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DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF SOLAR CABINET DRYER

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ABSTRACT

In India, the most of vegetables loss occur due to microbial and fungal attacks cause of improper processing methods. Solar radiation is the radiant energy emitted by the sun in the form of electromagnetic waves. Above the earth atmosphere, sunlight carries 1367 watts of power per square meter. Drying is one of the important and most energy consuming processes in the food processing. The product is protected against files, pests, rain and dust and also it is labor saving. To achieve these benefits we deals with the research work entitled Design, Development and Performance Evaluation of solar cabinet dryer. The cabinet is a large metal box and the product is located in trays or shelves inside a drying cabinet. First of all we made the frame of the dryer by welding and cutting operation on M.S angles, then the metal sheet joint to the frame structure by using drilling machine and tapping screw, after that the inlet and outlet port were made for the air passage. After the making of the chamber we made the tray by using wire mesh and wooden strips. And finally we placed the glass on the roof of the chamber and then sealed it with silicon. The performance evaluation was taken on the drying of various vegetables like bitter guard, coriander, potato slices and cauliflower. The drying of these vegetables were carried on the wet basis from which the result found that the moisture removed from bitter guard, coriander, potato slices and cauliflower were 92%, 88%, 88.75% and 79.14% respectively. The total cost required for fabrication of the solar cabinet dryer was 6445 Rs. only.

Key words - Drying, Dryer, Radiations, Wet basis, Temperature

I. INTRODUCTION

Renewable Energy can play vital role in day today life.The sources of energy are as commercial & non-commercial. The commercial sources include the fossils fuel [coal, oil & natural gas], hydroelectric power & nuclear power, while the non-commercial sources include wood, animal waste & Agricultural wastes. Major sources of energy includes Sun, wind, tides in the sea, geothermal, ocean thermal electric conversion, fuel cells, thermionic, thermoelectric generators. Sun is a very large nuclear fusion reactor which converts 40 lactones of hydrogen into helium in one second. Although the earth absorbs a minute portion of sun energy from which the amount of energy received is approximately of 5.4*10*24 J/yr.

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. Drying of agricultural products is an important unit operation under post-harvest phase. It refers to removal of moisture from food terminal level, whereas dehydration means removal of moisture to very low levels usually for bone dry condition. Drying is a thermo-physical & physiochemical operation by which the excess moisture from a product is removed.Drying makes food grains & other products suitable for safe storage & protects them against attack of insects, molds & other micro-organisms during storage.

Solar thermal technology is a technology which is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind & because it is abundant, in

exhaustible & non-polluting.Sun drying of fruits& vegetables is still practice largely unchanged from ancient times. Traditional sun drying takes place by storing the product under direct sunlight. Sun drying is only possible in areas where, in an average year, the weather allows foods to be dried immediately after harvest. The main advantages of sun drying are now capital & operating costs & the fact that little expertise is required. The quality of sun dried foods can be improved by reducing the size of pieces to achieve faster drying & by drying on raised platforms, covered with cloth or to protect against insects & animals.

Due to the current trends towards higher cost of fossils fuels & uncertainty regarding future cost & availability, use of solar energy in food processing will probably increase & become more economically feasible in the near future. Solar food drying can be used in most areas but now quickly the food dries is affected by many variables, especially the amount of sunlight & relative humidity. Typical drying times are in solar dryer ranges from 1 to 3 days depending on sun, air movement, humidity & the type of food to be dried.

II. MATERIAL AND METHODOLOGY

The chapter material and methodology consist of an approach for design of cabinet solar dryer, material and methodology adopted for conducting study, facilities developed for performance evaluation of cabinet solar dryer. To reduce the use of other energy sources solar cabinet dryer was developed and its performance was evaluated. The dryer was developed considering various factor affecting design and performance.

2.1 Design consideration

Ms. V. Chaughule *et.al*(2016) theystudy on topic design and fabrication of a solar drying system for food preservation; we have taken the following design consideration for the development of solar cabinet dryer with their reference.

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.

2. Design

The design was made for the optimum temperature for the dryer. T_0 of 60°C and the air inlet temperature or the ambient temperature T_1 = 30°C (approximately outdoor temperature).

3. Air gap

It is suggested that for hot climate passive solar dryers, a gap of 5 cm should be created as air vent (inlet) and air passage.

4. Glass or flat plate collector

It suggested that the glass covering should be 4-5 m thickness. In this work, 4mm thick transparent glass was used. She also suggested that the metal sheet thickness should be of 0.8 – 1.0 m thickness; here a Galvanized steel of 1.0mm thickness was used. The glass used as cover for the collector was 103 × 100cm^2.

