DESIGN AND FABRICATION OF SOLAR AIR DRYER

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Abstract-*The goal of this work is to configuration, create and assess execution of a circuitous sun based dryer model in a uninvolved and dynamic mode utilizing warm vitality The flighty ascent and successive shortage of fossil fuels quickened the persistent quest for an elective Power source. Sun powered is one of the inexhaustible and supportable Sources of intensity that pulled in a huge network of researchers from everywhere throughout the world. This is to a great extent because of its abundant in both immediate and roundabout structure. As such the development of proficient and cheap hardware for the Drying of agrarian, marine items, and furthermore used to dry garments, in this manner improving the nature of the items just as improving the personal satisfaction. The utilization of sun based dryers in the drying of horticultural items can altogether diminish or Eliminate item wastage, food contamination and at the sometime upgrade efficiency of the ranchers towards better Revenue determined. It was demonstrated that the utilization of this kind of sunlight based dryer decreased the drying time fundamentally and basically furnish better item quality contrasted and ordinary drying technique*

Keywords: Solar energy, dryer, passive, performance evaluation, ambient temperature, dryer efficiency, moisture loss, solar collector, optimum temperature, copper pipe.

1. INTRODUCTION:

A **solar dryer** is another application of solar energy, used immensely in the food and agriculture industry. Though sun is still used as the direct source for drying food items and clothes in certain parts of the world. An indirect source of solar power can also be used for the same purpose in the form of a solar dryer. The main disadvantage of drying directly under the sun is contamination – dirt, animals, insects etc. Also there is a fear of sudden change in weather conditions like wind or rain.

SOLAR DRYER are devices that use solar energy to dry substances, especially food. There are two general types of solar dryers: Direct and indirect.

DIRECT:

The item to be dried is exposed directly to solar radiation through a transparent material that covers the structure. The heat generated from the solar energy is used to dry the crops or food items and also heats up the surroundings. The main disadvantage of using the direct mode is that the heat that will be absorbed by the item cannot be controlled.

INDIRECT:

This method does not expose the crop directly to the sunlight. The solar radiation is absorbed and converted into heat by another surface (like a black top) usually called the collector. Air that will be used for drying is passed over this surface and gets heated, which is then used to dry the food item inside the dryer. The main advantage of indirect mode of drying is that the temperatures can be controlled.

1.1Problem Definition: Mechanical drying of agricultural products is an energy consuming operation in the post-harvesting technology.

Greater emphasis is given to using solar energy sources in this process due to the high prices and shortages of fossil fuels.

"Sun drying" is the earliest method of drying farm produce ever known to man and it involves simply laying the agricultural products in the sun on mats, roofs or drying floors.

This has several disadvantage since the farm produce are laid in the open sky and there is greater risk of spoilage due to adverse climatic situation like wind, rain, moist and dust, loss of product to insects, birds etc.

For these purposes, a new natural convection solar dryer consisting of a solar flat plate collector and a drying chamber was developed.

2. Design Consideration:

1. Air gap - a gap of 150mm should be created as air vent (inlet) and air passage.

2. Glass and flat plate solar collector - 5mm thick transparent glass was used. It also suggested that the metal sheet thickness should be of 0.8 – 1.0mm thickness was used.

3. Dryer Trays – Net was selected as the dryer screen or trays to aid air circulation within the drying chamber. Three trays were made of metal net. The tray dimension is 600*880mm

4.Dimension – The design of the drying chamber was made as spacious as possible of average dimension of 600*880*670mm and the dimensions of flat plate collector was 1219*880mm[2.]

5. Efficiency - This can be defined as the ratio of the output of a product to the input of the product.

2.1 Nomenclature:

A: Surface area, m^2

c_p: Specific heat at constant pressure, kJ/kg °C

g: Acceleration due to gravity, m/s^2

h: Heat transfer coefficient, W/m^2 · °C

h_{fg}: Latent heat of vaporization, MJ/kg

I: Solar insolation of collector, W/m^2

k: Thermal conductivity, W/m· °C

L: Length, m

$\dot{m}$: Mass flow rate, kg/s

m: Mass, kg

Q: Heat transfer rate, W

x: Thickness of metal sheet, m

Xm: Percentage moisture content at any time t,

% t: Sunshine hours (Time), hrs

T: Temperature, °C

ΔT: Temperature difference, °C

ΣR: Total thermal resistance, °C/W]

v: Kinematic viscosity, m^{2}s

μ: Dynamic viscosity, kg/m·s

β: Coefficient of thermal expansion K−1

δ: Drying time, days.

