NOVATEUR PUBLICATIONS
International Journal of Research Publications in Engineering and Technology [IJRPET]
ISSN: 2454-7875
VOLUME 3, ISSUE 4, Apr.-2017

DESIGN OF SOLAR DRYER FOR RICE AT KARJAT, RAIGAD, MAHARASHTRA

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ABSTRACT:

This paper deals with current practices of drying agricultural products in most of developing nations like India. It also try to coin the concept of utilization of Solar dryer at farm side. In a developing country like India, having the second largest population and agriculture as the source of income to nearly 60 % of the total population, post-harvest and storage loss is a major quandary, which needs to be addressed in due diligence. Many food preservation techniques like cold storage, drying, etc., have been evolved out over the years to tackle the above losses. The major constraint is that almost all the technologies are utilizing fossil fuel resources, which are depleting very fast and wise use of these precious resources are preferred for long-term energy sustainability. Therefore, sustainable methods for food preservation are the need of the hour. Solar drying is one of the best choices in this context. The effect of temperature to moisture contents against time and rate of drying are studied & discussed in this paper.

KEYWORDS: Solar Dryer, Rice, Absorber, Air Preheater, Solar Cabin, Relative Humidity

I. INTRODUCTION:

Drying is an excellent way to preserve food and solar food dryers are appropriate food preservation technology for sustainable development. Drying was probably the first ever food preserving method used by man, even before cooking. It involves the removal of moisture from agricultural produce so as to provide a product that can be safely stored for longer period of time. “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 disadvantages since the farm produce are laid in the open sky and there is greater risk of spoilage due to adverse climatic conditions like rain, wind, moist and dust, loss of produce to birds, insects and rodents; totally dependent on good weather and very slow drying rate with danger of mould growth thereby causing deterioration and decomposition of food grains. The process also requires considerable area of land, time consuming & laborious developments with time results in artificial electro-mechanical dryers but this process is highly energy intensive and expensive which ultimately increases product cost. Further efforts to regulate cost & maintain quality, lack of electricity in remote part of nation & geographical location of nation where we are having ample amount of solar energy we have to think for solar dryer instead of electro-mechanical dryer & sun drying or other preservation techniques.[1],[5]

In solar drying, solar dryers are specialized devices that control the drying process and protect agricultural produce from damage by insect pests, dust and rain. In comparison to natural “sun dries”, solar dryers generate higher temperatures, lower relative humidity, and lower moisture content and reduced spoilage & contamination. In addition, it takes up less space, quicker and relatively inexpensive compared to artificial mechanical drying method. Thus, solar drying is a better alternative solution to all the drawbacks of natural drying and artificial mechanical drying. The solar dryer can be seen as one of the solutions to the world’s food and energy crises.[9]

A. PROBLEM STATEMENT:

Food scientists have found that by reducing the moisture content of food to between 10 and 20%, bacteria, yeast, mold and enzymes are prevented from spoiling it.

The flavour and most of the nutritional value is preserved and concentrated. As per the reports published by International Rice Research Institute (IRRI) 2009 India stood second highest rice producer in the world & India is considered to be one of the original centers of rice cultivation covering 44 million hectares. Its rice harvesting area is the largest in the world. Around 65 percent of the total population in India eat rice and it accounts for 40 percent of their food production. Rice-based production systems provide the main source of income and employment for more than 50 million households.[7][6] Food Corporation of India (FCI) along with Central Warehousing Corporation (CWC) and respective State Warehousing Corporations (SWC) are the primary agencies entrusted with the task of grain storage. India has incurred post harvest losses to the tune of 502,389 metric tons of rice and 133,206 metric tons of wheat at the state-run FCI storage facilities from 1997 – 2013, according to FCI in response to an RTI application.[8] As per the news article published in ET dated 19thFeb.2016 India is still facing the power crisis we had a big gap between supply and demand so wasting an energy for drying a agricultural produce that to when we are having good solar radiation is not worth.

B. OBJECTIVES:

The major objectives of the drying process are as follows:

1. To reduce the food grains like rice as it is one of the major crop in Konkan Maharashtra region
2. Finding & practicing more hygienic way to store the rice grains.
3. reduce on farm post harvest treatment losses.
4. High-quality dried product will have good market value and hence will bring high profit to the producers.

