NOVATEUR PUBLICATIONS
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN No: 2581 - 4230
VOLUME 10, ISSUE 5, May - 2024

INVESTIGATING THE PERFORMANCE OF SOLAR DRYER USING PHASE CHANGE MATERIAL

Sanket Gondhali [1],
Harshal Bari [2],
Vikesh Kasewad [3],
Aniket Gaikwad [4],
Kunal Thopate [5],
Dr Amol Yadav [6,*]
[1,2,3,4,5,6] Department of Mechanical Enginering
Jaywantrao Sawant College of Engineering, Hadapsar Pune -028

ABSTRACT

Sun drying is the most popular technique utilized to preserve agricultural products in India. The rate of drying is affected by a number of factors, including but not limited to: the amount of available solar radiation, the temperature & wind speed of the surrounding area, the initial moisture content of the crop, the crop's absorptive surface area, and the product's mass per unit of exposed area. the present study was undertaken to evaluate solar dryer integrated with heat storage system for drying vegetables and fruits. Drying rate get reduced due to intermittent sunshine, interruption, and rains. Solar energy is available only during the day, and hence, its application requires efficient thermal energy storage so that the excess heat collected during sunshine hours may be stored for later use during the night. The overall objective of this research project is the conceptual development of a solar dryer for drying agricultural products.

Keywords: Solar Energy, Air Heaters, Solar Dryer, Efficiency of solar air heaters, Forced convection heatflow, Air Collector.

1. INTRODUCTION

In many parts of the world, awareness is growing about renewable energy which has an important role to play in extending technology to the farmer in developing countries like India to increase their productivity. Poor infrastructure for storage, processing and marketing in many countries of the Asia-Pacific region results to a high proportion of waste, which average between 10 and 40%[1].Although India is a major producer of horticultural crops, many Indians are unable to obtain their daily requirement of fruits and vegetables and the Human Development Index (HDI) is very low. Considerable quantities of fruits and vegetables produced in India go to waste owing to improper postharvest operations and the lack of processing.This results in a considerable gap between gross food production and net availability [1]. Reduction of postharvest losses is essential in increasing food availability from existing production [2]. Traditional techniques used in food preservation are drying, refrigeration, freezing, salting (curing), sugaring, smoking, pickling, canning and bottling. Among these, drying is especially suited for developing countries with poorly established low-temperature and thermal processing facilities. It offers a highly effective and practical means of preservation to reduce postharvest losses and offset the shortages in supplyin strategiclocations on theassembly tomeasure itsambient, collector case and cabinet temperature.

In essence, drying is a simultaneous process of mass and heat transmission. The energy required forthevaporizationofwaterfromamaterialisprovidedbythematerial'sabsorption of heat.The goal of solar drying is to provide the product with more heat than is typically accessible in an ambientenvironment.

Baniasadietal.(2017)developedamixed-modesolar dryer, which consistsofthermalstorage[2].Theeffectofphase change material was analysed. The mixed-modesolar dryer consists of a solar collector, drying chamberand fan which is driven by a PV panel. The drying rateincreasedby50%forthermalstorage.Overallthermalefficiencyandpickupefficiencyincreasesbyabout11%and 10% for using PCM energy storage. The blower isused in our project to increase the volumetric flow rate which increases efficiency.

Manjunath et al. (2017) carried out a CFD analysis. According to the investigation, at Reynolds number 23560, there is an average thermal performance improvement of 23.4% over the base model.

Kabeel et al. (2018). This design extended the working of the air heater by 4h after sunset and the outlet air temperature reached 8.6°C more than ambient, with 10.8 to 13.6% improvement in daily efficiency

Babalolaetal.(2019)usedanelectric blower for mixing and air supply to a tilting furnace [3]. Theblowerispoweredbyusingphotovoltaiccells.For continuing the drying process even after thesunsetPCM(PhaseChangeMaterial)canbeused.Srivastava et al. (2014) designed a flat plate collector inwhich the author used PCM material as Lauric acid fordryingpurposesofpotatoesandcarrots[4].

Weaim tooptimizethethermalefficiencyofanindirect forced convection solar dryerfor drying Bananas foraspecificlocationin Maharashtra.

