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Smart Solar Tunnel Dryer

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Abstract: *Solar energy is an important source of renewable energy and is the most readily available non-polluting source of energy. The objective of this project is to develop a highly intelligent solar tunnel dryer incorporated with sensors and controllers for large scale agricultural drying purpose. Temperature and humidity sensors are used for detecting the current atmosphere inside the dryer. A blower fan is also used for delivering the hot air to the surface of the product to be dried. Solar dryer gives faster drying rates, reduces humidity and risk of spoilage and improves the quality of the product.*
Keywords: *PV panel, auxiliary heating coil, controlled blowers, humidity sensor, solar collector, temperature sensor, microcontroller.*

I. Introduction

Traditional sun drying takes place by placing the product under direct sunlight. The main advantages of sun drying are low capital and operating costs and the fact that little expertise is required. The main disadvantages of this method are contamination, theft or damage by birds, rats or insects; slow or intermittent drying and no protection from rain or dew that wets the product, encourages mould growth and may result in a relatively high final moisture content; low and variable quality of products due to over - or under-drying; large areas of land needed for the shallow layers of food; laborious since the crop must be turned, moved if it rains; direct exposure to sunlight reduces the quality (colour and vitamin content) of some fruits and vegetables. Moreover, since sun drying depends on uncontrolled factors, production of uniform and standard products is not expected.

The quality of sun dried foods can be improved by reducing the size of pieces to achieve faster drying and by drying on raised platforms, covered with cloth or netting to protect against insects and animals. Solar dryers have some advantages over sun drying when correctly designed. They give faster drying rates by heating the air to 10-30 C above ambient, which causes the air to move faster through the dryer, reduces its humidity and deters insects.

The faster drying reduces the risk of spoilage, improves quality of the product and gives a higher throughput, so reducing the drying area that is needed. Solar dryers also protect foods form dust, insects, birds and animals.

They can be constructed from locally available materials at a relatively low capital cost and there are no fuel costs. Thus, they can be useful in areas where fuel or electricity are expensive, land for sun drying is in short supply or expensive, sunshine is plentiful but the air humidity is high. To produce a high-quality product economically, it must be dried fast, but without using excessive heat, which could cause product degradation.

The most important advantage of the solar dryers is that they work on renewable energy and are pollution free. Also, solar dryers can be easily constructed from local materials. It is successfully proved how solar dryer technology is key element to climatic and environmental protection as well as sustainable development.

The mainly used conventional methods of sun drying include natural open drying and mechanical drying. Natural open air drying involves simply laying the agricultural products in the sun on mats , roofs or drying floors. Natural open drying possess ill effects such as spoilage of crops, fungus attack, threat from birds and insects, labour intensive. Also there is no protection from rain and other adverse climatic conditions.

The working principle of open sun drying by using only the solarenergy. The crops are generally spread on the ground, mat, cement floor where they receive short wavelength solar energy during a major part of the day and also natural air circulation. A part of the energy is reflected back and the remaining is absorbed by the surface depending upon the colour of the crops. The absorbed radiation is converted into thermal energy and the temperature of the material starts to increase. However there are losses like the long wavelength radiation loss from the surface of crop to ambient air through moist air and also convective heat loss due to the blowing wind through moist air over the crop surface.

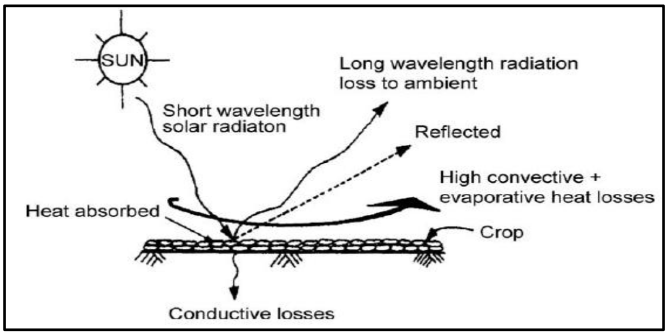

Fig. 1 Working principle of open sun drying

With cultural and industrial development artificial mechanical drying came in to practice. Here forced heated air is used for drying, using specialized equipment.Forced heated air is obtained from burning the fossil fuel.