5. Dimensions

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 100 ×103 × 76 cm^3 with air passage (air vent) out of the cabinet of90 × 10cm^2. The drying chamber was roofed with glass of 100 × 103 cm^2. This is to keep the temperature within the drying chamber fairly constant due to the greenhouse effect of the glass.

6. Dryer Trays

1cm^2 Net was selected as the dryer screen or trays to aid air circulation within the drying chamber. Two trays were made having wooden edges. The tray dimension is 96 × 98 cm of 2.5cm × 2.5cm wooden sticks used as frame. The design of the dry chamber making use of GS sheet wall sides and a glass top (tilted) protects the food to be placed on the trays from direct sunlight since this is undesirable and tends to bleach color, removes flavor and causes the food to dry unevenly.

2.2 Development of solar cabinet dryer

In order to develop Solar Cabinet Dryer having 5 kg capacity, it was decided keeping the dimensions with reference of M.A. Ismail and F.A. Ahmed developed solar cabinet dryer for mango slices. These solar dryer is replaced by the some different material used for construction make new developed dryer. The 360^0 rotation wheels was attached to the developed dryer for easy to rotate and transportation facility.

2.3 Design description

Table -1 Design description of Solar Cabinet Dryer

Sr. no	Component	Material	Dimensions
01	Frame	Cast iron	Length 103cm, width 100cm, Front height 50cm and other side 76cm
02	Chamber	MS sheet	Length 103cm, width 100cm, Front height 50cm and other side 76cm
03	Glass	Borosilicate	101×98 cm 4mm thick
04	Black coating	--	--
05	Wheels	Fiber	10 cm dia.
06	Tray	Wood & wire mesh	96×98 cm
07	Handle	Iron angle	L- 30cm and D- 4cm

2.4 Operations performed for development of dryer

1. Cutting

There were two machines used for cutting first was manually operated and second was power operated machine. The cutter machine was used to cut the raw material, the making of the frame and chamber & also cutter machine was used to cut the MS sheet and angle bars.

2. Welding

The welding machine was used to join the different iron parts or component. The arc welding operation was performed to join the angles and MS sheet for making of the frame and chamber.

3. Drilling

To perform the drilling operation, hand drill machine and vertical drilling machine was used. The drilling operation performed to join the MS sheet to the frame, in these operation 2.5 cm tapping screw was used.

4. Polishing

The grinder was used for finishing of the dryer. For this operation the hand grinding machine was used. The finishing is the important operation for shining.

2.5 Experimental setup of solar cabinet dryer

In experimental setup the dryer first the frame of the dryer was make by L angle then the

for making of chamber the metal sheet was join to the frame by using tapping screw, after the making of chamber the inner side of the chamber was coated by black color and at the roof of the chamber glass cover was placed and sealed by silicon to avoid thermal losses. After the development, the dryer inlet side was always taken as the wind direction. Adjust the dryer according to the direction of sun rays in day time. Dryer should be place in open space where the maximum sun rays should fall on the dryer. Before the placing of tray the Hygrometer was placed inside the chamber to record the temperature and humidity. The dryer should be required fully insulated to minimize the heat losses inside the chamber.