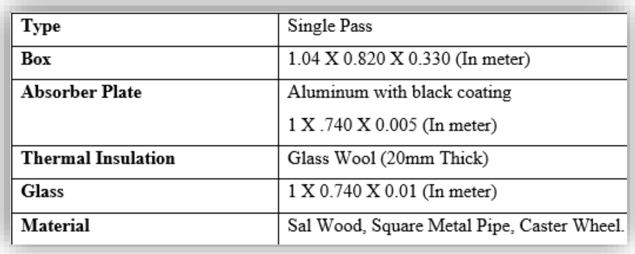
ManyResearchersworksondirectandindirectsolardryerwithPCMbutfewresearchersworkon Mixedmodedrying. So,ourmainfocusonhereistostudyof Experimental AnalysisofInvestigate the performance of solar dryer with phase change material.

RESEARCHMETHODOLOGY

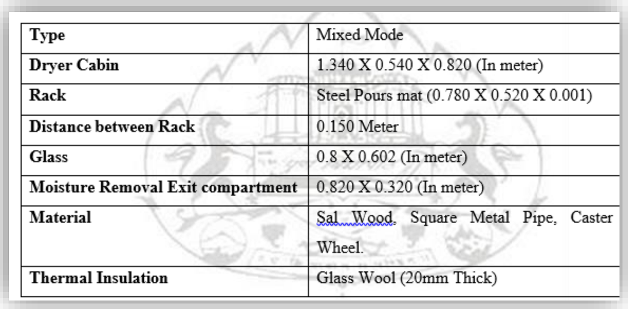
This study evaluates a food-preserving mixed-modesolar drier.Every person living in this region mayaffordthedryerthatwillbebuiltafterconsultingnumerousresearchpublications,anditcanbeproduced using materials that are readily availablelocally. The dryer will be built to prevent unforeseenandunwantedfoodspoilingcausedby alackoffacilities in the area. The drying cabinet's glass roofallowsittodirectlyabsorbsolarenergy,& dryerutilizes hot air from a separate solar collector. Thelow cost of dryers will be the key goal of this design. The componentsthatmakeupthisdesignwerechosenbecausetheyareeitherinexpensiveoreasily accessible. The test results will show that thedryer & solarcollectorhadsubstantiallygreatertemperaturesthan outside throughout the day.

BASIC DESIGN

Thedesignconsistsofarectangular,fiberglass-encased insulation. The overall experimental setup,including the auxiliary collector and thermal storage. The bottomandtopofthecontainerincludeopenings that let dry air out and fresh air in.



Type	Single Pass
Box	1.04 X 0.820 X 0.330 (In meter)
Absorber Plate	Aluminum with black coating 1 X .740 X 0.005 (In meter)
Thermal Insulation	Glass Wool (20mm Thick)
Glass	1 X 0.740 X 0.01 (In meter)
Material	Sal Wood, Square Metal Pipe, Caster Wheel.



Type	Mixed Mode
Dryer Cabin	1.340 X 0.540 X 0.820 (In meter)
Rack	Steel Pours mat (0.780 X 0.520 X 0.001)
Distance between Rack	0.150 Meter
Glass	0.8 X 0.602 (In meter)
Moisture Removal Exit compartment	0.820 X 0.320 (In meter)
Material	Sal Wood, Square Metal Pipe, Caster Wheel.
Thermal Insulation	Glass Wool (20mm Thick)

Collector and Dryer Specification:

Design Calculation:
Area of collector (Ac) = Lc * Wc (m2)
=1.02 * 0.820
=0.8364 m2

Volume of collector (Vc) = Ac * Hc(m3)
=0.8364 * 0.540
=0.451656 m3
Area of dryer (Ad) = Ld * Wd (m2)
=1.340 * 0.540
=0.7236 m2
Volume of dryer = Ad * Hd (m3)
=0.7236 * 1.24
=0.897264 m3
Dischare (V) = Ac ∗ Hc
time
0.8364 ∗ 0.330
=8 *hr*
=0.034 m3/hr

Mass Flow Rate of Air (m'a) = ρ A V(kg/sec)
= 1.10 * 0.034

= 0.037 kg/hr

7. Energy or heat needed to evaporate water from product (Q'E) = m Cp ΔT

= 0.037 * 1.004 * 103 (40-35)

= 190.51 watt

8. Solar Energy (I) = (Lc * Wc * 1000) * n

= (1.04 * 0.820 * 1000) * 1

= 852.8 watt

Fig.1: CAD Model of Experimental Set up

Fig 2: Actual Experimental Set Up

EXPERIMENTATIONOFDRYEROPTIMISATION

Performance testing of the dryer was determined byusing a full factorial design. The factors of the designwere: The dryerwith and without thermal storage.. In addition, the slicethickness suitable for drying using this cabinet dryerwasalsoinvestigated.

