International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

Design, Modeling, and Performance Analysis of Parallel Flow Double Pass V-Groove Solar Air Collector for Preservation of Onion in University Students' Cafeteria: Wolaita Sodo University

Mulugeta Tadesse

Lecturer in Wolaita Sodo University, Ethiopia, College of Engineering, Department of Mechanical Engineering

***Abstract:* - Drying is the oldest mechanism to preserve crops, fruit, vegetables, and cooked food for long time usually by using direct sun drying as well as solar drying by using solar collectors. Onion and related vegetables are need drying to preserve them for the required time before its use to avoid its contact spoilage. In this project v-grooved parallel double pass solar collector selected for its high efficiency and high mass flow rate of hot dry air to dry 30 kg sample onions. For preservation of onion it is needed to evaporate 5.16 kg moisture from its total moisture content. The mass of dry air required to evaporate the given mass of moisture is 565.88 m³ dry-airs at a least 20 ^{o}C temperature difference.**

The overall efficiency of the selected type solar collector which required supplying the required amount of hot dry air is calculated based on the initial its model is 41.79%. The output temperature to the mass flow rate of working fluid, output temperature to flow contact area, and overall efficiency of the collector to mass flow rate of the working fluid is relation simulation made by using math lab software.

***Keywords:* - Dehydration, Dry chamber, Onion Preservation, V-grooved solar collector, working fluid**

I. Introduction

Drying of crops, vegetables, fruits, and like is may be need to extend the life of preserve, to increase the quality, and/or to prepare it for further processing of the drying product.

Peoples may dry or dehydrate onion to add the value for exportation the moisture content from 86% (wb) to 7% (wb) or less. Dehydrated onions in the form of flakes or powder are in extensive demand in several parts of the world, for example UK, Japan, Russia, Germany, Netherlands and Spain [1]. Onion can also be dehydrated for the preservation by only drying at least one outer most shells and that is approximated as 20-25% of its total moisture content.

A. Introduction to sun and solar drying

The traditional open sun drying utilized widely by rural farmers which has a characteristic limitations such as: high crop losses in the process of inadequate drying, fungal attacks of the product, insects, birds and rodents encroachment, unseasonal down pour of rain and other weathering effects. In relative to such conditions of sun drying, solar energy dryers appear increasingly to be more appropriate in commercial as well as domestic propositions. Climatic conditions have a great influence on the extent of material losses and deterioration during sun drying. If a climate is warm and dry, the material can be dried well. For this to be feasible, the ambient relative humidity during the harvest period must be low enough to ensure that the crop adequately remove its moisture when dried to its equilibrium moisture content can be stored safely. The drying materials also require an undesirably long period to reach this equilibrium moisture content. In hot and humid climates, drying materials deterioration is obviously worse, as both warmth and high moisture contents promote the growth of fungi, bacteria, mites and insects in drying materials. Warmth weather is propitious conditions for natural open sun drying. Unfortunately, the tropics are characterized by hot damp climates. If the relative humidity of ambient air is too high to facilitate drying in the field, such air would obviously be of limited value for drying the harvested drying materials [2]. Thus, these climatic conditions dictate the need for more effective drying methods. The basic essence of drying is to reduce the moisture content of the product to a level that prevents deterioration within a certain period of time, normally regarded as "safe storage period" [3]. Drying is a dual process of: heat transfer to the drying product from the heating source through dry air and mass transfer of moisture from the interior of the product to its surface and from the surface to the surrounding air.

The supply of heat procedure could involve the passage of preheated air through the product from separate solar collector or by directly exposing the product to solar radiation through dry chamber or a combination of both. Absorption of heat by the product is the amount of energy necessary for the vaporization of water from the product, and is usually the product of the mass of moisture and latent heat of vaporization of water, and which is 2.44 MJ energy for unit mass of water to be evaporated. The solar radiation absorptances of the product are an important factor in direct solar drying. Fortunately, most agricultural materials have relatively high absorptances (between 0.67 and 0.90) [3] which may increase or decrease as the drying progresses. The thermal conductivity of the crop is also important, particularly if the drying layer is deep enough to require heat conduction between particles.

B. Systematic Classification of Drying Systems

All drying systems can be classified primarily according to their operating temperature ranges into two main categories as high temperature dryers and low temperature dryers. However, dryers are more commonly also classified based on their heating sources into fossil fuel dryers (more commonly known as conventional dryers) and solar energy dryers. Usually, all practically commonly known designs of high temperature dryers are fossil fuel powered dryers, while the low temperature dryers are either fossil fuel or solar-energy based drying systems.

High temperature dryers

High temperature dryers are essentially when very fast drying process is desired. It is usually employed when the products require a short exposure to the drying air. High temperature dryers are usually classified into batch dryers and continuous flow dryers [4].

Low temperature dryers

In low temperature drying systems, the moisture content of the product is usually brought in equilibrium with the drying air by constant ventilation of drying air.

C. Classification of solar-energy drying systems

First based on the presence or absence of external aid to force hot air over the drying material, solar drying system may be divided in to active and passive solar drying system. Active solar energy drying system usually uses fan or blowers for force circulation of air over a drying material while passive solar energy dryers the flow of drying air is naturally due to change density.

