Design and Analysis of Multi Stage Force Draft Solar Dryer

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Abstract: This paper is based on the design analysis and experimental procedures of solar dryer installed with various electronics equipments. This solar dryer consist of one solar plane glass, matte m.s sheet, two copper strips for heat conduction , two mini blowers, integrated dual 18V batteries ,humidity sensor, aurdino temperature sensor, plywood for an insulation to minimize the heat loss beneath to absorber and 18V solar panel . This compound structure of solar dryer indirect type based on forced convection used to carryout dehydration processes on majority of fruits and vegetables in order to preserve the food quality for a longer time spawn. This solar dryer despite forced convection its complete green way to take out the experimental analysis.

KEYWORDS: Indirect Forced convection, Solar drying performance study, moisture content(ginger and grapes), temperature gradient, heat losses, 3-D model analysis and solar dryer efficiency and conclusive weights of ginger

Introduction: The notion to build solar dryer is to gain the zenith applications for drying process using no electricity and stepping into green revolution and can execute the conclusive drying process. There are various factor which have major affecting role in solar dryer efficiency. They are (1) air velocity (2) temperature gradient (3) heat losses (4) humidity factor (5) solar intensity (6) moisture extraction rate (7) cutoff -temperature (to maintain texture of food which is placed inside solar dryer. This dehydrating process is solely depend upon solar intensity. The average solar radiation in western provinces of India is obtained in sunny days is 180W/m2 and maximum 217W/m2 during noon of summer results are taken using pyranometer. The rate of drying depends on various parameters such as solar radiation, ambient temperature, wind velocity, relative humidity, initial moisture content, type of crops, crop absorptive and mass of product per unit exposed area .This form of drying has many drawbacks such as degradation by windblown from blowers.

Solar driers using natural convection or forced circulation have been investigated to overcome these problems. For commercial applications, the ability of the drier to process continuously throughout the day is very important to dry the products to its safe storage level and to maintain the quality. Normally thermal storage systems are employed to store thermal energy, which includes sensible heat storage, chemical energy storage and latent heat storage but we have used copper strips for an instant absorption of heat and good output of heat in chamber after the ambient air preheated after absorbing the heat in absorber.

Traditionally, drying of agricultural products is done by open sun with the consequent postharvest losses and damage to the products. Shortcomings of open sun drying of agricultural products have been reported. The disadvantages of this method include exposure of the products to rain and dust, uncontrolled drying; exposure to direct sunlight which is undesirable for some foodstuffs; infestation by insect; attack by animal, etc. In respect to better quality product, several authors have recommended solar drying as an alternative to sun drying. However, the intermittent effects and weather dependency nature of solar dryer have been major barriers to the effective use of solar energy. Consequently, different configurations of solar drying systems integrated with thermal storage materials to eliminate the reabsorption of moisture have been proposed by several researchers. Excess heat energy can be stored in fluids and solids as a change in internal energy of a material as sensible, latent and thermo-chemical heat or combination of these.