No Load Test

Dryer temperatures were measured without any food productspresentindirectmodeaspartofthefirstperformanceinvestigationoftheexperimentalsetup (Figure 9). Variations in collector, drying chamber, fibreglasscover,&ambienttemperatureswereallmeasured and recorded at regular intervals. The no-loadexperimentshelpeddeterminethedryingchamber's maximumtemperature increase in relationto fluctuationsin solar intensity, ambient temperature,& air velocity. During these experiments, we monitoredthecollector'sperformanceby recordingkey metricsliketemperatureatvariouszones&solarradiationintensity.

Fig3 : No Load test

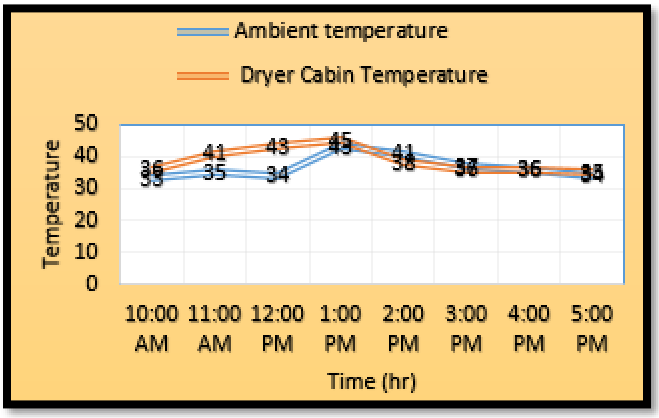


Fig 4: Temperature variation of no load test.

D DeterminationofSliceThickness

Therearealotofmovingpartsinvolvedintheprocess of preserving food. Fruits & vegetables areplentifulyetperishable.Eventhoughtherearedifferentpreservationmethods,mostaffecttheproduct'scolor&texture(Figure10).Customersseek high-quality, long-lasting products. Solar dryingperishablefoodsavesmoney.Thisexperimentexamined how temperature & moisture affect driedproduct texture and color. The trials used bananasbecause of their high moisture content and loss inIndia.Thisstudyexaminedthreebananaslicethicknesses.Thisstudydetailedtherarelyrecognized effect of slice thickness on dried productquality.

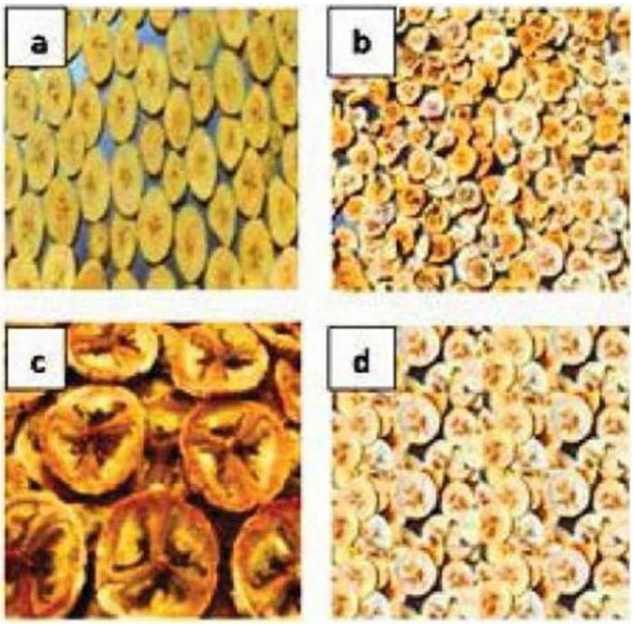


Fig:5 Colour and Texture of slice

Full Load Test

The studies ran without PCM cans and pipelines forseveral days. Outside air, dryer, & collector outputtemperaturesweremeasuredregularly.Sunsetmeasurementsrevealedperformancewithoutthermalstorage.Observationsestimatedperformance.