Advanced artificial mechanical drying utilizes excess energy that leads to wastage of fossil fuels and electrical energy due to furnace, additional machinery for heavy blowers and compressors. Moreover environmental pollution occurs due to the burning of fossil fuels. In conventional tunnel drying, the crop is spread in an even layer on tables or drying racks inside the tunnel which is exposed to sun.But this conventional method of drying is not an effective method of drying during rainy or cloudy climate. An improved technology in utilizing solar energy for drying is the use of solar tunnel dryers along with solar collectors and other auxiliaryequipment like blowers. Air is heated in a solar collector and this heated air blown to the chamber by blower.

II. Block Diagram

The Block diagram depicting the working of the smart solar tunnel dryer is as shown. It shows the microcontroller interfacing of the keypad, sensor and feedback mechanism.

The drying chamber serves as the main area where the actual process is undertaken, i.e. drying. The blower and heating coil acts as the auxiliary heating mechanism and becomes operational automatically on the failure of the main solar network. It can also be manually controlled. It takes over the duty of drying and heating on cloudy or rainy days, when sufficient solar energy becomes unavailable.

The sensors monitor the conditions within the chamber and give the input to the microcontroller. The buzzer is provided for alerting in case of completion of set time or in case of any emergency or faulty conditions of the device. The microcontroller used is Atmega 16.

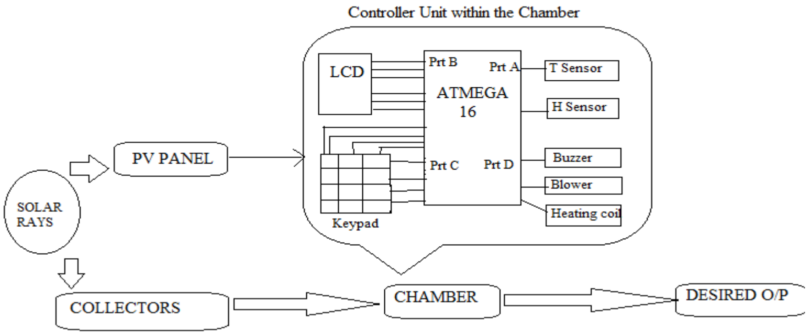

Fig. 2 Schematic representation

III. Layout of the Project

Smart solar tunnel dryer consist of solar panel, drying chamber blower fan, heating coil, temperature and humidity sensor.

Solar panel provides the power supply for the whole system. Drying process is carried out in the drying chamber. The heated air flows through the drying chamber whose walls are coated with aluminium foil which helps in retaining the heat inside the chamber. Trays are arranged inside the drying chamber to carry the products to be dried. An auxiliary heating coil is used along with a blower fan.

This arrangement helps in the uniform circulation of hot air through the chamber. Drying of the product occurs because of the movement of the hot air inside the chamber.The drying time depends on the amount of sunlight intensity, temperature within the chamber, air circulation, humidity, and the nature of product.

Humidity and temperature play an important role in the drying process. When the hot air is blown through the product to be dried, it will take up the moisture until absolute humidity is reached. The rate of drying is directly proportional to the temperature and the circulation speed.

Solar food drying can be used in most areas but how quickly the food dries is affected by many variables especially the amount of sunlight and relative humidity. Typical drying times in solar dryers range from 1 to 3 days depending on sun, air movement, humidity and the type of food to be dried.

The principle that lies behind the design of solar dryers is as follows: in drying relative and absolute humidity are of great importance. Air can take up moisture but only up to a limit. This limit is the absolute (maximum) humidity and it is temperature dependent. When air passes over a moist food it will take up moisture until it is virtually fully saturated, that means until absolute humidity has been reached. But the capacity of the air for taking up this moisture is dependent on its temperature. The higher the temperature higher the absolute humidity and the larger the uptake of moisture. If air is warmed the amount of moisture in it remains the same but the relative humidity falls and the air is therefore enabled to take up more moisture from its surrounding.