Nomenclatures

A- Cross section area of the pipe connecting the drying chamber, m2

DR - Drying rate, kg of water/ kg of dry matter. h

hfg - Latent heat of vaporization of water, kJ/k

k- Drying constant

Md- Final mass of the sample at any time , g

Me- Equilibrium moisture content, %

Mo- Mass of the sample at t0, g

Mt- Initial mass of the sample at any time , g

Mwb- Moisture content (wet basis), %

Mw- Moisture evaporated in time t, kg/s

Pd- Blower power, kWh

R- Calculated parameter

SMER- Specific moisture ratio, kg/kWh

Td- Drying air temperature,

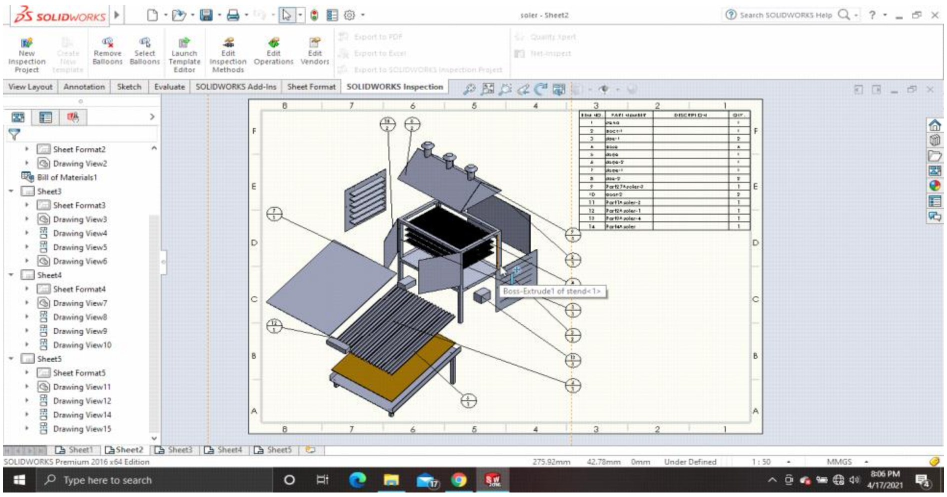
Ti- Temperature of at solar air heater inlet, oC

To- Temperature of at solar air heater outlet,

wr- Total uncertainty

x1 x2…..xn Independent variables

Design and experimental setup:



The design casted in solid works the data consideration of the multi-stage force draft solar dryer are taken for increment in efficiency and the tilted absorber tilted (23 degree) for better solar radiation penetration and increase the thermal efficiency. As the side view perspective, the two blowers are being used on the both ends of absorber. The very first blower at the beginning is installed to absorb the ambient air from outside and pushes into absorber. The air will first come across to the copper strips which are intended to preheat the air suddenly because the copper has good thermal comp ability compare to majority of metals.

The second blower has the function to pull in preheated air which is flowing in absorber. This blower will pushes the air into main phase name chamber. As we can see the chamber is mounted by three hollow cylindrical chimneys which will exhaust the humid air from the chamber. The absorber has two M.S. plates inside it which gives two air flows beneath and above.

SR NO	COMPONENTS	MATERIALS	QUANTITY	MEASUREMENTS
1	solar glass	glass	1	2ft x 4ft
2	solar panel	semi metal	1	8in x 10in
3	copper strips	metal	2	12inch
4	mild steel sheets	metal	36SQFt	36sqft
5	plywood	insulator	1	2ft x 4ft
6	thermostat aurdino	semi metal	1	14v
7	moisture sensor	semi metal	1	12v
8	blowers	non metals	2	12V
9	trays	metals	3	5in x 12in
10	intergarted battery	insulator	2	24v
11	wires	metal	6	0

Experimental procedure:

The solar dryer is based on force convection as the two blowers are equipped in it. the efficiency has been estimated about 74% calculated on ginger. The initial weight was 28grams (wet basis) before carrying out the dehydration process. The experiment carried out at 10am when the sun partially head over. Firstly, the ginger was sliced away in order to increase the drying process because the penetration on ginger will be effective. The ginger had 74% percentage of moisture before getting dried whose weight was almost 20grams excluding pulp and fibers of essential oil inside it. The ambient air temperature was noted 32 degree Celsius and the thermostat displayed the 41 deg celcius. The thermostat has been coded to not increase the temperature above 58 deg celcius inside chamber. once the solar dryer touches the limit which is encoded in thermostat then the blowers will automatically stops and won't inlet the air. the temperature noted at the chimney was 55 deg celcius during working. the ginger got dried in 5 hrs starting from 10am and finished at 3pm. the every half hourly monitoring of the process was taken in hands. the gradual declination in graph of moisture was appeared when the solar radiation begins to get intensive.

The total amount of moisture extracted from the ginger was 74% and the final weight of ginger displayed 8 grams (dry basis).