Fig 6: Full Load Banana Slice

Full Load test with PCM:

Fig 7: PCM filled in Can

Result discussion:

1.Solar Dryer Without Thermal Storage:

Fig 6 illustrate typical direct & mixed mode no load test results. April 2024 experiments lasted six days. Direct mode tested the dryer for 3 days. After adding an auxiliary collector, the dryer was tested in mixed mode for three days. These tests were done at 10 a.m. at peaksunlight.until4p.m.,duringpeaksunradiation.Onday3ofdirectmodeexperiments,solar insolation reached 900 W/m2. The first day of mixed mode experimentation had the greatest average solar insolation of 800 W/m2. The 2nd, 3rd, & 6th days of experiments recorded 42°C ambient temperatures, whereas the 4th day recorded 32°C.

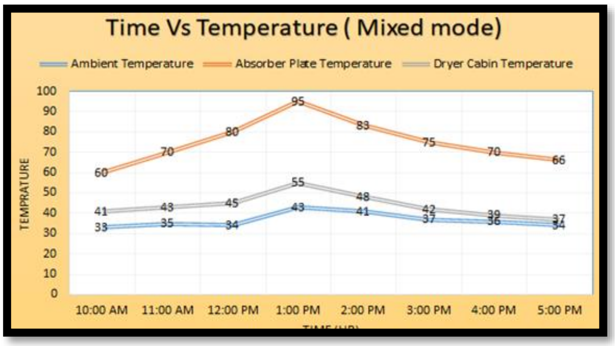
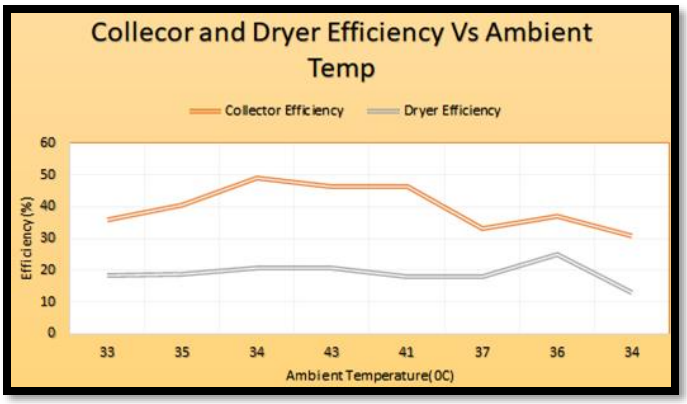


Fig : 8 Temperature Variation in mixed mode



The main collector's efficiency ranged from 30% to 31% in direct mode & 38.22% to 42.29 in mixed mode. Although while heat incident on the 3rd day of inquiry under direct mode (428.5 W) approximately matched that of the 2nd day under mixed mode (428 W), efficiency under mixed mode (42.29%) was 10.39% greater than under direct mode (31.9%). Consequently, mixed mode was used for further testing because the dryer performed better.

2.Solar Dryer With Thermal Storage:

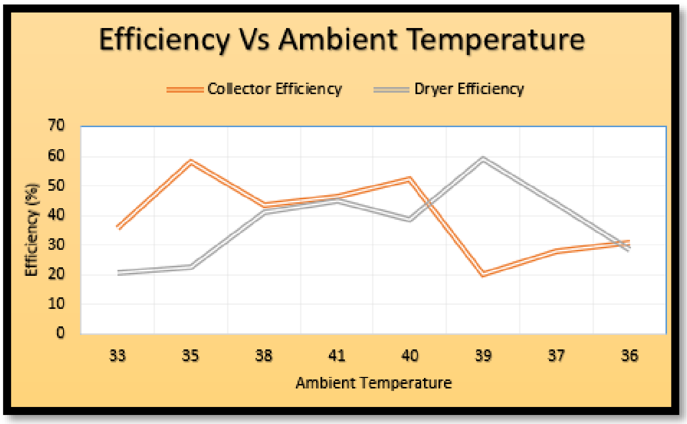


Fig 10: Efficiency Vs Temperature variation

The PCM was found to reduce thermal waste by storing & dissipating energy with little losses. Regardless of changes in sun intensity, it functions as a stabilizer of the heat input. The natural convection drier performs admirably even at the nominal sun intensity with a low air flow rate. The total amount of energy stored grows as more storage material is used. By increasing the PCM's conductivity, we can guarantee that it will melt & harden consistently. The presence of a storing medium improves moisture removal. A product's texture & color can be enhanced through thermal preservation after drying. Storage media guarantee a consistent drying process.