Three distinct sub-classes of either the active or passive solar drying systems can be identified which vary mainly in the design arrangement of system components and the mode of utilization of the solar heat energy, namely [5]: integral (direct) type solar dryers, distributed (indirect) type solar dryers, and mixed-mode solar dryers as shown figure-1 below.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

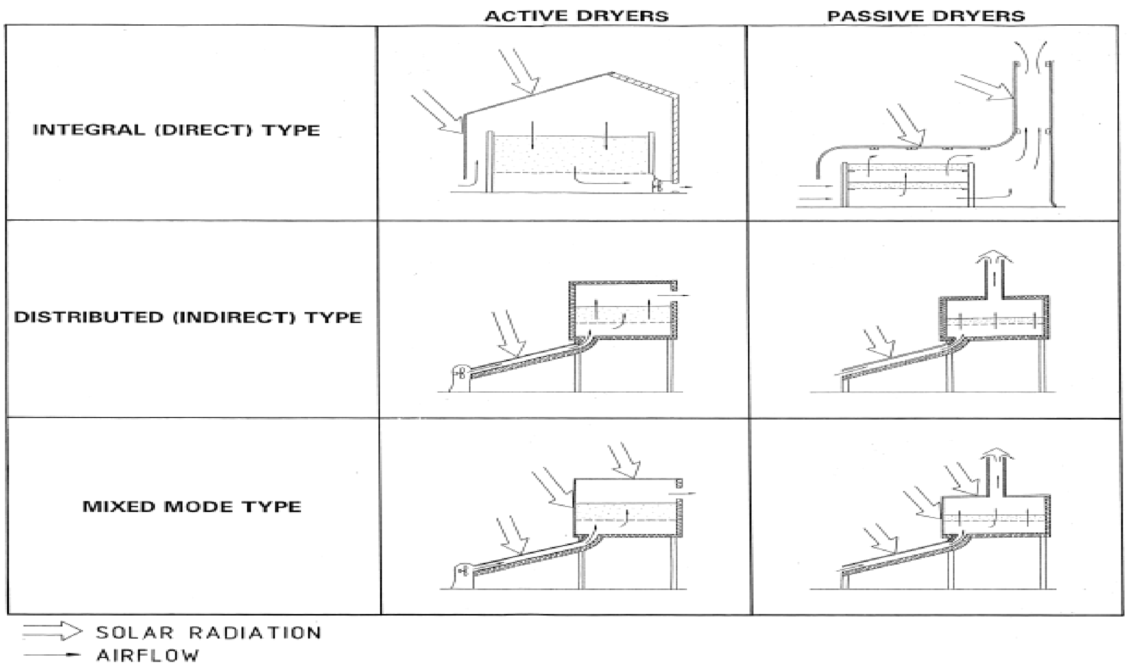


Figure-1: Types of Solar Dryers [5]

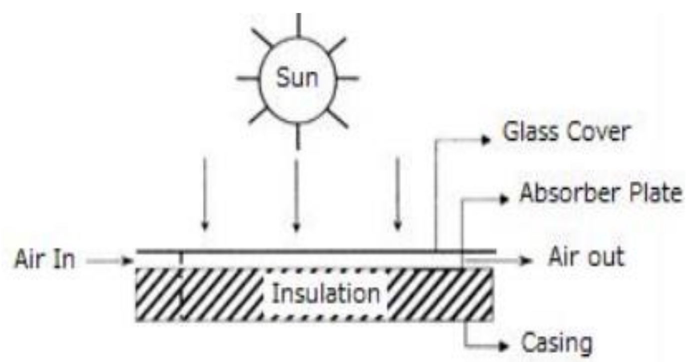
D. Types of air solar collectors

Solar collector is a device mechanism to collect solar radiation energy and convert it into heat energy which in turn used as sources of energy for the required purpose. Solar air collectors have been used for several applications which include space heating, food drying, swimming pool heating, thermal industrial process, and solar drying of crop, vegetable, and fruits.

There are several designs configurations of solar air collectors which are currently used in different applications. The designs are based on the required amount of heat energy, and to increase the efficiency of the collector which can be achieved by increasing the heat energy gain by decreasing its losses through the bodies of the collector, increasing the air contact area, and also increasing the air flow length of the collector. Based on these concepts v-grooved and sometimes finned solar collector absorber are introduce and also making double pass of air is possible in extending the flow length of the collector. There are series and parallel flow double pass solar air collectors.

In series flow double pass solar collectors same fluid passes twice below and above of collector absorber while different fluid pass below and above of collector absorber parallel way and directly admit to the dry chamber in case of parallel flow double pass air solar collectors.

In order to improve the performance of the collector, flow arrangement could be changed to reduce the heat loss and the absorber shape could be changed to a v-groove and sometimes finned plate used in order to increase the absorbent area. Some designs of the air solar collectors are shown in the figure-2 below.