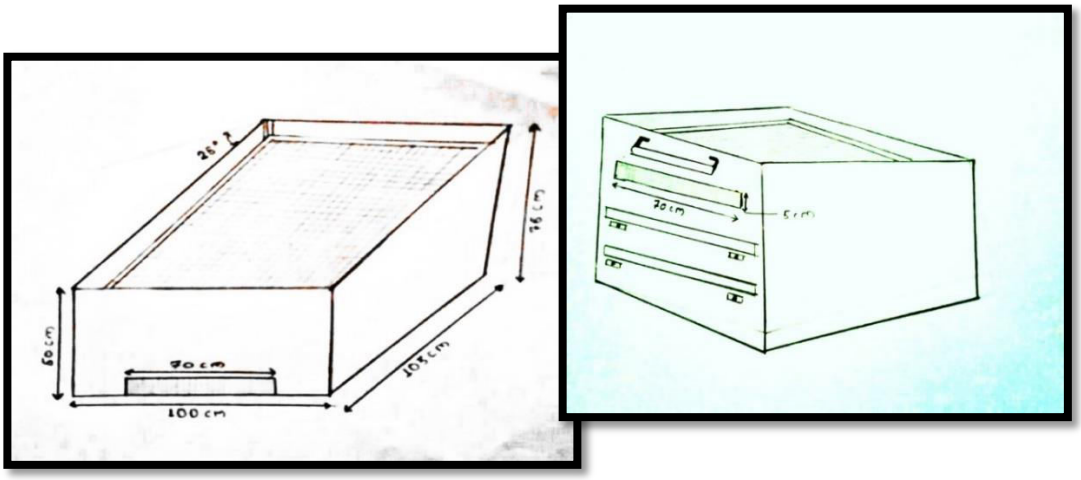

Fig. 1 Schematic view of Solar Cabinet Dryer

2.6 Working of Solar Cabinet Dryer

The solar cabinet dryer is work on the following three principles,

- Converting light into heat
- Trapping heat
- Moving the heat through the sample

The working principle of solar cabinet dryer is to convert the solar radiation energy into the heat energy and then this heat energy is heated the air and the air passes through the food sample inside the chamber for drying purpose.When the solar radiations are fall on the glass cover the maximum amount of sun rays passes through the glass and very small amount of rays reflected due to the borosilicate material, this sun rays trapped inside the chamber and sun rays absorbed by the black color coating, the solar radiation energy convert into the heat energy, due to this heat energy the air inside the chamber is heated and these air passes through the food material due to these the heat transferred to the sample and the moisture present inside the sample is removed, and by the outlet the air is removed the continuous supply of fresh air is provided by naturally through inlet port.

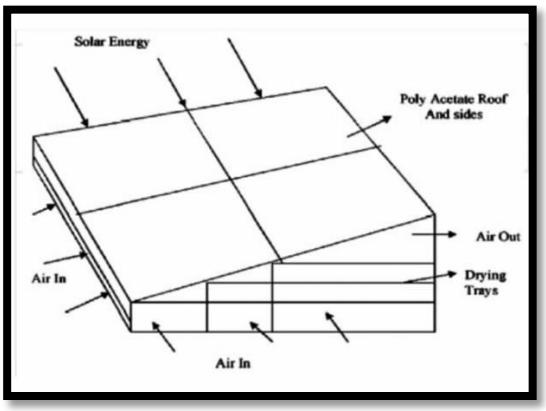

Fig. 2 Pictorial view of solar cabinet dryer Fig. 3 Thermophilic view of solar cabinet dryer

III RESULT AND DISCUSSION

In the result and discussion chapter we discuss the results obtained after drying carried out in solar cabinet dryer and efficiency of solar cabinet dryer. In the performance evaluation of the solar cabinet dryer, we take the four samples of the vegetables as follows

1. Coriander
2. Cauliflower
3. Bitter guard
4. Potato

The following Fig. 4 shows the preparation of the potato slices sample for drying,

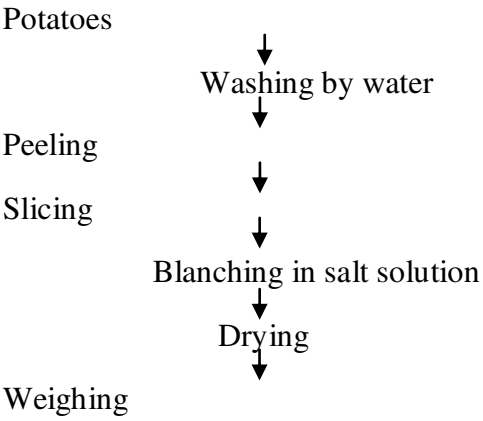

Fig. 4 Flow chart of preparation of potato slices sample

The first test was taken on the potato chips and cauliflower, in first tray cauliflower was placed and second tray potato slices were placed. The drying period of the chips and cauliflower was 24 hrs. After in 24 hr the product is removed from the solar cabinet dryer and calculations were carried out. Similar process was taken on next day with coriander and bitter guard and result follows,

The table 2 shows the calcution of the moisture content removed from the vegetable binin percentage. The moisture removed from the patato chips is about 88.75 % in 24 hr. and moisture removed from from the corinder,bitter guard,and cauliflower is 88%, 92%, and 79.14% . These all calculations are as wet basis.

