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Development and cost estimation of natural circulating solar dryer

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Abstract
A natural circulating solar dryer is fabricated and its cost is estimated. This solar drying system was made up of two units solar collector and drying cabinet. The solar collector is made up of rectangular wooden box (1.6 m x 0.91 m x 0.19 m) having a front face area of 1.45m^2 in which black painted rocks were placed and rectangular vertical drying cabinet made up of float glass sheet was erected on angle iron frame. Rocks of an average size of 10 cm diameter and painted with blackboard paint are placed in solar collector to absorb maximum solar radiation. A rectangular cuboids shaped drying cabinet is made by adhering four float glass of rectangular shape having dimension of 0.95 m x 0.56 m x 0.39 m (l x b x t) and having a front face area of 0.532m^2.This cabinet is further divided into five divisions with the help of removable shelves, made up of aluminium wire mesh.

Keywords: Solar dryer, solar collector, solar cabinet, ventilation

Introduction
Sun is the primary source of energy in the planet earth. From ages sunlight has been used for drying crops in the field. This energy is freely available in nature and with the application of some basic concepts of science and technology; this energy can be utilized in much better, safer and efficient way. With the recent advances of science it is now possible to convert this energy to other forms of energy like electric energy & thermal energy. Fossil fuels are depleting day by day at a much faster rate than before and it is expected that we will run out of it in the coming future. So in the present scenario renewable energy is focused for acceptance of it as an alternate source of energy in almost all the countries of the world. Drying is a heat and mass transfer process in which water is removed from the product. This results in lowering of water activity in the final dried product, due to which growth and reproduction of microorganism is also hindered, which causes deterioration of product. Open sun drying is one of the oldest methods of drying, practised for drying various plant and animal food products like paddy, wheat, fish, meat, fruits and vegetables. Although sun drying is economical to farmer but because of it open in nature and climate dependent it suffer losses from rain, dust, rodents, birds etc. Use of solar dryer eliminates the problem associated with open air drying. (Madhlopa *et al.*, 2002) [1]. Solar dryer is advantageous over sun drying in terms of time of drying, quality of product and energy utilization. Solar dryer gives faster drying rate than sun drying as its temperature is relatively higher than sun drying. Solar dryer is closed therefore it is less affected by dust, dirt and surrounding environment. Now varieties of solar dryers have been developed throughout the world. These solar dryer can broadly be classified in two groups: natural convection type and forced convection type. In natural convection type dryer hot air naturally moves upward, as it is relatively lighter than cold air, which remains below it, while in forced convection dryer fan is required to force the air inside and/or outward the dryer. In present study the solar dryer made is of natural convection type. This solar dryer consist of two main parts solar collector and drying cabinet. Solar collector is used for heating the air while drying cabinet is used for drying the product.

2. Materials and methods
The solar collector is made up of rectangular wooden box (1.6 m x 0.91 m x 0.19 m) having a front face area of 1.45m^2 ,inside this box, rock is placed which is painted black to absorb maximum radiation. For entrapping the radiation the collector is also covered with glass. A rectangular shaped drying cabinet is made by adhering four float glass of rectangular shape having dimension of 0.95 m x 0.56 m x 0.39 m (l x b x t) and having a front face area of 0.532m^2. Exhaust is also provided on the top most of the cabinet, for carrying out of humid air. Four selves are also provided inside this cabinet. These selves are made up of wire mesh with supporting corner provided is of wooden frame. Finally these two integral parts of the dryer are placed on a frame made up of angle iron to provide support and stability to the structure.

2.1 Fabrication of solar dryer
The list of major items used for fabrication of solar dyer were plywood, float glass, aluminum frame, angle iron, rubber, thermocol and other miscellaneous items. The solar dryer fabrication consists of two major units solar collector and drying cabinet. These two units were connected together by PVC pipe and placed on a frame made of angle iron to provide it support and base. The description regarding fabrication of these units is mentioned below:

2.2 Construction of solar collector
The solar collector was fabricated using plywood of 18mm thickness. This plywood was cut into pieces of various dimensions and a box of dimension1.6m long x 0.91m wide x

0.19m high having top open was made. This box was insulated from all sides by using thermocol sheet and on this box black painted rocks were placed then covering on the top of box is done using glass. Paint used for the coloring the rock is blackboard black paint, which is dull in color and hence absorb maximum solar radiation and store thermal energy in the rocks. Glass is placed on the top portion of collector and fastened by screw by providing a border of Aluminum frame. In order to reduce the heat losses from the collector the joining of glass and wooden frame was insulated with rubber.

Air enters through the small opening provided at the bottom end of the collector and is heated while it passes over the rocks. The hot air outlet of the collector is connected to the bottom side of the drying chamber through two PVC elbow coupler pipes having diameter 75 mm.