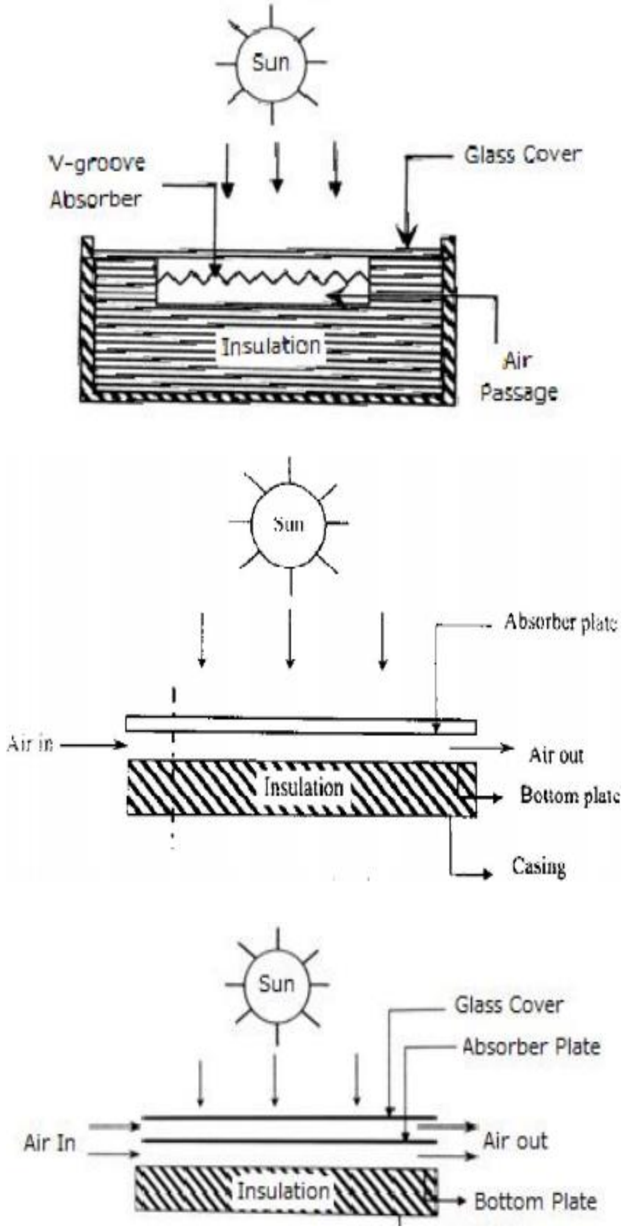


Figure-2: Types of Solar Air Collectors

The flat plate single pass flow air collector has efficiency of 41%, flat plate double pass flow air collector has efficiency of 55%, v-groove single pass flow collector has efficiency of 54% and v-groove double pass flow collector has efficiency of 56% [7]. That investigation clearly indicates that that v-groove double pass flow solar air collector has the highest efficiency than any other type.

E. Statements of problem

Onion and related vegetables are need drying to preserve them for the required time before its use.

In Wolaita sodo university, in Ethiopia there are more 16, 000 students feeding their café for all breakfast, lunch and dinner by university preparation. Thus, university usually buys more than ten quintals of onion for the students' cafeteria and it is stored in store room until its finish distributing on the floor of room for the preserve.

However, due to the room place limitation and overloading there is always spoilage approximately 10% of the total onion bought once. This also make bad smell disturbance around cafeteria and expenses the need of external worker for cleaning the area and removing the spoiled onions.

F. Objectives

General objective

The main objective this research project is to design and model v-grooved parallel flow double pass solar collector and dry chamber for preservation of onions and related products of the students' cafeteria of Wolaita Sodo University.

Specific objectives

- ✓ To collect different types of data required for the research and review related research works
- ✓ To modeling the entire system (v-groove parallel flow double pass solar collector and insulated dry chamber)
- ✓ To work with major target groups i.e. commercial scale hotels and enterprises and to convince them the advantage of adopting this advanced preserving method for vegetables.
- ✓ To compile full design and modeling of v-groove parallel flow double pass solar collector and dry chamber document

II. Materials And Methods

A. Configuration of the drying system

The atmospheric air enters from the bottom of v-groove plate solar air collector and it moves up by density difference due to gaining heat energy from the collector absorber plate.

The hot air from the collector directly distributes over the wet onion in the dry chamber and it removes the moisture content of onions outer one or two shells and that reduce the moisture exchange with the nearby onion.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

Thus, the onions can exist after dry for the required time before its use with no spoilage.

Finally the moisture air from the surfaces of the onions is exhaust through the outlet of the drying chamber through its chimney.

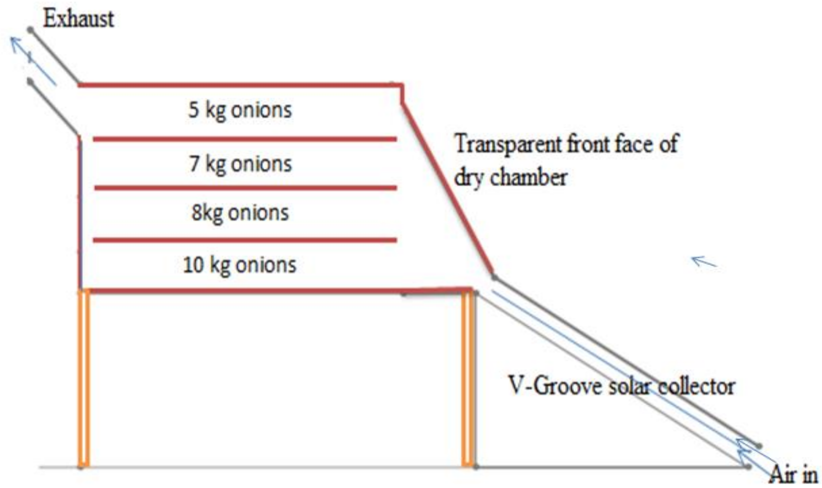


Figure-3: Overall System Drying Configuration

The amount of onions dry once is taken 30 kg which distribute from the bottom tray-1 has 10 kg, tray-2 has 8 kg, tray-3 has 7 kg, and the last top tray has 5-kg onions for this model.