τ: Transmittance

ρ: Density, kg/m³

α: Absorptivity

ε: Emissivity

σ: Stefan-Boltzmann constant, W/m²K⁴

η: Efficiency,

% γ: Moisture removal, %

M_{dr} = average drying rate (Kg/hr)

M_e= mass of water to be extracted from the product[kg]

t_s= time required for drying

2.2 Design Calculation:

1) **Solar collector tilt angle (Φ)** = 15° + Latitude of Ahmedabad (For winter condition).

= 15° + 23.0225°

= 38.0225°

2) Insolation on the collector surface:

Suppose time = 9 AM.

= 15(9-12) = -45° =$-\frac{\pi}{4}$.

d = 31+29+5=64 days.

Y = 23.45° - $\sin(\frac{360}{365}$ (204° + d)).

Y = 23.45° - 0.271°

= 23°27'0 - 0°16'19"

= 23°10'41"= 23.178°.

Z = cos^{-1} (sinX sinY + cosX cosY cosH)

X = Latitude of Ahmedabad.

Z = cos⁻¹(sin23.0225 * sin23.178 + cos23.0225 * cos 23.178*cos-π/4)

= 0.7389.

3) Heat Loss by Convection and Conduction through the Base of the Collector.

$Q_{cb, loss} = \underline{\Delta T_{cb}}$

$\sum R_{cb}$

ΔT_{cb} is the temperature difference between the collector and the environment.

Rcb = $1/h_{cb}A_{cb} + x/kA_{cb}$ is the thermal resistance offered by the wall and film at the inside of the collector.

4) Direct insolation:

I.D. = $1.353 * 0.7^{(AM^{0.679})}$.

I.D. = $1.353 * 0.7^{1.0}$

= 0.9470 KW/m^2

= 947.08 W/m^2.

I = $947.08 * (1.2192 * 0.9144)$

= 1055.84 W.

The air gap height was taken as 150mm and the width of collection is 914mm

Q_u = mc_p (T$_c$ – T$_a$) = $Q_{rad, in}$ – $Q_{cb,loss.}$

Q $_{useful}$ = 929.87-0.4347 (Q $_{loss}$ = 0.4347W/m²°C)

= 929.4353W

U $_{useful}$ = Q total* 0.8807.

= 1055.84 * 0.8807

= 929.87 W.

Heat gain by air Q = 929.87 W.

5) Thermo syphen effect:

$C_p air$ = 1005 J/Kg*k.

Q = mC_p (ΔT).

929.87 = m * 1005 * 313

m = 0.0308 Kg/sec.

δ = 1.225 kg/m^3..

ΔT = 30°

Va =Velocity of air.

V = Volume rate of air.

= M/δ.

δ = m/V

When ΔT = 40° V = 0.025 m^3/sec ,Va =0.02517/0.15*0.914=0.18 m/sec

When ΔT = 45° V = 0.0167 m^3/sec ,Va = 0.12 m/sec.

When ΔT = 35° V = 0.0215 m^3/sec, Va = 0.1157 m/sec.

When ΔT = 25° V = 0.030 m^3/sec , Va = 0.22 m/sec.

ΔT increases with decrease in velocity of air(Va)..

As per the experiment,

Initial wet mass of product=55 gm

Final dry mass of product =22 gm

Mass of water removed = (55 - 22) g

 = 33g.

6) % of total moisture content loss $= \frac{Initial\ mass - Final\ mass}{Initial\ mass} * 100$

$= \frac{55-22}{55} * 100$

= 54.6%.

7)% efficiency of the dryer $= \frac{Work\ output}{Work\ input} * 100$

$= \frac{22}{55} * 100$

= 40%.