To produce a high quality product it must be dried fast but without using excessive heat which could cause product degradation.

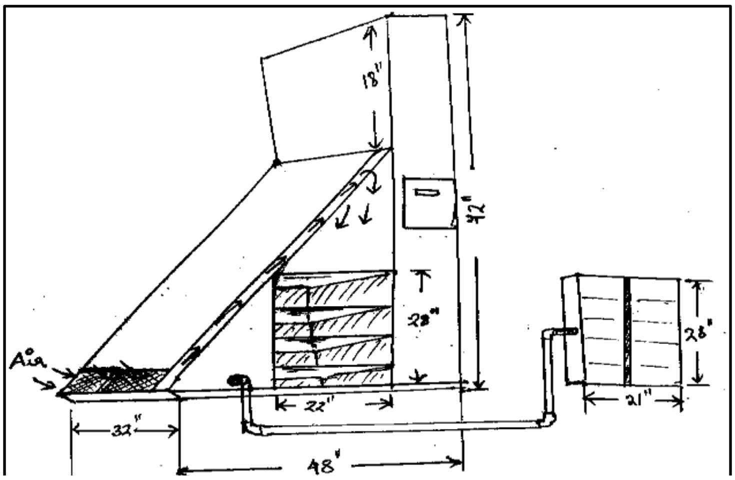

Fig.3 Schematic layout with air flow diagram of solar tunnel dryer

IV. Hardware Description

The hardware model of solar tunnel dryer consists of both mechanical and electrical parts. The mechanical parts consists of drying chamber, solar collectors, trays, blower and heating coil. The electrical part consist of solar PV panel, temperature sensor, humidity sensor and micro-controller.

4.1 Mechanical Components.

4.1.1 Drying Chamber

The drying chamber is an air tight chamber where the drying process is carried out. A cubical chamber having a capacity of 250 litres is used in this project. The dimension of the chamber is 70 x 70 x 70cms.

Marine plywood is used for fabrication purpose to minimize heat loss. The advantages of marine plywood as a material are that it is a poor conductor of heat and it has smooth surface finish. Also they won’t catch fire also heat loss by radiation is minimum.

Matte black is the colour chosen for the outer portion of drying chamber. Aluminium foil is coated on the inside portion of the drying chamber. This type of foil generally has a silvery finish along with high reflectivity. Hollow transparent polycarbonate sheet is used to cover the upper most part of the drying chamber.

The heat energy from the solar rays is trapped by the polycarbonate sheet. This energy heats up the air inside the tunnel. The density of the air decreases as the air gets heated. This heated air passes through the tunnel and circulates inside the drying chamber causing uniform drying of the product.

4.1.2 Solar Collector

Solar collector collects heat by absorbing sunlight. A collector is a device for capturing solar radiation. Solar radiation is energy in the form of electromagnetic radiation from the infrared (long) to the ultraviolet (short) wavelengths.

The quantity of solar energy striking the Earth's surface (solar constant) averages about 1,000 watts per square meter under clear skies, depending upon weather conditions, location and orientation.

Fig.4 solar collector

The heat transfer rate from absorber plate to air flowing in the duct of solar air heater can be increased to improve the solar air heater.

The enhancement of convective heat transfer can be done by creating turbulence at heat transfer surface with the help of artificial roughness on absorber plate.Hence in this dryer, we use a solar collector employing baffled aluminium sheet. It's dimension is 70 x 52 x 4.2 cm (l x b x h).

The air follows a winding path due to the baffles, thereby doubling the length of the air passage through the collector. The baffles are positioned vertically upward pointing to the polycarbonate sheet, such that they create turbulence which forces the air to come in close contact with hot surface of the absorber and decreases the thermal sub layer.

Air vents are provided on one vertical side of the collector, whereas the opposite side is connected to the blower which is placed inside the chamber.