A 30 kg average sized onions having the approximate volume of 0.125 m^3 and the gaps between the trays of the dry chamber and its area specified accordingly.

TABLE-I:
SPECIFICATIONS OF SOLAR COLLECTOR AND DRY CHAMBER

Specifications of the solar collector	
Total dimensions and type	2.25m*1.05*(0.1m)2, v-grooved parallel double pass
Absorber material	Grade 1100 aluminum stainless steel
Absorber paint	Matt black, black chrome selective
Plate type	v-grooved (60^0), (reflection of solar insolation can be bounced on the other spikes) height of 60 mm parallel air passes from both side to the dry chamber
Back insulation	Fiberglass wool
Number of glazing and type	One , normal window glass (thickness 5mm)
Side insulating	Polystyrene, wood and silicon rubber
Sealing	Silicon rubber
Collector frame material	Cast iron (thickness 20 mm)
Specifications of the dry chamber	
Insulations of all sides	Fiberglass wool
Tray height	10-15 cm
Frame material	Cast iron (thickness 20 mm)
Types of dryer	Passive distributed type dryers

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

B. Assumptions made for modeling the solar dryer system

In order to simplify the collector modeling, the following assumptions were made.

- The temperature drop through the glass cover, absorbing plate, and bottom plate are negligible.
- The heat flow through the back insulation is one-dimensional, that is the direction perpendicular to the air flow.
- The sky is assumed to be a blackbody for long-wavelength radiation at an equivalent sky temperature.
- The front and back surfaces losses are the same as the ambient temperature.
- Dust and dirt on the collectors are considered negligible in its effect of shading of the collector absorbing plates.
- The thermal inertia of collector components is neglected.
- The operating temperatures of collector components and mean air temperatures in air channels are assumed to be uniform.
- Temperature of the air varies only in the flow direction.
- The channels are free of air leakage.
- The thermal losses through the collector backs are neglected

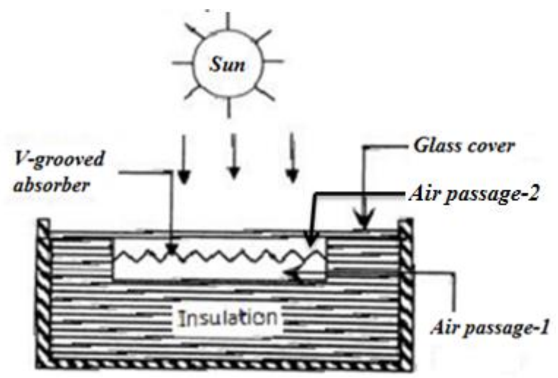


Figure-4: V-Grooved Double Pass Parallel Flow Air Solar Collector

III. Modeling And Design Analysis Of The System Components

A. Mathematical Modeling of the System Based on Energy Balances

Energy balance through the collector

The thermal network for double-pass solar air collector is illustrated in Figure-5 below. The equations indicated step by step of energy balance will be used to calculate the thermal performance using the matrix method.

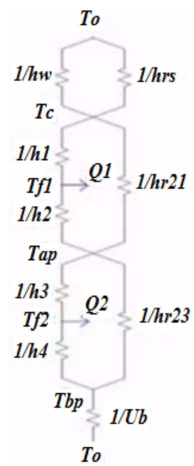


Figure-5: Thermal Network of a Double-Pass Solar Air Collector

i. Energy balance equation for the top cover:

$$S1 + hr21(Tap - Tc) + h1(Tf1 - Tc) = Ut(Tc - Ta)$$

ii. Energy balance equation for the fluid's first pass:
$h2(Tap - Tf1) = Q1 + h1(Tf1 - Tc)$
-where Q1 is The amount of heat transferred in the first pass fluid; $Q1=mCp(T_{f0}-T_{fi})$

iii. Energy balance equation for the absorber plate; the amount of solar energy absorbed by the plate of solar collector:

$$S2 = h2(Tap - Tf1) + hr21(Tap - Tc)$$
$$+h3(Tap - Tf2) + hr23(Tap - Tbp)$$

iv. Energy balance equation for the fluid's second pass:
$h3(Tap - Tf2) = h4(Tf2 - Tbp) + Q2;$
-where Q_2 is The amount of heat transferred in the second pass fluid; $Q1=mCp(T_{f0}-T_{fi})$
Energy balance equation for the bottom plate:

$$hr23(Tap - Tbp) + h4(Tf2 - Tbp)$$
$$= Ub(Tbp - Ta)$$

The solar radiation absorbed by the absorbing plate per unit area which is equal to the difference between the incident solar radiation and the optical loss, is calculated by:

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

$S_1=\alpha I$

The convection heat transfer coefficient between the glass cover and the absorbing plate is: $h_1=Nu_{ap-c}\frac{K}{H'}$

H' –is the mean gap thickness between the cover and the absorbing H′ (m) is calculated by H′ =Hc + 0.5Hg where Hg is the high of the v-groove absorber.

For flat plate and v-groove collector, Nusselt number for natural convection can be estimated by the following correlation:

$$Nu_{ap-c}=1+1.44\left[1-\frac{1708(\sin 1.8\theta)^{1.6}}{Ra\cos\theta}\right]\left[1-\frac{1708}{Ra\cos\theta}\right]^{+}+\left[\left(\frac{Ra\cos\theta}{5830}\right)^{173}-1\right]^{+}$$

The equation above is valid for 0° ≤ θ ≤ 75°.