Result Comparison of With and Without Thermal storage
:

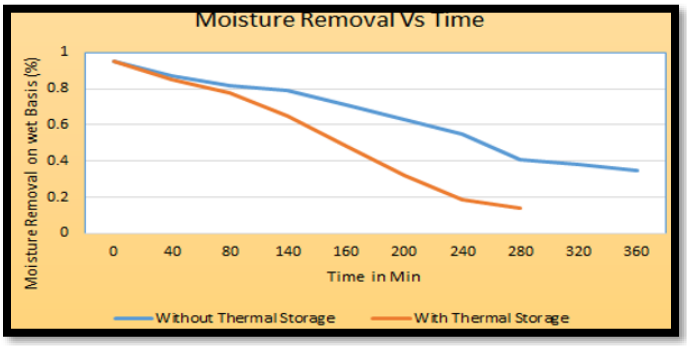


Fig:11: Moisture removal rate

CONCLUSION

In this analysis, we evaluate how well a solar dryer with a mixed-mode design can keep food safe from spoilage. Every person living in this region can afford the research-based dryer design because it is made from inexpensive, readily available materials. Due to a lack of infrastructure in the area, the dryer was built to prevent unplanned & erratic food rotting. The dryer takes in solar energy both indirectly (via the glass roof) and directly (through the hot air from a separate solar collector). As was previously said, one primary motivation for this design was to make the dryer's price as cheap as possible. We opted on inexpensive and readily available components for this layout. Thermal storage capacity of the dryer can be investigated using different phase change materials. Different PCM container materials and geometries can be employed for further investigation.

REFERENCES

1. Amer,B.,Hossain,M.A.,Gottschalk,K.,(2010), Design and Performance Evaluation ofa New Hybrid Solar Dryer for Banana, Energyconversion andmanagement,51:813-820.
2. AmirHematian,YahyaAjabshirchiandAmirAbbas Bakhtiari,“Experimental analysis of flatplatesolaraircollectorefficiency”,IndianJournalofScienceandTechnology, 5,2012 .
3. Aritesty,E.,&Wulandani,D.(2014).Performanceoftheracktype-greenhouseeffectsolardryerforwildginger(curcumaxanthorizzaroxb.) drying. Energy Procedia, 47,94-100.
4. ArunKumarShuklaandShravanKumarVishwakarma,“Design,constructionandperformancestudyofPhotovoltaicIntegratedForcedFlowSolarDryer”,Proceeding of International Conference onEnergyand Environment,2009, pp:19-21.
5. Arun,K.R.,Srinivas,M.,Saleel,C.A.,Jayaraj,S.,“Activedryingofunripenedbananas(MusaNendra)ina multi-traymixedmode solar cabinet dryer with backupenergystorage,”SolarEnergy,188,pp.1002-1012,2019.
6. AssociatedChambersofCommerce ofIndia(2019), “ The Assocham Bulletin”. https://www.assocham.org/userfiles/Assocham%20Bulletin%202019(1).pdf
7. Atalay, H., Kincay, O., Kincay, O., “Modelingofthe Drying Processof AppleSlices:ApplicationwithaSolarDryerandtheThermal Energy Storage System,” Energy,2017.
8. Ayensu.AandAsiedu-Bondzie.V,“Solardrying with convective self-flow and energystorage”, J.of.SolarandWind Technology,3,1986,pp:273-279.
9. Azaizia Z, Kooli S, Elkhadraoui A, Hamdi I,GuizaniA.Investigationofanewsolargreenhousedryingsystemforpeppers.InternationalJournal ofhydrogenenergy.2017 Mar30;42(13):8818-26.
10. Babagana G, Silas K, Mustafa BG. Designandconstructionofforced/naturalconvection solar vegetable dryer with heatstorage. ARPN Journal of Engineering andApplied Sciences.2012;7(10):1213-7.