8)from the experiment,

$\mathbf{M_{dr}} = \frac{M_e}{t_s}$

It takes 20 minutes to absorb 33 gm of moisture from the chamber

Therefore,
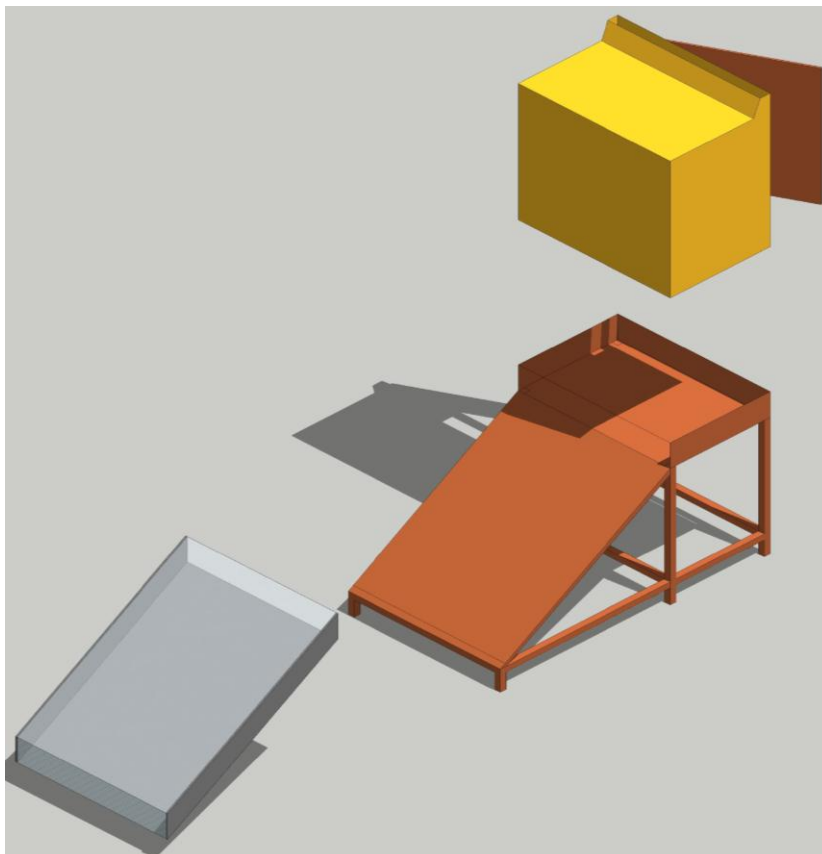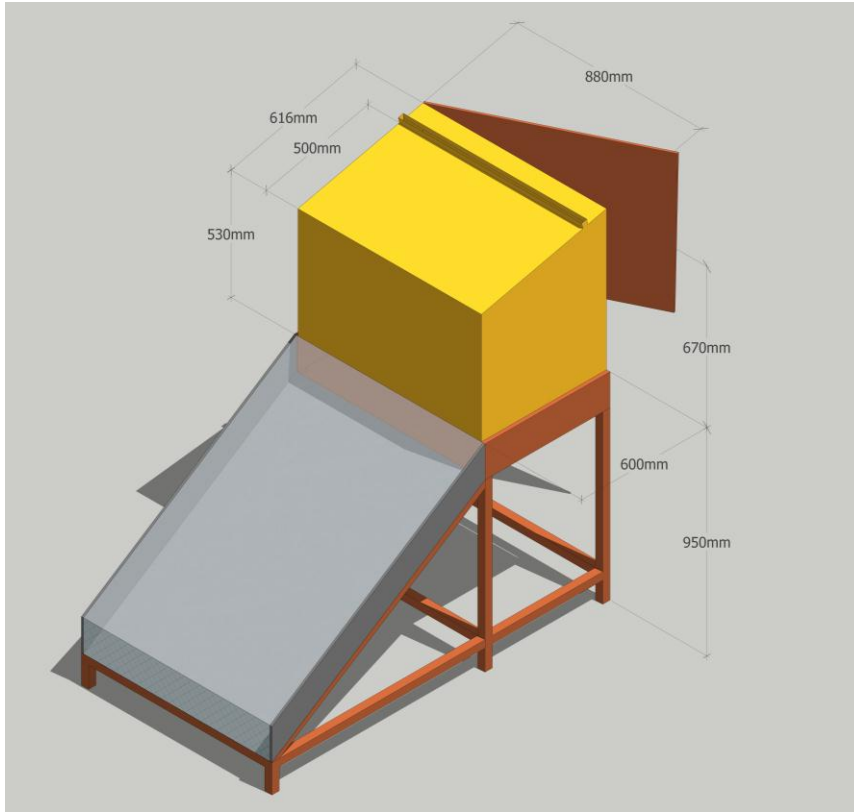
$\mathbf{M_{dr}} = \frac{0.033}{(20/60)}$

$\mathbf{M_{dr}}$ = 0.099kg/hr.

If the sunlight is for 10 hours per day

Then $\mathbf{M_{dr}}$ = 0.099 * 10

 = 0.99 kg or 1kg/day.

2.3 CAD Design:

3. Construction:

The materials used for the construction of the passive solar dryer are cheap and easily obtainable in the local market. The solar dryer consists of the solar collector (air heater), the drying cabinet and drying trays.