II. DESIGN:

A. DESIGN CONSEDERATIONS:

1. The amount of moisture to be removed from the given quantity of Rice
2. Time period within which freshly harvested rice has to be dried.
3. The daily sunshine hours for the selection of the total drying time
4. The quantity of air needed for drying
5. Daily solar radiation to determine energy received by the dryer per day
6. Wind speed with which it has to be supply for the drying of rice grains

B. MATERIAL SELECTION:

Table I. Material selection

Sr. No	Material	Use
1	Plywood	Cabin And Air collector
2	Glass	For cover on absorber plate
3	Copper sheet	Absorption plate
4	Thermocole	Insulation
5	PVC Pipe	Air circulation
6	MS Net	Tray in cabin
7	MS-Channel (L-section)	Fabrication of Stand

C. DESIGN OF SOLAR DRYER:

Various solar geometry for the location Karjat, Raigad, Maharashtra, India are as follows:

Latitude angle (φ) = 18.55°, Longitudinal angle (Ψ) = 73.19°, Tilt Angle / Slop angle (β) = Latitude angle (φ) = 18.55°, Declination Angle (δ) = -0.8072° (Declination Angle is zero on the two equinox days of march 21 and September 22 Positive during northen hemisphere i.e summer Negative during southern hemisphere i.e winter) Hour Angle (ω) = 45°, Incident angle (θ) = 45.00569°

As we know that,

Energy Balance Equation

$$q_{useful} = A_{plate} S - q_{loss}$$

Where,

q_{useful} = useful heat gain's = incident solar flux absorbed in the absorber plate,

A_{plate} = Area of absorber plate ,q_{losses} = Rate at which heat is lost by convection and re-radiation conduction

Before that we must known total incident radiation fall on top of absorber plate (I_T)

$$I_T = I_b r_b + I_d r_d + (I_b + I_d) r_r$$

But radiation data for location at latitude angle (Φ) for(karjat) =18.55° (NASA) Longitudinal angle (Ψ) for (karjat) = 73.19° (NASA)

$I_b = 6.29310009766$ kwh/m²day = 262.2125 W/m²

$I_{global} = 6.762$ kwh/m²day = 281.75 W/m²

(http:/mnre.gov.in/sec/solar-assmnt.htm)

r = Tilt Factor

Tilt factor for beam radiation (r_b)

$$r_b = \frac{[\sin\delta \sin(\varphi-\beta)+\cos\delta \cos\omega \cos(\varphi-\beta)]}{[\sin\varphi \sin\delta+\cos\varphi \cos\delta \cos\omega]} = 1.0619$$

Tilt factor for diffuse radiation (r_d)

$$r_d = \frac{(1+\cos\beta)}{2} = 0.9740$$

Tilt factor for beam reflected radiation (r_r)

$$r_r = \rho_{gr}\frac{(1-\cos\beta)}{2} = 5.19536 \times 10^{-3}$$

flux absorbed by solar plate

$$S = I_b r_b (\tau\alpha)_b + [I_d r_d + (I_b + I_d) r_r](\tau\alpha)_d$$

Where, Transmissivity – Absorptivity product (τα)

It is calculated by following equ^n

$$\tau\alpha = \frac{\tau\alpha}{1-(1-\alpha)\rho_d}$$

absorptivity for copper = (α) =0.94 &

ρ_d = diffuse reflectivity = for m = 2 (cover) is 0.21 & *form* = 1 (cover) is 0.15 Type equation here.

Here we need to consider, Transmissivity-Absorptivity for beam radiation (τα) = 0.869745, Transmissivity-Absorptivity for diffuse radiation $(\tau\alpha)_d$ = 0.813662.

Transmissivity based on Reflection Reflectivity for diffused radiation can be determined by ($_r$) =0.9169 ,

Transmissivity based on absorption can be determined by using following relation(τ_{ad})

Again coming back to flux absorbed by solar plate,

$$S = I_{b}r_{b}(\tau\alpha)_b + [I_{d}r_{d} + (I_b + I_d)r_r](\tau\alpha)_d$$

$$= (262.2125 \times 1.0619 \times 0.869745) + [(19.5375 \times 0.9740) + (262.2125 + 19.5375) \times (5.19536 \times 10^{-3})]$$
$$\times 0.813662) = 242.17480 + (19.2953 + 1.46379268) * 0.813662 = 242.17480 + 16.6746379$$

$S = 258.8494$ W/m²

$$(I_T) = I_b r_b + I_d r_d + (I_b + I_d)r_r$$

$$= (262.2125 \times 1.0619) + (19.5375 \times 0.9740) + [(262.2125 + 19.5375) \times (5.19536 \times 10^{-3})]$$

$$= 278.4435 + 19.0295 + 1.46379$$

$I_T = 298.93679$ w/m²

As we know , Energy Balance equation applying to absorber plate .

$$q_{useful} = A_{plate} S - q_{losses}$$

in above equation

$$q_{losses} = q_{top} + q_{bottom} + q_{side}$$

For finding above losses we must know area of plate so calculate for area of plate (A_p)

A prototype is designed for 10 kg of rice.