Ra is the Rayleigh number, which is defined as:

$$Ra=\frac{\rho^2 C_p g\beta(T_{ap}-T_c)H_c^3}{k\mu}$$

Radiation heat transfer coefficients between the glass cover and the absorbing plate and between the absorbing plate is represented as:

$$hr21=\frac{\sigma(Tap^2+Tc^2)(Tap+Tc)}{\frac{1}{\varepsilon ap}+\frac{1}{\varepsilon c}-1}$$

The overall top loss coefficient is:

Ut=hw+hrs, whereas the convection heat transfer coefficient from the glass cover due to wind is hw = 5.7 + 3.8Vw and the radiation heat transfer coefficient from the glass cover to sky referred to the ambient air temperature Ta can be obtained as follows:

$$hrs=(Tc+Ts)(TC^2+Ts^2)\frac{(Tc-Ts)}{(Tc-Ta)}$$

The sky temperature T੍ਰ is estimated by:

Ts= $0.0552Ta^{1.5}$

The incident solar radiation absorbed by the absorbing plate is

$S2\approx 0.97\tau_C\alpha_{ap}I$

The Nusselt number for V-groove collector is estimated by the following correlation

When Re< 2800

$Nu_{ap-f}=2.821+0.126Re\frac{Hg}{L}$

When 2800 ≤ Re ≤ 10^4

$Nu_{ap-f}=1.9\times10^{-6}Re^{1.79}+225\frac{Hg}{L}$

When $10^4\le$ Re ≤ 10^5

$Nu_{ap-f}=0.0302\,Re^{0.74}+0.242\,Re^{0.74}\frac{Hg}{L}$

Where Reynolds number for a v-groove plate absorber is:

$$Re=\frac{Dh\rho Uf}{\mu}$$

Hydraulic diameter of the airflow channel formed by the absorbing plate and the bottom plate is Dh (m). And the hydraulic diameter for a v-groove absorber is given as:

Dh=(2/3)*Hg

The radiation heat transfer coefficients between the glass cover and the bottom plate are predicted by:

$$hr23=\frac{\sigma(Tap^2+Tbp^2)(Tap+Tbp)}{\frac{1}{\varepsilon ap}+\frac{1}{\varepsilon bp}-1}$$

The convection heat transfer coefficients for the fluid moving on the absorbing plate and on the bottom plate are calculated by:

$$h3=Nu\ ap-f\ \frac{K}{Dh}$$

The conductive heat transfer coefficient between the second pass fluid and the bottom plate is assumed to be equal, therefore:

$h_3=h_4$

The heat gain equation is given as: $Qu=\gamma(T_{fo}-T_{fi})$, where, $\gamma=Cp\dot{m}a$

The conduction heat transfer coefficient across the insulation from bottom and sides of the collector is estimated by:

$$Ub=\frac{Ki}{\Delta t}$$

Finally, the collector efficiency can be determined by:

$$\eta=\frac{\dot{m}Cp(Tfo-Tfi)}{I}$$

Energy balance through the dry chamber

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

The assumptions made for the simplification of the dry chamber are:

- The heat losses through the walls of the dry chamber are negligible
- There is uniform distribution of the hot through all shelves of the chamber
- Drying is the removal of onions moisture by convection heat gain and which is equal to latent heat of evaporation through its chimney

Heat balance in the dry chamber:

Total useful heat gain =latent heat of evaporation of the required amount of the moisture

Qu=m*hfg

Where

⇒ mc-mass of onion moisture content, and

⇒ hfg- latent heat of vaporization of water

TABLE-II:
VALUES OF THE CONSTANTS

Parameters	*Value*	*Unit*
I	600	W/m^2
Θ	30	degrees
Ta=Tfi	300	K
Ki	0.025	W/mK
ϵap	0.94	---
ϵbp	0.92	---
ϵc	0.94	---
αap	0.06	---
αc	0.95	---
τc	0.90	---
Vw	4.32	m/s

B. Design Analysis of V-Groove Solar Collector

Thermal analysis

The thermal performance of a solar collector depends on many parameters such as:

- ✓ Ambient conditions (Ambient temperature, wind speed, solar radiation)
- ✓ Geometry of collector
- ✓ Characteristics of working fluid (Cp, K, ρ)
- ✓ Inlet temperature of fluid (T_{in})
- ✓ Flow rate ($\dot{m}$)
- ✓ Choice of the absorber material
- ✓ Location of the construction: Inclination angle, direction

The energy balance on the absorber of solar collector is obtained by equating the total heat gained from sun to the total heat lost by the heat absorber of the solar collector. Therefore:

$$IA_c = Q_U+Q_{cond}+Q_{conv}+Q_R+Q_P$$

The three heat loss terms, Qcond, Qconv and Qradia are usually combined into one-term (Q_L) that is:

$$Q_L=Q_{cond}+Q_{conv}+Q_R+Q_P$$

Then, the useful energy will be available on the absorber of the solar collector is:

$$Qu = IAc - Q_L$$

Energy Balance Equation

In steady state, the performance of a solar collector can be described by the useful gain energy from the collector, *Qu*, which is defined as the difference between the absorbed solar radiation and the thermal loss or the useful energy output of a collector:

$$Q_U = A_P S - Ac\ UL\ (Ta_p - T_a)$$

Where *Ac* and *AP* are the gross and aperture area of the collector, respectively

The first term is the absorbed solar energy and the second term represents the heat loss from the collector. The solar radiation absorbed by a collector per unit area of absorber *S* can be calculated using the optical properties of covers and a plate. The thermal energy loss from the collector to the surroundings can be represented as the product of a heat loss coefficient U_L times the difference between the mean absorber plate temperature *Tap* and the ambient temperature *Ta*.