Following tools were used in measuring and marking out on the wooden planks:

Carpenter's pencil.
Steel tapes (push-pull rule type).
Steel meter rule.
Angle plate.
Hand saws (crosscut saw and ripsaw).
Hammer.
Pinch bar and pincers.
Electric cutter machine.

3.1 Materials:
The drying chamber was made up highly polished wood wish consist of three drying trays also made of wood, the material has been chosen since wood is a poor conductor of heat and its smooth surface finish and also heat loss by radiation is minimized.

- Cover plate: This is a transparent sheet used to cover the absorber, thereby preventing dust and rain from coming in contact with the absorber, it also retards the heat from escaping, common materials used for cover plates are glass, fibre glass, flexi glass but the material used for this project is glass.
- Absorber plate: This is a metal painted black and placed below the cover to absorb, the incident solar radiation transmitted by cover thereby heating the air between it and the cover, here aluminium, is chosen because its quick response in absorption of solar radiation and also copper because of its good ability to keep the absorbed solar radiation.
- Insulation: This is used to minimize heat loss from the system, it is under the absorber plate, the insulator can withstand stagnation temperature, it is fire resistant and not subject to out-going gassing and it is damageable by moisture or insect, insulating materials are usually fibre glass, mineral wool, but here thermocol was chosen.