Determination of moisture content in ginger

The quantity of moisture present in a material can be represented on wet basis and expressed as percentage. About 28g samples were taken and kept in a convective solar dryer, which was maintained at 56±1oC until constant weight has reached. The initial and final mass, Mt , and final mass, Md,of the samples were recorded with the help of electronic balance. The moisture content, Mwb, on wet basis was calculated by using. The procedure was repeated for every one hour interval till the end of drying.

$$Mwb = \frac{M0 - MF}{M0}$$

= (28- 8/28 x100) = 74%

Determination of drying rate

The drying rate, DR, should be proportional to the difference in moisture content between material to be dried and the equilibrium moisture content . The concept of thin layer drying was assumed for the experiments

DR = DM/dt = -k(Mt - Me) (where k is slope of ratio)

=0.83 x 100 (28 - 8)

= 16.6 kg -1

Determination of specific moisture extraction rate

The specific moisture extraction rate, which is the energy required for removing

one kg of water. SMER was calculated using

SMER = md / td

= 20grams / 300mins

= 0.06 kg/s

Determination of drier thermal efficiency

The thermal efficiency of the solar air heater was estimated using

η = flow rate / AcIs

Qa = mCpdt

=mCpdt/AcIs

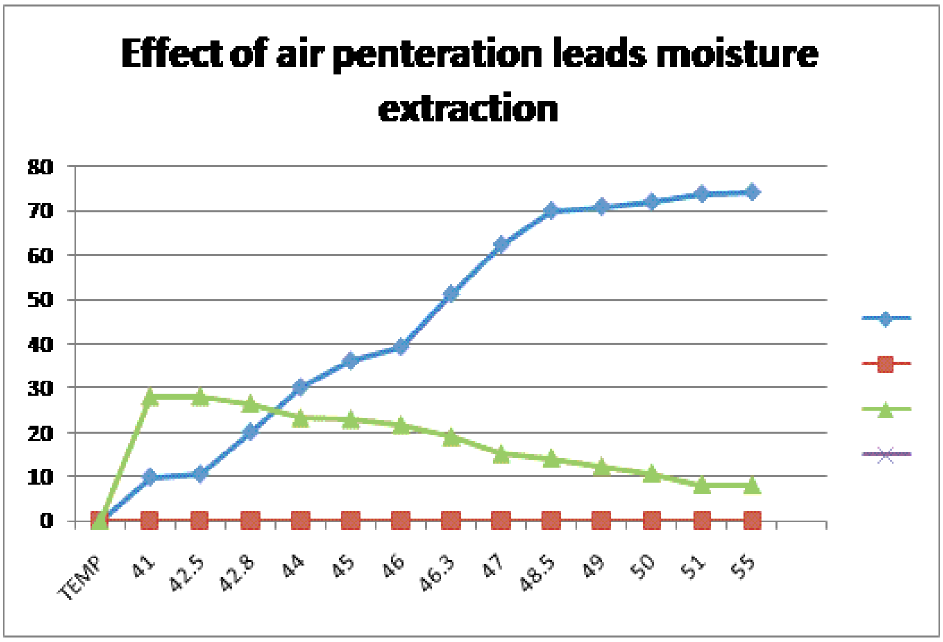
= 53%

The above assessments were calculated on basis of the experimental outcomes of our solar dryer. we concluded that about 53 percentage efficiency has been found for the ginger. The efficiency is solely based on the content ion which the experiment is established. The temperature gradient at the ends of solar dryer are 32 deg and 60 deg respectively.

Experimental observation

TEMP	MOISTURE %	TIME	WT. of GINGER
41	9.8	10.00am	28
42.5	10.5	10.30am	28
42.8	20	11.00am	26.5
44	30.1	11.30am	23.2

45	36	12.00pm	22.9
46	39.2	12.30pm	21.6
46.3	51.1	13.00pm	18.9
47	62.3	13.30pm	15.1
48.5	70	14.30pm	14.1
49	70.9	15.00pm	12.2
50	71.9	16.00pm	10.7
51	73.7	17.00pm	8.2
55	74.1	17.30pm	8



GRAPHICAL ANALYSIS:

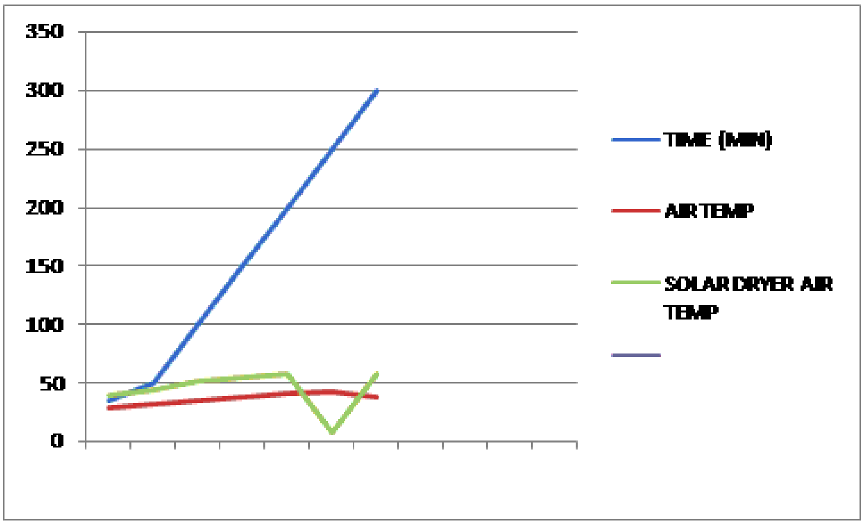
The above graph shows the rate of moisture extracted from ginger with respect to time. the constant monitoring leads this data of the moisture extracted from the ginger as the temperature rises up. the final weight of ginger noted 8 grams (dry basis) and about 74% of moisture took off from ginger.

well, apparently the data differs when the different items placed in dryer. the more moisture content food place in dryer, the more time it takes to get completely dried. the rate of extraction of moisture depends upon the outer skin or layer of the item whose testing is going to be done. the hard and non-fragile skins often requires to slice them off before putting them into chamber to decrease the time taken for drying process.

Temperature gradient observation table

(1) Ambient temperature (2) solar dryer air temperature

TIME (MIN)	AIR TEMP ©	SOLAR DRYER AIR TEMP
35	25-28	25-39
50	32-31	44-49
100	33-34	51-52
150	35-38	53-55
200	38-41	55-58
250	41-42	58-57
300	42-38	57-57.5



GRAPHICAL ANALYSIS :

The above graph depicts the declination in moisture rate in ginger after placing the ginger in solar dryer for dehydration process. This graph refers that when the temperature increases with respect to the time, the fall of graph represented in delineation. Initially the ginger was selected of 28grams with 74% moisture inside it and rest 26% was essential oil and pulp. so. the functioning of the solar dryer had executed, at the first phase of solar dryer the absorber sucks in the ambient air whose temperature was 28 deg celcius and after getting inside absorber the air receives sudden temperature and air temperature becomes 39 deg celcius. after a while the constant elevation in air temperature has been noted and thus, the nature of air becomes light dense due to excitement of molecules inside the mixture of air took place. The solar dryer is equipped with thermostat (AURDINO RATING W1209) which controls the inlet of air as the temperature inside the chamber exceeds to 58 deg celcius.

Dehydration of grapes :

Technical and economical results have proved that solar drying of grapes is quite feasible. Commercialization of solar drying of grapes has not gained momentum as expected, may be due to high initial investment and low capacity of the dryers. Even, the farmer's acceptance of solar dryers developed is not encouraging. Exhaustive research and development work has to be carried out in order to make solar drying of grapes economical and user friendly. There has been a remarkable achievement in solar drying of grapes due to sustained research and development associated with the adoption of advanced technologies. A review of various solar drying models for grapes is thus necessitated.