Table 2 Moisture removed from vegetables (wet basis)

Sr no.	Vegetable	Initial weight (grams)	Final weight (after drying) (Grams)	Weight of water (grams)	Moisture removed in %
1	Potato chips	400	45	355	88.75
2	Corinder	50	6	44	88

3	Bitter guard	200	16	184	92
4	Cauliflower	350	73	277	79.14

The results have been shown graphically. The graph shows relation between times of day vs. temperature for natural convection. The two temperatures shown are ambient temperature and collector outlet temperature and from the bar chart it is clear that the difference of the temperature is between 9°C to 11°C. The potato chips were dried by cabinet solar dryer in one day reducing the weight from 400 grams to 45 grams. The coriander was dried by solar dryer for the period of 24 hrs. Then we found the weight of sample reduced from 50 grams to7 grams. The coriander was dried by cabinet solar dryer convection in one day reducing the weight from 50 grams to 6 grams. The cauliflower was dried by solar cabinet dryer in one day reducing the weight from 350 grams to 45 grams. It is observed that the drying time is less in solar cabinet dryer than the open sun drying method.

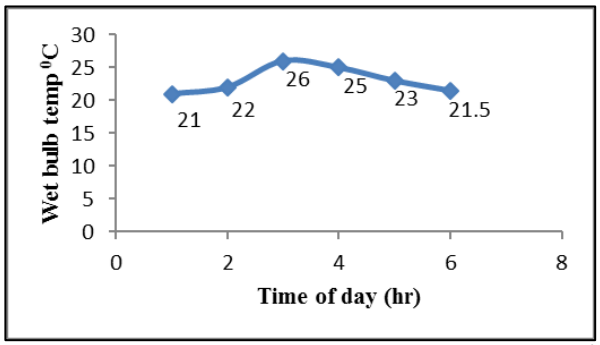

Fig 4 Time (hr) vs Wet Bulb Temperature ^{0}C

The above graph was plotted between wet bulb temperature and time of day. The graph shows the wet bulb temperature inside the dryer chamber with respect to the time of day. The wet bulb temperature rise upto the 27^0 C. the minimum wet bulb temperature record inside the chamber was 21^0 C.

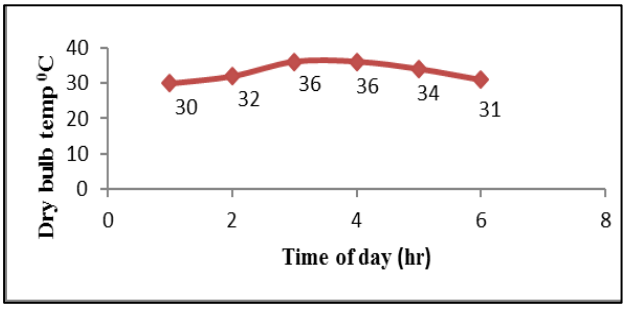

Fig. 5 Time (hr) vs Dry Bulb Temperature °C

The fig 5 which shows relation between time of the day vs. temperature for cabinet dryer. The two temperatures shown are ambient temperature and inside dryer chamber. From chart it is clear that the difference of the temperature is between 9^0 to 11^0 C. the temperature inside the chamber is suddenly rise upto 31^0 C.

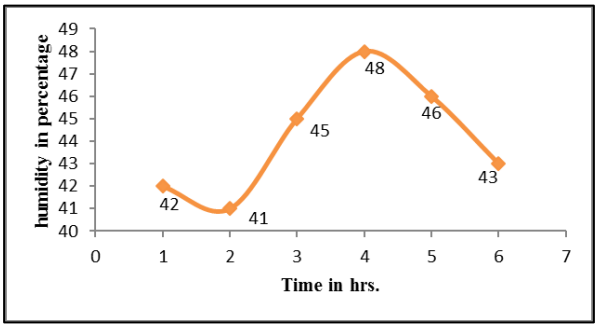

Fig 6 Time (hr) vs Humidity %

The fig 6 plotted between humidity and time of the day and data taken on the basis of dry bulb temp and wet bulb temp. the graph shows the hourly variation of humidity inside the drying chamber.as the day progress humidity is increases. The maximum humidity obtain during test is 48 %.

From the above result we can say that the performance of the dryer should be satisfied.

IV. CONCLUSIONS

From the design & test carried out on developed solar cabinet dryer model the following conclusions were made

- The efficiency of the solar dryer is 85 – 90 % which is greater than open sun drying method
- The time required for the drying is less than traditional open sun drying method.
- Less contamination of products occur in the solar cabinet dryer.
- Dryer is useful for urban areas because it requires less space.
- Quality of the dried product in the solar cabinet dryer is superior as compared to open sun drying method.
- The solar cabinet dryer does not require any external power source.
- In the fabrication of dryer there is less parts therefore less maintenance is required.
- Drying operation is simple, dryer is easy to handle, transport & operate.
- For operating the dryer there is no need of educated & skilled person.
- The solar cabinet dryer is helpful to avoid high market rates of vegetables.

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