4.1.3 Trays

Drying chamber designed in a such a way that it consists of 4 trays which would hold drying products. It's dimension is about 70 x 52 x 4.25 cm (l x b x h). About 12 litres of product volume can be placed in each tray. Hence the total capacity of the trays is approximately 50 litres.

Rusting can be avoided by using aluminium as the material for trays. The main reason for using aluminium is because aluminium meshes are light weight, strong and there is significant resistance for atmospheric corrosion.

Wooden frames are used for each tray. Due to the usage of wire mesh heated air passes through these trays and the product gets evenly dried on both sides.

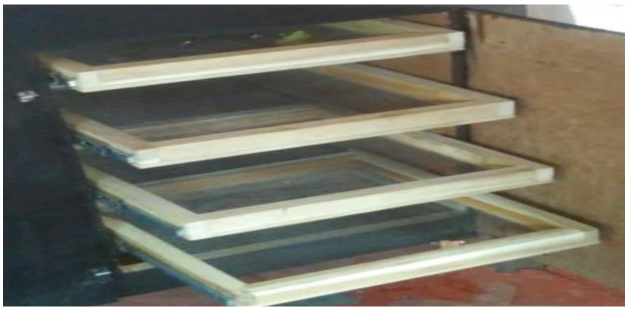

Fig.5 trays

4.1.4 Blower

Blowers are provided as an auxiliary heating equipment case of absence of sunlight or at nightfall. Blowers are used instead of fans because they can achieve much higher pressure than fan's. They are sturdy, quiet, reliable, and capable of operating over a wide range of conditions.

They use the kinetic energy of the rotating blade to increase the pressure of the air/gas stream which in turn moves them against the resistance caused by ducts, dampers and other components. The main function of the blower is to suck hot air from the solar collector through a connecting tube and blows it into the chamber. In this project we use a 230 V, 450 W ac blower.

4.1.5 Keypad

A basic 12 button keypad is used for user input. The buttons are setup in a matrix format. This allows a microcontroller to scan the 7 output pins to see which of the 12 buttons is being pressed.

Keypads allow users to input data while a program is running. A keypad is often needed to provide input to a system. A 12 button keypad consists 3 columns and 4 rows. Pressing of key will leads to one of the row to one of the column. From this, the system can determine which button was pressed.

4.1.6 Heating coil

A heating element converts electricity into heat through the process of resistive heating. Electric current passing through the element encounters resistance resulting in heating of the element.

Heating elements consists of coils of wire, which may be wrapped in an insulating material or protective materials, depending on whether they are used. When electricity passes through the wire, it encounters resistance, thus generating heat.

The amount of heat generated can be adjusted by varying the amount of current passed through the wire. They are made from metal alloys which are well suited to use as heating elements in different applications.

Heating element is used to maintain a constant temperature inside the drying chamber. The replacing of heating coils are usually easy. The power rating of heating coil that we are used inside the drying chamber is 1000W.

4.2 Electrical Components

4.2.1 Solar panel

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity. A photovoltaic module is a packaged, connected assembly of typically 6 x 10 solar cells. Solar Photovoltaic panels constitute the solar array of a PV system that generates and supplies solar electricity for the electrical components. Here we use a 40watt PV panel. The output of the PV panel drives the electrical components of the dryer.

4.2.2 Microcontroller

The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the Atmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed.

The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowingtwo independent registers to be accessed in one single instruction executed in one clockcycle.

The resulting architecture is more code efficient while achieving throughputs up toten times faster than conventional CISC microcontrollers. The Atmega16 provides the following features: 16K bytes of In-System ProgrammableFlash Program memory with Read-While-Write capabilities, 512 bytes EEPROM, 1Kbyte SRAM, 32 general purpose I/O lines, 32 general purpose working registers, aJTAG interface for Boundary-scan, On-chip Debugging support.

4.2.3 Temperature and humidity sensor

The Temperature and humidity sensors are used for determine the temperature and humidity levels inside the drying chamber. The output of the sensors are connected to the microcontroller. According to this signals the blowers, buzzer and heating coils are activated. The values of temperature are displayed in the LCD.Here we are using LM 35 temperature sensor and DHT 11 humidity sensor.