Rice is harvest nearly 37.5% of moisture it has in maze , for better storage it must be demoisture upto 15.5% of moisture and heated upto temperature 45°c.

Let's assume

Φ_m= Moisture to be remove ,Φ_{mi}= Initial moisture = 37.5 %, Φ_{mf}= Final moisture= 15.5 %, mi = Initial mass = 10 kg moisture to be remove on wet basis

$$\varphi_m = \frac{mi\,(\varphi_{mi} - \varphi_{mf})}{100}$$

$$= \frac{10\,(37.5 - 15)}{100}$$

φ_m = 2.25 kg of water

Amount of energy required to evaporate water (E)

$$E = \Delta\varphi_m H_{fg}$$

H_{fg} 4.186 x 10^{-3} (597 – 0.56 x $T_{product}$)

(Solar dryer from Yousuf Ali et . All)

Hear $T_{product}$ is assume to be in equilibrium with $T_{ambient}$and slightly below

i.e$T_{product}$ 29°C

H_{fg} 4.186 x 10^{-3} (597 – 0.56 x 26)

H_{fg} 2.438094 WJ / kg

$$E = \Delta\varphi_m H_{fg}$$

= 2.25 x 2.438094

5.4857 MJ

Mass of air needed to drying of rice (M_{air})

$$M_{air} = \frac{\varnothing_m}{\text{Final specific humidity} - \text{Initial specific humidity}}$$

From a Sychrometric chart at ambient temperature at 26°C and relative humidity of 70% which is equal to 0.0196 kg of water vapour / kg of dry air and the air leaving the dryer is assumed to have relative humidy of 80%. Than final sp.humidity following a constant enthalpy line along the sychometric chart is found to be 0.29 kg / kg of dry air

$$M_{air} = \frac{2.25}{0.029 - 0.0196}$$

M_{air} 239.36 kg

- Volume of air required (V)

PV = M_{air} RT

Whear,

P = 101.3 kpa

R = 0.291 kpa m³ /kg°k

$T_{ambient}$= 299.15 k

$$V = \frac{\text{Mair RT}}{P}$$

$$= \frac{239.36 \times 0.291 \times 299.15}{101.3}$$

V 205.6966 m³

- Air flow rate (Q_{air})

$$Q_{air} = \frac{V}{t}$$

In karjat annual average wind speed is 3.47 m / sec (NASA)

$$Q_{air} = \frac{205.6966}{8 \times 3600}$$

Q_{air} 0.007142 m³ / sec

- Area of Duct

We know that contineuty equation state

Q = A_{Duct} x V

$$A_{Duct} = \frac{Q}{V}$$

$$= \frac{0.007142}{3.47}$$

A_{Duct}= 0.002058 m²

- Calculated area of duct (A_{Duct})

A_{Duct}= 0.002058 m^2

=2.058 mm^2

This diamension area of duct is difficult to manufacture in any conventional process , for this resion to ease manufacturing , we assume the area of duct

A_{Duct} = 0.1 m^2

A_{Duct} = 100 mm^2

We select circular cross section for duct

$A_{Duct}=\pi/4\ d^2$

$100 = \pi/4\ d^2$

d = 11.28 mm

Diameter of Duct (d) = 11.28 mm

- We change the area of duct it change the air flow rate (Q_{air})

Than recalculate the air flow rate

Q_{air} = A_{Duct} × V

= 0.01 × 3.47

Q_{air} = 0.347 m^2/sec

- Collector Plate Area (A_{plate})

It is shown that the efficiency is 25 to 30 % at 9 am in the morning . But we are using only one cover the absorber plate and Dusty environment of Karjat which leads to reduce efficiency say 15 %.