Weight of grapes initially: 100 grams

Weight of grapes finally: 22 grams

The total weight loss : 78 grams

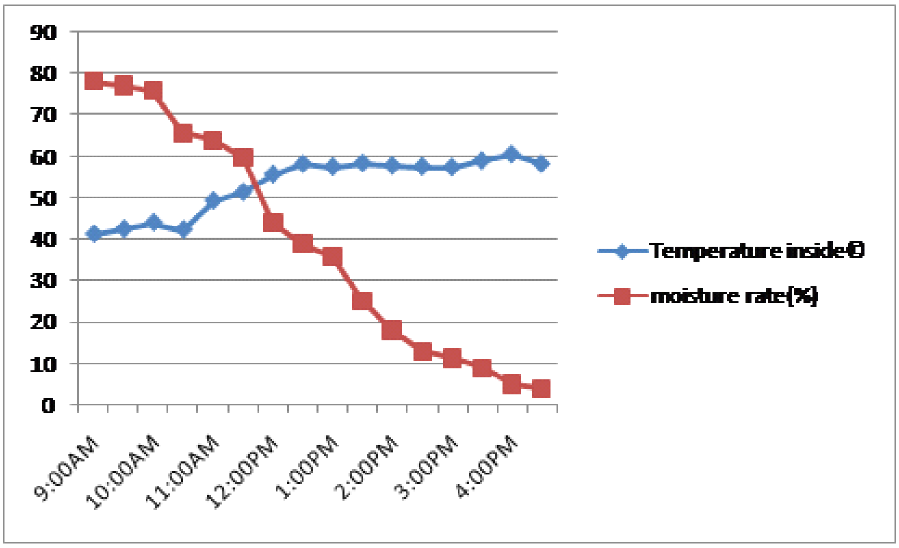
Total time taken : 8 hours (480mins)

Moisture content : 78 %

OBSERVATION TABLE OF GRAPE

Time (mins)	Temperature inside©	Moisture rate(%)
9:00AM	41.23	78
9:30AM	42.45	77
10:00AM	44	75.76
10:30AM	42.33	65.6
11:00AM	49.3	63.8
11:30AM	51.32	59.5
12:00PM	55.64	43.78
12:30PM	58.1	38.89

1:00PM	57.44	35.7
1:30PM	58.3	25
2:00PM	57.7	18
2:30PM	57.5	12.87
3:00PM	57.3	11.3
3:30PM	58.9	8.8
4:00PM	60.4	5
4:30PM	58.1	3.9



GRAPH DEPICTS THE DECLINATION IN MOISTURE OF GRAPE (SEEDLESS)

IMAGE DEPICTING THE GRAPES ARE BEING PLACED IN DRYER

Conclusion:

solar drying has proved to be technically and economically valuable for several fruits and vegetables. The amelioration of the errors like heat losses can be further vital aspects which will give splendid impact in terms of efficiency of solar dryer. The conclusive evidence of ginger shows that the tougher skins vegetables are required to slice off for better results during execution of solar dryer. This is a green revolution to use renewable energy sources and to contribute the efforts towards nature. The complete isolation is not possible in solar dryer as it is made of metal sheet but to minimize the losses we had to use plywood and result in dearth of losses for better heat conduction. The efficiency is depend upon the intensity of solar radiation

Future prospective :

The solar box dryer has been designed to be suitable for household drying of agricultural products. The dryer can dry about 4-5 kg of fish, fruits and vegetables in a single batch, at a drying air temperature of about 40-50°C. The dryer design was based on thermal performance and product quality optimization.

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References

[1] PERFORMANCE OF A FORCED CONVECTION SOLAR DRIER INTEGRATED GRAVEL AS HEAT STORAGE MATERIAL FOR CHILI DRYING M. MOHANRAJ1,*, P. CHANDRASEKAR2 2016

[2] Annales de Chimie - Science des Matériaux – n° 1/2018, 23-39 Design and fabrication of a forced convection solar dryer integrated with heat storage materials Clement Adekunle Komolafe1,*, Mufutau Adekojo Waheed 2017 129-140

[3] Design and Construction of Forced Convection Indirect Solar Dryer for Drying Moringa Leaves S.K. Amedorme1 , J. Apodi2 , and K. Agbezudor3 1Ghana Prisons Service, Senior Correctional Centre (SCC), P. O. Box 129, Accra 2Department of Agricultural Engineering,Bolgatanga Polytechnic, P.O. Box 767 Bolgatanga. 3Department of Mechanical Engineering, KNUST, Kumasi, Ghana 2018

[4] Drying of chilli using solar cabinet dryer coupled with gravel bed heat storage system A.K. Kamble1*, I.L.Pardeshi2 , P.L. Singh3 and G.S. Ade4 2019