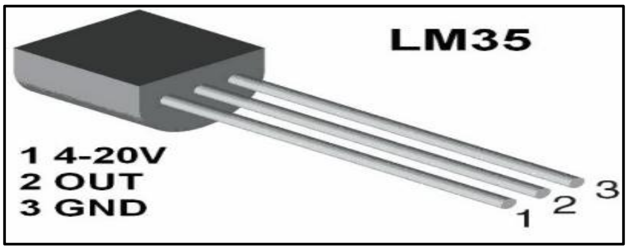

Fig.6 LM 35 temperature sensor

The LM 35 series are precision integrated circuit temperature devices with an output voltage linearly proportional to the centigrade temperature. The LM35 device does not require any external calibration or trimming to provide typical accuracies of +/-0.25 centigrade at room temperature and +/-0.75 centigrade over a full -55 to150 centigrade.

The device is used with single power supplies or with plus and minus supplies.It draws only 60 microampere from the supply. 0.55 centigrade accuracy is ensured at 25 centigrade. Operating voltage is from 4-30V. low self-heating limited to 0.08 centigrade in still air. Output impedance is very low, 0.1 ohm for 1 mA load.

DHT 11 is an ultra-low cost capacitive humidity sensor. It has 4 pin outs. The output signal is given through the data pin which is refreshed every 2 seconds. It has an accuracy of 5% for 20-80% humidity reading. It draws only a small current of 2.5 mA and works on power supply of 3 to 5 V

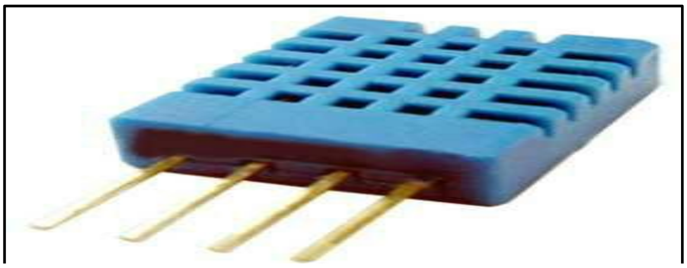

Fig.7 DHT 11 humidity sensor

V. Solar Drying Working Principle

Drying involves the application of heat to vaporize moisture and some means of removing water vapour 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 micro-organisms like bacteria, yeasts and moulds causing decay and minimizes many of the moisture-mediated deteriorative reactions.

Indirect solar drying differ from direct dryers with respect to heat transfer and water vapour removal. The crops in these indirect solar dryers are located in trays or shelves made of aluminium wire mesh(for uniform drying) inside an opaque drying cabinet and a separate unit termed as solar collector is used for heating of the entering air into the cabinet.

The heated air is allowed to flow through/over the wet crop that provides the heat for moisture evaporation by convective heat transfer between the hot air and the wet crop. Drying takes place due to the difference in moisture concentration between the drying air and the air in the vicinity of crop surface.

Fig.8 Fully constructed solar tunnel dryer

Several advantages of indirect solar drying are that it offers a better control over drying and the product obtained is of better quality than sun drying. Localized heat damage do not occur as the crops are protected. Solar dryers can be operated at higher temperature, recommended for deep layer drying. They are highly recommended for photo-sensitive crops. Solar drying of agricultural produce permits several traits such as early harvest, planning of the harvest season, long-term storage without deterioration, maintenance of the availability of seeds and finally sells a better quality product.

Numerous types of solar drying systems have been designed and developed in various parts of the world. Improving of the drying operation to save energy, improve product quality as well as reduce environmental effect remained as the main objectives of any development of solar drying system. Solar dryers have been proposed to utilize free, renewable, and non-polluting energy source provided by the sun.

VI. Experimental Study

In India, there is a significant amount of post-harvest losses of fruits and vegetables estimated at about 35 %, themonetary value of which corresponds to approximately 104 million US dollars annually [1].