Gross collector area *Ac* is defined as the total area occupied by a collector and the aperture collector area *Ap* is the transparent frontal area. ASHRAE Standard employs the gross area as a reference collector area in the definition of thermal efficiency of the collector. The useful gain from the collector based on the gross collector area becomes:

$$Qu = A_C\ FR(\ Sc - U_L\ (Tfi - Ta)\ )$$

Where *Sc* is the absorbed solar radiation per unit area based on the gross collector area, defined as:

$$Sc = S\ (Ap/Ac\ )$$

Since the radiation absorption and heat loss at the absorber plate is considered based on the aperture area in this study, it is convenient to make the aperture collector area the reference collector area of the useful gain.

Collector Heat Removal Factor:

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

The collector heat removal factor, F_R, is the ratio of the actual useful energy gain of a collector to the maximum possible useful gain if the whole collector surface were at the fluid inlet temperature. It is defined as:

$$FR = \frac{\text{mCp (Tfo} - \text{Tfi)}}{\text{Ap (S} - \text{UL'(Tfi} - \text{Ta))}}$$

Where the aperture area *Ap* is used as a reference area for the useful gain from the collector.

$$FR = \frac{\text{mCp}}{\text{AcUL}}\left(1 - \frac{\text{S/UL(Tfo} - \text{Ta)}}{\text{S/UL(Tfi} - \text{Ta)}}\right)$$

Physically the collector heat removal factor is equivalent to the effectiveness of a conventional heat exchanger. By introducing the collector heat removal factor and the modified overall heat transfer coefficient, the actual useful energy gain *Qu* can be represented as:

$$Qu = ApF_R\,[S - UL(Ti - Ta)]$$

Using Equations, the useful energy gain can be calculated as a function of the inlet fluid temperature not the mean plate temperature.

C. Collector Thermal Efficiency

The efficiency of solar collector is defined as the ratio of the useful energy gain to the incident solar energy. Efficiency of the solar collector is given by:

$$\eta = \frac{\text{Qu}}{\text{IAc}} = \frac{\text{mCp(Tfo} - \text{Tfi)}}{\text{IAc}}$$

The efficiency of a solar collector is defined as the ratio of the amount of useful heat collected to the total amount of solar radiation striking the collector surface during any period of time. Useful heat collected for an air-type solar collector can be expressed as:

$$Qu = \dot{m}aCp(Tfo - Tfi)$$

The calculation of the overall loss coefficient (U_L) is based on simulation convection and re radiation losses from the absorber plate to the atmosphere. The radiation flux absorbed by unit area of the absorber plate (S) is defined as:

S = (τcαc)I = 0.90*0.95*600=513 W/m^2

Collector overall loss coefficient

The solar thermal efficiency depends essentially on thermal losses from outer surfaces of the collector. To attain higher efficiency of the solar collector, the losses of it must be minimized.

The top heat loss coefficient, Ut:

The top heat loss coefficient Ut determined by using the empherical formula indicated below which is in joint term of radiation heat loss, wind loss and convection losses:

$$Ut = \left[\frac{N}{\frac{C}{Tp}+\left(\frac{Tp-Ta}{N+F}\right)^e}\frac{1}{hw}\right]^{-1} + \frac{\sigma(Tp^2-Ta^2)(Tp-Ta)}{\frac{1}{d}+\frac{2N+f-N}{\epsilon c}-N}$$

Where:

$$C = \frac{204.429(\cos\theta)^{0.252}}{L^{0.24}}$$

d = ϵc+0.0425N (1-ϵc)

$$f = \left(\frac{9}{hw} - \frac{30}{hw^2}\right)\left(\frac{Ta}{316.9}\right)(1 + 0.091N)$$

e = 0.252

hw =5.7+3.8*Vw, where Vw-wind speed (in Wolaita sodo town V=4.32 m/se)

hw =21.66

Substituting all the values Ut=2.725 W/m^2

The bottom heat loss coefficient, Ub:

The bottom heat loss coefficient Ub is mainly the conduction heat loss through the thickness of the bottom insulation neglecting the radiation loss.

$$Ub = \frac{Ki}{\Delta t}$$

Where ki conduction coefficient, Δt insulation thickness from bottom of the collector

$$Ub = \frac{0.0252}{0.050} = 0.504\text{W/m}^2$$

Heat loss coefficient from sides of the collector, Ue:

The side or collector edge heat loss coefficient Ue is similar to that of the bottom heat loss coefficient is mainly the conduction heat loss through the thickness of the edges of the collector's insulation neglecting the radiation loss.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

Ue = $\frac{Ke}{\Delta t} = \frac{0.0252}{0.0250} = 1.008$ (loss coefficient for both sides of the collector 2.016 W/m^2)

Therefore, the overall heat loss coefficient U_L which is the sum of all loss coefficients from the collector:

U_L=Ut + Ub + Ue = 2.725 W/m^2+ 0.504W/m^2 + 2.016 W/m^2

=5.245 W/m^2

The useful heat gained by the collector

Qu=A_P (S - U_L(Tap - Ta))

Tp-the mean absorber plate temperature K
Ta -ambient temperature K
AP-absorber plate area m^2

Substituting these values, the useful energy gained by the collector area will be:

Qu=1184.82W

The overall thermal efficiency of the collector which is the ratio of useful heat energy gained by the collector absorber to the total solar radiation come to the collector absorber thus which is estimated as:

ɳ = Qu/I*Ap

=1184.82W/600W/m^2*(2*2.25m*1.05m)

(V-groove shape have total area is twice of the area of flat-plate solar collector)

=0.4179

=41.79%

The energy gain by the working fluid of the system which is in turn equal to the energy gain to the collector absorber, thus useful energy is estimated as:

Qu = mia Cp (Tfo - Tfi)

Where:

- To-fluid output temperature in K from collector absorber to dry chamber
- Ti-fluid inlet temperature in K to the collector absorber
- Cp-specific heat capacity
- mia-mass flow rate of air through collector absorber

Drying dry air requirement

Onions are generally dried from an initial moisture content of about 86% (wb) to 7% (wb) or less for efficient storage and processing of long time preservation. Drying of onion for the short time preservation is mainly for drying the outer two layers of the stalk which is approximated 20% of the total moisture content. Therefore, the mass of moisture water is 20% of the total 86% of moisture of the total 30 kg sample.

mc = 30*0.86*0.20= 5.16kg

Hence, the total amount of heat energy required to remove the required mass of moisture of the onions is:

Qd=mc*hfh=5.16*2.44MJ = 12.5904 MJ

Where: hfg-latent heat of evaporation of water, mc-mass of moisture a procedure for calculating the amount of water which can be removed by the airstreams; this is then employed using a psychometric chart [9]. Assuming an input air temperature of 25°C (dry bulb) and a relative humidity of 70%, the psychometric chart shows that its humidity ratio is 0.0141 kg water/kg dry air. When the solar collector heats it to, say, 45°C (dry bulb), and the humidity ratio remains constant. If on passing through the crop, the air absorbs moisture until its relative humidity is 90%. The psychometric chart shows the humidity ratio to be 0.022 kg water/kg dry air. The change in humidity ratio is therefore: 0.020 - 0.0141 = 0.00791 and the corresponding dry bulb temperature is 28.6°C.

From the ideal gas laws equation:

PV=maRT

where P is the atmospheric pressure which is 101.3 KPa, V is the volume of air in m^3, ma is the mass of the air in kg, T is the absolute temperature in Kelvin, and R is the gas constant which 0.291 kPa m^3/kg K. For a humidity ratio increase of 0.00791 kg water/ kg dry air, and each kg of water will require 1/0.00791 = 126.58 kg dry air.

For this calculation, the absolute temperature is 28.2+ 273 = 301.6 K and the volume of air needed to remove 1 kg of water is:

126.58*0.291*301.6/101.3=109.67 m^3

Hence 5.16 kg water will require (5.16 × 109.67) = 565.88 m^3 dry air

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

For a drying time of 6 hour operating time per day, which equal to 6 × 3600 = 21600 seconds, the total volumetric air flow rate will be 565.88 m³/21600 s = 0.0262 m^3/se

The mass flow rate of dry air at the given operating time is:

$$(\dot{m}a = (\dot{v} * \rho a)^{\cdot})^{\cdot}$$

$\dot{m}a = 0.0262 \frac{\text{m3}}{\text{se}} * \frac{\text{1.127kg}}{\text{m3}}$ = 0.0295 kg/se at a given range of temperature during drying

D. Average drying rate and drying time

In dry chamber, the total useful heat energy gained from solar collector should be equal to that of the latent heat of evaporation of moisture content of the material neglecting all heat losses during the drying process.

The latent heat of vaporization, Qd to evaporate 20% moisture content of the total moisture is calculated as:

Qd =mc*hfg=5.16 kg*2.44 MJ/Kg=12.5904 MJ

Then, the latent heat of vaporization that needed to evaporate moisture is equal to the product of useful heat gain, Qu from solar collector and drying time, τd.

Qd=Qu* τd

Therefore, the interval of time for drying a given mass of product is:

τd = Qd/Qu=12590400 J/1184.82 J/s

=2.952 hrs

Average drying rate, dr [kg/hr], is determined from the mass of the moisture to be removed by solar heat and drying time by the following equation.

dr = mc/ τd = 5.16 kg/2.952 hr

=1.75 kg/hr

This shows that the rate of drying is 1.75 kg onion in one hour.

IV. Results And Discussions

In this project design the type of solar collector used is double pass parallel flow v-corrugated solar collector which is for the purpose to have high collector absorber area, and same time to have high hot air flow rate that is from the collector to the dry chamber to dry onions. In this increase area of collector absorber, the useful energy calculated is 1184.82 W which twice of that of the flat-plate solar collector. Since the useful energy gain to the absorber of the collector is equal to the amount of energy that is gained to the working fluid, the output temperature of the fluid from the collector absorber to dry chamber has inverse relation to the amount of mass flow rate of working fluid.