2.3 Construction of Supporting Frame:

Supporting frame was constructed for supporting and withheld solar collector and drying cabinet together. It was fabricated by L shaped angle iron having thickness 3mm for placing the solar collector inclined from the horizontal ground surface. Inclination of solar collector depends on latitude and longitude of that particular area to absorb maximum solar radiation & drying chamber at 90 degree from the horizontal (for effective natural circulation of air.This frame was made by cutting angle iron of various sizes and joining them by welding and nut and bolts.

2.4 Construction of Drying cabinet

It consists of float glass, aluminum frame and plywood. Drying cabinet is made by joining four glass sheet perpendicular to the adjoining glass and held tightly to each other by providing aluminum frame at all corners. Nuts were used to fasten the aluminum frame together and rubber was used to provide perfect seal between glass and aluminum frame. Bottom of the drying cabinet is made up of plywood on which two holes is provided at the bottom to connect the outlet air from the solar collector to the bottom of drying chamber with PVC elbow pipe. The dimension of the chamber is 0.95m high x 0.56m wide x 0.39mthick. Heated air passes through four removable trays each of size 0.5m length x 0.3m thick kept at equidistance from each other and made of wire mesh frame of wooden border on which the drying product can be kept. The trays can be inserted or removed from the doors provided in the back side of the cabinet. To increase air circulation rates, ventilator made up of PVC pipe is placed on the top of the dryer chamber.

The drying chamber has 0.95 m x0.56 m x0.39m outer dimensions. Out of four shelves/trays TR1, TR2, TR3 & TR4 were placed inside the drying chamber. The depth of each tray is 8 mm with wire mesh at the bottom. The four drying trays TR1, TR2, TR3&TR4 each have same areas of 0.15m^2, with a total area of 0.6m^2.A relative positions of the four trays TR1, TR2, TR3& TR4 are 0.19m, 0.38m, 0.57m& 0.76m respectively from the base of drying chamber (hot air entry point) (Hegde *et al*. 2015) [2].

Table 1: Dimensions of solar dryer's parts

Specification of dryer	
Total height of cabinet	0.95m
Front width of cabinet	0.56m
Side width of cabinet	0.39m
Length of solar collector	1.6m
Width of solar collector	0.91m
Depth of solar collector	0.19m
Glass thickness	6mm
No. of tray(TR)	4
Type of tray(TR)	Wire mesh
Area of tray(TR)	0.15m^2

2.5 Cost of Construction

An approximate cost analysis data for construction of a solar dryer having solar collector of dimension (1.6 m x 0.91 m x 0.19 m) and drying chamber(cabinet) of dimension of 0.95m x 0.56m x 0.39m is shown in table 2.

Table 2: Cost of construction

S. No.	Material Required	Quantity	Amount (Rs.)
1.	Plywood (2438.4 mm length, 1219.2 mm wide & 18mm thick)	1	1500
2.	Float glass(6mm)	4	1250
3.	Aluminum frame(kg)	2.5	1550
4.	Wire mesh(Net in feet)	10	200
5.	Rubber(feet)	10	150
6.	Bracket-*	2	30
7.	PVC pipe (feet &110mm dia.)	1	50
8.	Elbow (75mm dia.)	2	50
9.	Handle	1	50
10.	Screw	150	100
11.	Adhesive (gm)	500	70
12.	Thermocol	4	200
13.	Black board black paint, primer, brush	-	425
14.	Solvent (PVC adhesive)	2	70
15.	Glass adhesive (tape)	1	200
16	Miscellaneous items (hinge, nut, bolt etc.)	-	1605
17	Labour Charge	-	2000
Total			9500

3. Result and Discussion

The solar collector is rectangular shape with dimension of 1.6m x 0.91m having 190 mm depth and glass cover, 6 mm thick float glass insulation was used at the bottom of the collector to reduce the back and edge losses. The collector which is inclined at the angle of 37^0 (according to latitude and longitude of Mungeli district, Chhattisgarh, India) from the horizontal is oriented along the N-S direction. The solar collector is covered with 6 mm thick float glass. The lower end face of collector is the air inlet whereas; its higher face end is connected to the circular duct of the chamber.

The highest temperature recorded inside dryer during experimental study in winter season (November- December 2013) in Mungeli district of Chhattisgarh was found to be 58 °C in solar tray dryer and 30 °C in open sun drying (Basunia, M.A. *et al.*,2013) [3].

Fig 2: Natural circulating solar dryer

3. Conclusion

The solar drier having a drying cabinet with front face area of 0.532m^2 and solar collector with a front face area of 1.45m^2 is constructed with an approximate amount of Rupees 9,500/- (Nine thousand five hundred rupees only). The capacity of drying camber is 0.207 m^3. The initial cost of solar drying is higher than sun drying but the dried material is protected from direct sun light, insects, birds and contamination by dust, producing a product with improved quality. The highest temperature recorded inside dryer during experimental study in winter season (November- December 2013) in Mungeli district of Chhattisgarh was found to be 58 °C in solar tray dryer and 30 °C in open sun drying.

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