Inefficient drying practices are a major cause for these losses. In developing countries, majority of population is engaged in farming activities. Almost 80% of the total food products are cultivated by small farmers. These farmers use conventional means of drying (open sun drying) for their produce. But, this type of drying has many drawbacks like contamination problems, uneven type of drying, and uncontrolled moisture content in end products, causing degradation in the quality of the products.

Solar dryers have thus been developed to overcome these problems of open sun drying. Due to the current trends towards higher cost of fossil fuels and uncertainty regarding future cost and availability, use of solar energy in food processing will probably increase and become more economically feasible in the near future.

In this method we preserve the food items by taking out the moisture content from them.The more we heat the air, its moisture absorbing capacity increases. This is the main principle behind the working of solar dryer. This is an economic way of preserving food and that too using solar energy.

No other source of conventional energy is used in this process. In today's world,where there is rapid demand for conventional fuels and the fact that it will not be available to us in the near future,in that case the need and development of non-conventional sources of energy is good for the future generations.

VII. Results and Discussion

Testing of the system is carried out by some experiments using some products.A comparative study of with pebbles and without pebbles is also conducted. The analysis results are briefly explained in this section.

7.1 Comparative Analysis of Thermal Storage System

The solar dryer was developed with a thermal storage system. The storage unit stores the heat in thermal storage system during the day and supplies hot air during the night and overcast periods. In this work, the experiments were conducted with and without the presence of pebbles and made a comparative study with both the cases.As a storage material, pebbles are cheap and readily available have good heat transfer characteristics with air.

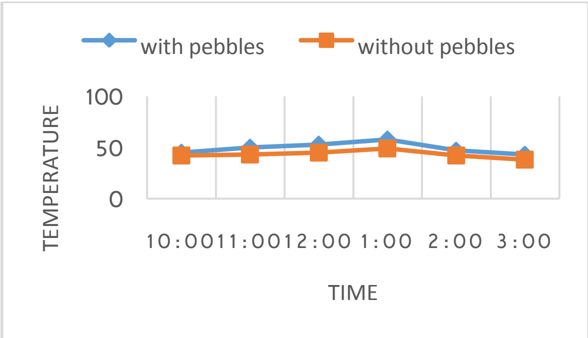

Fig. 9 Temperature variation inside the chamber with pebbles and without pebbles

7.2 Temperature Variation in Trays inside the Solar Dryer

The solar dryer implies total three slots of trays inside the drying chamber, increasing profile temperature was observed from bottom tray to upper tray. Overall humidity inside the dryer was minimum as compare to outside condition.

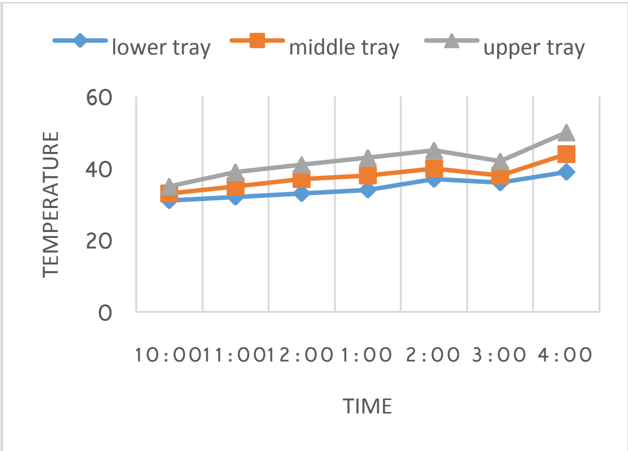

Fig.10 Temperature variation in trays

7.3 Hourly Reduction in Moisture Content of Potato in Closed Drying and Open Drying

The amount of moisture in agricultural materials and food products affects the potential for storage without molding or deterioration from chemical reactions such as oxidation. It also affects the physical properties of the material.

Particle density tends to decrease as the moisture content increases because the dry components such as starch and protein have a greater density than water. Products with higher moisture contents have higher thermal conductivities and lower electrical resistances because water is an excellent conductor of heat and electricity.