So,

$$\eta = \frac{E}{(Aplate * I_{global})}$$

$$A_{plate} = \frac{E}{(\eta \times I_{global})}$$

I_{global} = 6.762 Kwh / m^2 day = 6.762 $\times 10^{-2}$ × 3600 = 24.3432 MJ/m^2day

$$A_{plate} = \frac{5.4857}{0.15 \times 24.3432}$$

A_{plat} = 1.50 m^2

Finding out (q_{losses})

q_{losses}= q_{top} + q_{bottom}+ q_{side}

Finding out losses from top (q_{top})

Losses from top (U_t)

q_{top}= U_t A_{plate} ($T_{mean\ plate}$ – $T_{ambient}$) = U_t= 5.2443 W /m ^{2} ^{o}k

Losses from bottom (U_b)

U_b = (k_i /δ_b) = 0.66 W /m^2 ^{o} k

Losses from Side (U_S)

$$U_S = \frac{(L1 + L2)\ L3\ ki}{L1\ \ L2\ \delta S} = 0.1034\ W\ /\ m2\ 0K$$

Therefore, total losses are U_{losses}=U_{losses}=U_{top}+ U_{bottom}+ U_{side} = 6.0077 W / m^2

qlosses= qtop + qbottom+ qside = 126.16 W / m^2 ^{o}k

- Q_{useful}=A_{plate}S - q_{losses}

=(1.50× 258.8494) – 126.16

Q_{useful} = 262.114 W / m^2 ^{o}k

- Another way to calculate actual efficiency is

$$\eta = \frac{Quseful}{(Aplate\ x\ I_T)}$$

$$= \frac{262.114}{1.50 \times 298.93679}$$

= 0.5761

η = 58.45 %

- Maximum Temperature achieve by the drying air as it passes the collector

The maximum temperature of incoming air as it pass the collector area is determined by the amount of energy collected and the nature of the product

$A_{plate}I_g\eta$= $m_{air}C_p$ T = E

$$T = \frac{Aplate\ \ Ig\ \eta}{mair\ Cp}$$

$$= \frac{1.50 \times 24.3432\ x\ 0.5846}{0.23936 \times 1.006}$$

T = 88.64^{o}C

This shows that the drying air at ambient should be preheated to temperature of

T_f before it enters the drying chamber

Calculated maximum temperature achieved by the drying air is T = 87.497^{o}C

This temperature is greater than the required maximum temperature for this reson we Recalculate the exact Area required to gain maximum temperature

$A_{plate}I_g\eta$ = $m_{air}C_p$ T = E

$$A_{plate} = \frac{mair\ Cp\ T}{Ig\ \eta}$$

$$= \frac{0.23936 \times 1.006 \times 45}{24.3432 \times 0.5845}$$

A_{plate} = 0.76155 m^2

At this recalculated area of collector we recalculate the efficiency of plate

$$\eta = \frac{E}{(Aplate \times I_{global})}$$

$$= \frac{5.4857}{0.76155 \times 24.3432}$$

= 0.2959

η = 29.59 %

Drying Time Required

Drying time required can be calculated by using following equation

$$Drying\ Time = \frac{Moisturetoberemoved}{Airflowrate \times C_{p \times Temperaturedifference}}$$

$$= \frac{\emptyset_m}{Af \times C_p \times (T_{mean\ plate} - T_{ambient})}$$

$$= \frac{2.25}{0.0347 \times 1.006 \times (318.15 - 299.15)}$$

Drying Time = 3.39hr

This drying time is required if the maximum temperature obtained in air collector i.e 45°C [1,2,3,4]

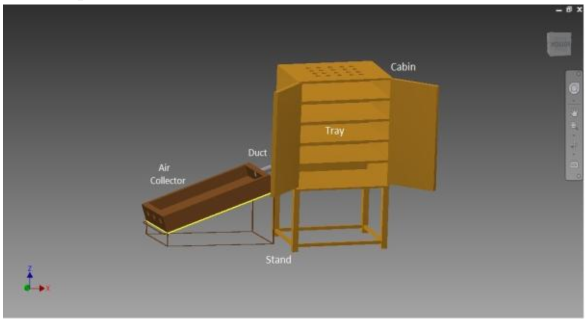

Fig.1. CAD model Experimental set up

Fig.2 Experimental Setup

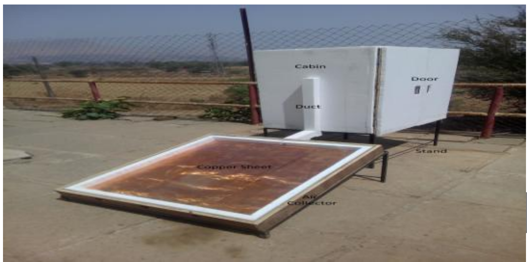

Fig.3 Experimental setup

Fig.4 Experimental setup showing Trays & Ducts

III.RESULT TABLE:

We have conducted the trial test KGCE, Karjat on 03rd.April. 2017 and got the following result. Time for which rice is kept in cabin & temperature attained are two factors considered. For temperature measurement Infrared Temperature sensor is used with range -30 to 550° C is used. Setup is kept facing North-South direction.

