, G.L., 2009, Design and Characteristics of Industrial Drying Systems. Ph. D. thesis, Institute of Chemical Technology, Mumbai, India.

- Sharma, V. K., Sharma, S., Ray, R. A., Garg, H. P., 1986, Design and performance studies of a solar dryer suitable for rural application, Energy Conversion and Management, 26, pp. 111-119.

- Montero, I., Blanco, J., Miranda, T., Rojas, S., Celma, A. R., 2010, Design, construction and performance testing of a solar dryer for agro-industrial by-products, Energy Conversion and Management, 51, pp. 1510-1521.

- Sharma VK, Colangelo A, Spagna G, Experimental performance of an indirect type solar fruit and vegetable dryer, Energy Conversion & Management, 1993, 34(4), 293-308.

- Ekechukwu, O.V. and Norton, B. Review of solar-energy drying systems II: an overview of solar drying technology. Energy Conversion and Management, 1999,40 : 615-655.

- Mujumdar, A.S., 2007, Handbook of Industrial drying, Part-I, Taylor and Francis group, U.K.