Moisture content also affects force-deformation characteristics. Two methods are used to express the moisture content of materials: wet basis moisture content and dry basis moisture content.

Wet basis moisture content is described by the percentage equivalent of the ratio of the weight of water to the total weight of the material. Wet basis moisture is used to describe the water content of agricultural materials and food products. Dry basis moisture content is described by the percentage equivalent of the ratio of the weight of water to the weight of the dry matter. Dry basis moisture is most commonly used for describing moisture changes during drying. When performing these calculations, it is assumed that the sample loses only water and that the weight of the dry matter remains constant. The drying was carried out by loading the weighted potato in dryer from morning 10:00 am to 4:00 pm. The products were dried up to the final moisture content. The drying time required for drying the samples from initial moisture content to final moisture content in solar dryer and under open sun drying condition was critically observed. In closed drying ,for example the quantity of water evaporated per 2.5 kg of raw potato is 1.83 kg and in open drying the quantity of water evaporated is 1.68kg.The quality of the final product is of great importance particularly to commercial producers because thesale of their product and the price received will depend greatly on the grade or quality produced.

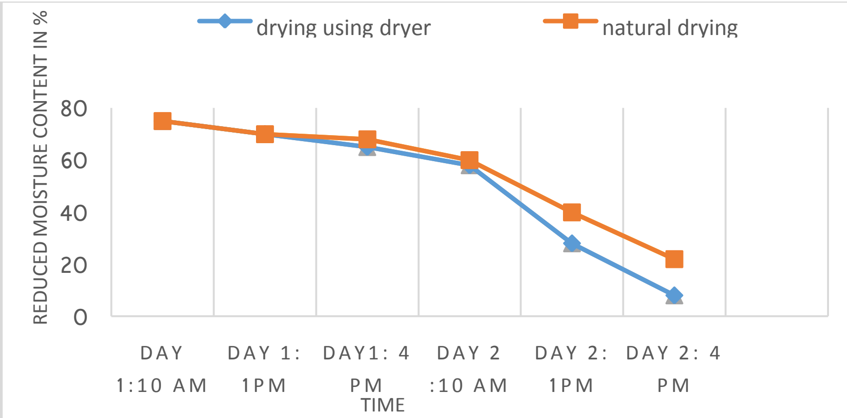

Fig. 11 Reduction in Moisture Content of the Potato in Closed drying and Open Drying

Comparison between Natural drying and Solar drying

Fig. 12 Comparison between natural drying and solar drying

VIII. Conclusion

An efficient solar dryer has been constructed and its drying characteristics have been studied. The constructed dryer can be used to dry agricultural products under controlled and protected conditions. The drying system proved efficient and economical for drying agricultural products.

The result obtained during the test period reveals that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the daylight. The experiments were conducted on some products. The dryer exhibited sufficient ability to dry food items rapidly to a safe moisture level and simultaneously it ensured a superior quality of the dried product.

Since the product was not directly exposed to solar radiation, the colour and quality of the product was retained even after complete drying. The capital cost of the dryer is dependent on the size as required for the use and application.A sophisticated solar tunnel dryer is designed and developed suitable for drying all kinds of agricultural produce, spices, marine products, etc.

Detailed performance analysis is undertaken with fruits loaded in the dryer and drying characteristics has been evolved out. The developed tunnel dryer is economically viable and preferred to be replicated for the drying applications among small and marginal farmers. Same design parameters are preferred to be applied for developing big solar drying systems for commercial applications.

With the help of this project we find how much solar dryer is more efficient in our Morden generation. The function of solar dryer is more effectively and efficiently with minimal maintenance cost, hence it is easy to access and is affordable by local farmers because of its low cost.

There had been a lot of impediments while performing this project. This project can be proved thriving if it is being brought in used for many purposes.The research determines the effectiveness of the solar tunnel dryer developed and the product dried in the device is superiorin quality and also it is compatible with branded products available in the market.Drying of farm produce is an energy intensive operation, and improving energy efficiency by only 1% could increase the profits by 10%.

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