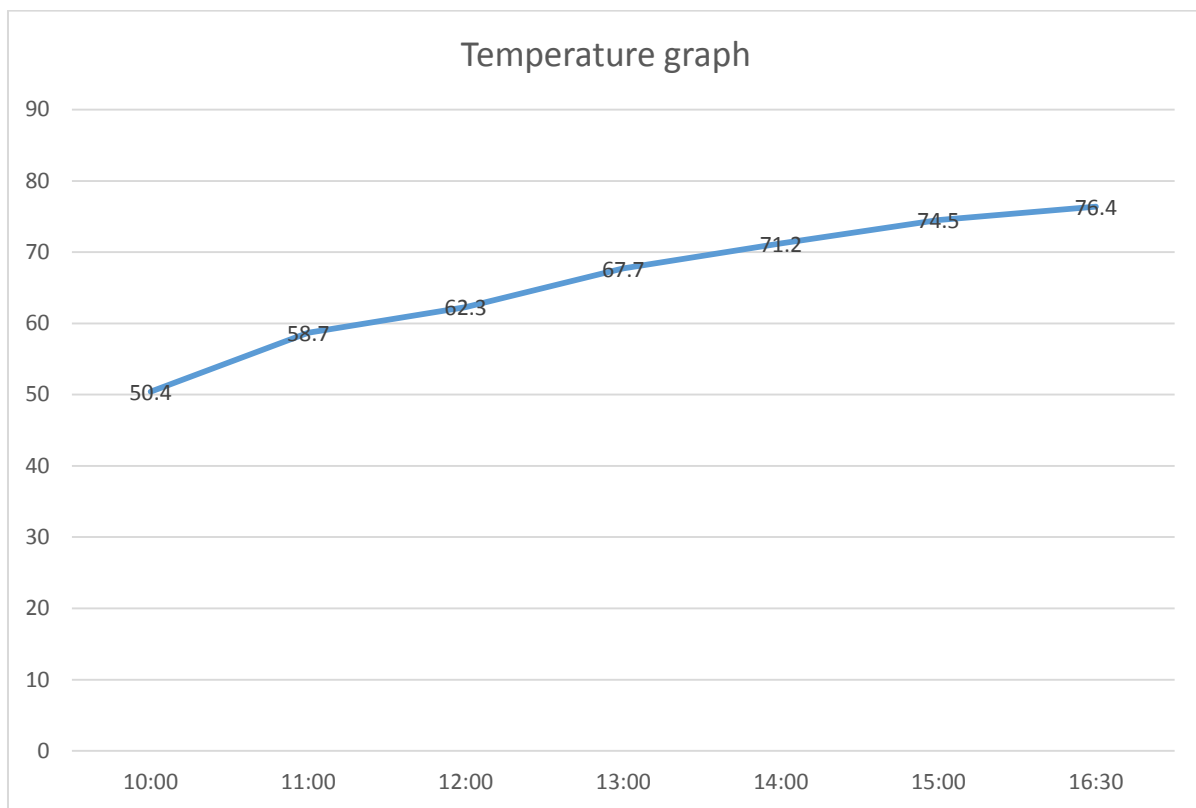
3.2 Images of Solar dryer::
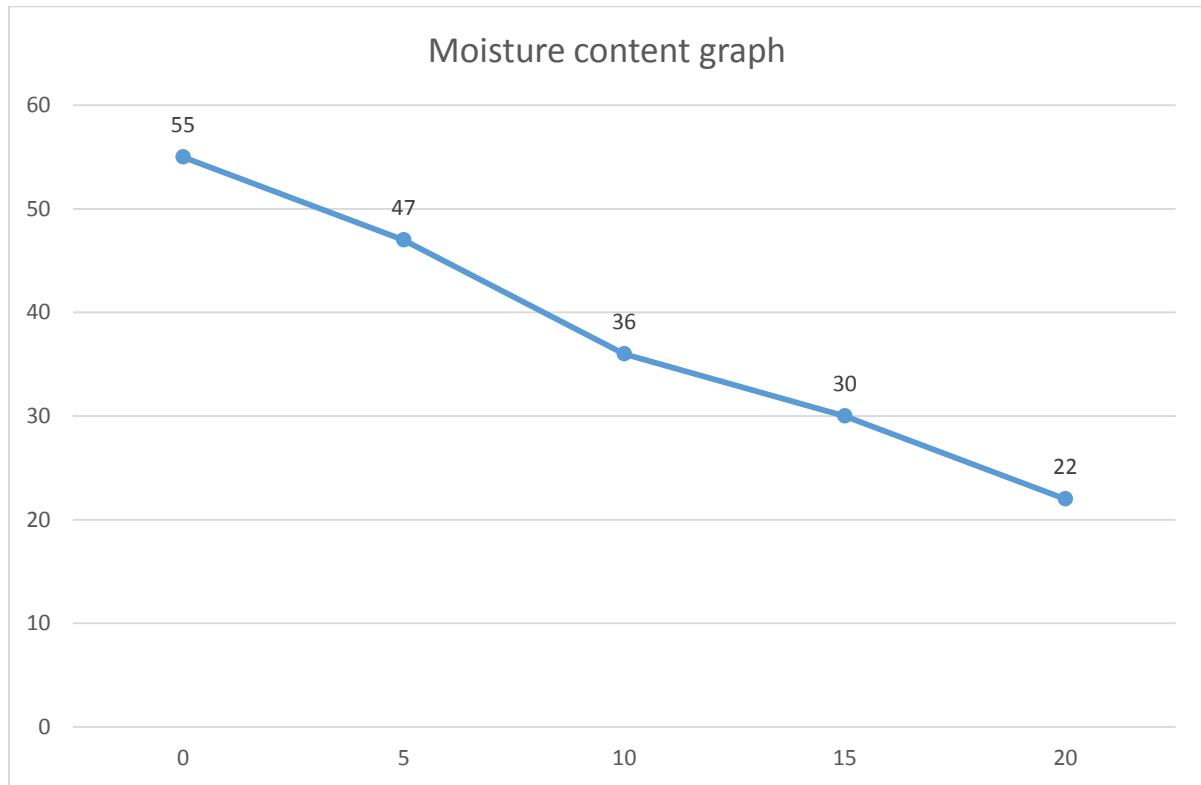
4. Results:

Temperature result:

TIME	TEMPERATURE OF COLLECTOR(°c)
10 : 00	50.4
11 : 00	58.7
12 : 00	62.3
13 : 00	67.7
14 : 00	71.2
15 : 00	74.5
16 : 30	76.4

Moisture result:

TIME(In minutes)	MASS OF MATERIAL(In gram)
0	55
5	47
10	36
15	30
20	22

5. Graphical validation:

Moisture content graph

6. Future Scope:

Increasing the absorbivity of the absorber plate.

Increasing the air flow rates at the inlet section of the prototype to increase the efficiency.

Providing dehumidifier before the drying chamber for removing moisture content in the air to improve the drying rate.

Decreasing the distance between the tray and bottom plate of the drying chamber to reduce thermal loss.

Provide copper tubes to the side wall of the dryer to recover heat.

7.Conclusion:

From the test carried out, the following conclusions were made.

The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of the given materials.

The material inside the dryer requires less attentions, like attack of the wind, rain, other environmental conditions.

There is ease in monitoring when compared to the natural sun drying technique.

The capital cost involved in the construction of the solar air dryer is much lower than a mechanical dryer.

The dryer efficiency is very reasonable. We achieved the highest temperature of approximately 76.5° C.

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