A) AIR COLLECTOR:

Table II. Observation Table

Sr. No.	Time	Temperature (° C)		
		Bottom	Middle	Top
1	12:00 pm	31	31	31
2	12:30 pm	54	58	59
3	1:00 pm	55.1	59.7	61.8
4	1:30 pm	56	61.2	63.5
5	2:00 pm	54	60.1	62.3
6	2:30 pm	53.7	60.1	62.6
7	3:00 pm	53.3	57	59.7

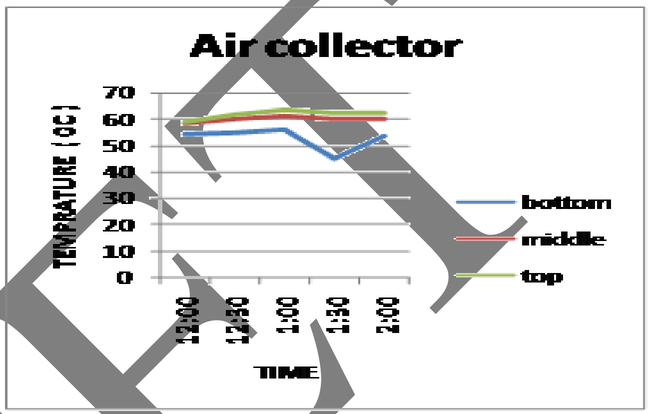

Fig. 5. Relation bet.n. Temperature variation in Air Collector.

B) CABIN:

Table III. Observation Table

Sr. No.	Time	Temperature (°C)			
		Tray 1	Tray 2	Tray 3	Tray 4
1	12:00 pm	31	31	31	31
2	12:30 pm	39	37.6	40.4	42
3	1:00 pm	42	40.9	42.2	45.6
4	1:30 pm	43	42.9	46	50.9
5	2:00 pm	43.8	44.6	47.3	51.2
6	2:30 pm	45.2	46.2	49.9	53.1
7	3:00 pm	46	46.7	49.4	53.1

Fig. 6 Relation bet.n. Temperature variation in Cabin.

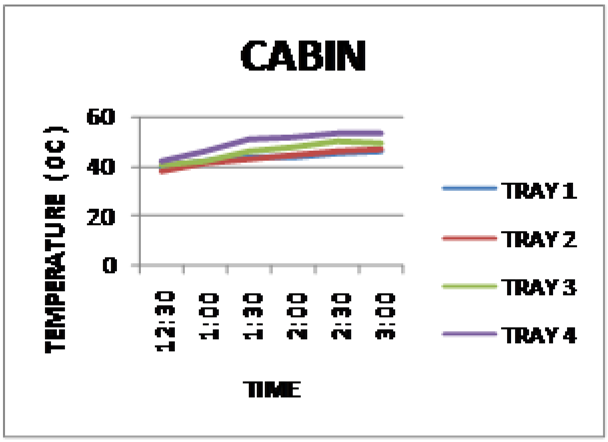

Fig. Relation bet.n. Temperature variation in Cabin.

IV. CONCLUSION:

Agriculture produce waste is serious problem especially developing countries in India where 24% of population is below poverty line. 1,94,502 metric tonnes food grains especially rice and wheat are wasted in last few years. Every year averagely India bears loss of 738.670 Cr Rupees due to food loss.

1. In India post harvest losses nearly accounts 23% of total agriculture produce out of that losses due to improper drying is about 7-8 percent which shows the care has to be taken while drying the food cereals.
2. Solar dryers are specialized devices that control drying process and protect agricultural produce from damage by insects, dust and rain.
3. While comparing with sun drying i.e. open drying solar dryers generates high temperature up to 45^0C which results into low relative humidity and moisture content in cereals like Rice eventually reduces spoilage during storage in other words ensures long life storage of cereals and other food grains.
4. It takes lesser time 3.3 hrs for 10 kg of freshly harvested rice after achieving desired temperature i.e. 45^0 C which requires 2 to 3 days doing the same with convention sun drying i.e. open drying.
5. Relatively solar drying is less expensive compared to artificial mechanical drying method where chances of change in color of cereals, cracks due to overheating, loss of vitamins and other nutritional values due to higher rate of heating thus solar drying is better alternative and can stood as solution to all drawbacks of natural drying and artificial drying.

So solar dryer can be one of the best solution towards food energy crisis; with drying most of agricultural produce can be preserved and this can be bitterly achieved through Solar Driers

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