The output temperature to the air mass flow rate graph simulation is the inlet air temperature is 300 K and the graph shows that there is no more change in decline of output temperature of air with the change of further air mass flow rate.

In other hand the overall efficiency of the solar air collector direct relation with the mass flow rate of the system. As the air mass flow rate increases the efficiency of the solar collector also increase.

Similarly based on the useful solar heat energy gain of the collector, the efficiency of the collector, the output working fluid temperature rather than mean absorber temperature has direct relation with the aperture air contact area of the collector.

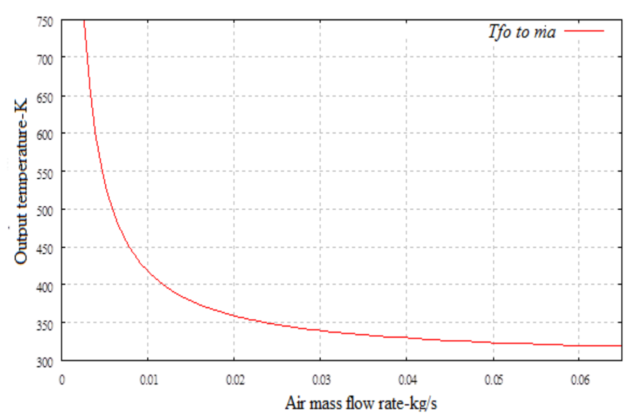


Figure-6: Output temperature to air mass flow rate

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 6, Issue 6, June 2017)

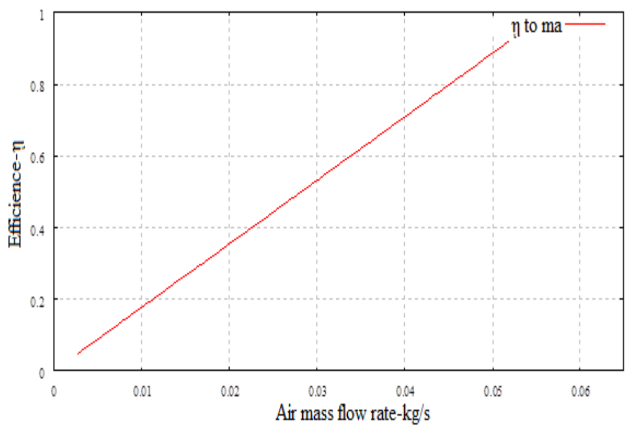


Figure-7: Collector overall efficiency to air mass flow rate

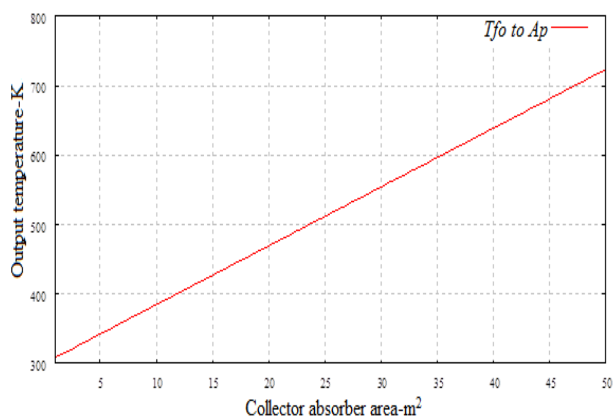


Figure-8: Output temperature to collector absorber area

V. CONCLUSION AND RECOMMENDATIONS

Onion and related vegetables need drying to preserve them for the required time before its use. Drying of crops, vegetables, fruits, and like is may be need to extend the life of preserve, to increase the quality of it, and/or to prepare it for further processing.

In this project, design and modeling of v-grooved parallel flow solar collector and dry chamber performed for the preservation of onions in the university students' cafeteria to preserve onion and related products of the same purposes.

Therefore, developing the drying system constructing solar collector and drying chamber for onion in the University of Students Cafeteria based on the design of this research project is possible.

However, the design of the parts of drying system should be developed further for the required application of drying to make it practical.

REFERENCES

[1] Sarsavadia PN, Sawhney RL, Pangavhane DR, Singh SP. "Drying behavior of brined onion slices". J Food Eng. 1999;40:219–226. doi: 10.1016/S0260-8774(99)00058-8

[2] McLean KA. "Drying and storage of combinable crops". Suffolk Farm Press, 1980.

[3] Ekechukwu OV. "Experimental studies of integral-type natural-circulation solar-energy tropical crop dryers". Kingdom, 1987.

[4] Arinze EA, Schoenau G, Bigsby FW. "Solar-energy absorption properties of some agricultural products". ASAE paper, no. 79-3071, 1979.

[5] Brooker DB, Bakker-Arkema FW, Hall CW. "Drying cereal grains". Westport AVI, 1974.

[6] O.V. Ekechukwu, B. Norton, "Review of solar-energy drying systems II: an overview of solar drying technology". Energy Research Centre, University of Nigeria, Nsukka, Nigeria 1997

[7] M.A. Karim and Z.M. Amin, "Mathematical Modeling and Performance Analysis of Different Solar Air Collectors". IIUM Engineering Journal, Vol. 16, No. 2, 2015

[8] Ong KS. (1995), "Thermal performance of solar air heaters: Mathematical model and solution procedure". Solar Energy, 55:93-109.

[9] Mudafer kareem Abdullah and Ahmed Abed Gatea, "Performance evaluation of a v-groove solar air collector for drying maize (Zea mays) in lraq". January, 2011