*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
*e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 2 Ser. II (Mar. – Apr. 2021), PP 01-09*
*www.iosrjournals.org*

# Design of a solar dryer for Corn

Yahy Mohammed Othman[1], Mohammed Ahmed Mohammed Haweel[2]
[1](Chemical Engineering Department, Faculty of Engineering College., University of bright star Albrega, Libya)
[2](Mechanical Engineering Department, Faculty of Engineering College, University of bright star Albrega, Libya)

***Abstract:*** *A corn was dried in the local manufactured solar dryer by natural flow. It consists of solar collector 1.71m2area and drying chamber, the dryer capacity is 25kg. The result showed that the corn drying unable by using solar energy in Jalo, Libya. This paper describes the design considerations followed and presents the results of calculations of design parameters. 1.71m$^2$ solar collector area is required to dry a batch of 25kg Corn in 10hours. The initial and final moisture content considered were 29% and 8% wet basis, respectively. The average ambient conditions are 28 º C air temperatures, with daily global solar radiation incident on horizontal surface of about 900w/m$^2$ at 12 o'clock on15 of June (Libyan National Meteorological Center). The weather conditions considered in Jalo, Libya. This prototype dryer will be used in drying tests. The Moisture content of water are reduced with increasing day hours, especially by using higher solar dryer than using natural sun drying method. And the equations were calculated for Corn moisture content and temperature of drying chamber for solar drying. The use of solar dried gave the highest efficiency of natural drying by studies and this is a good design in drying grain, vegetables and fruits too.*

***Keywords:*** *Solar dryer, drying methods, drying efficiency, corn dryer*

---

Date of Submission: 12-03-2021 Date of Acceptance: 27-03-2021

---

## I. Introduction

Drying is the oldest method of food preservation. For several thousand years people have been preserving dates, figs, apricots, grapes, herbs, potatoes, corn, milk, meat, and fish by drying. Until canning was developed at the end of the 18th century, drying was virtually the only method of food preservation. It is still the most widely used method. Drying is an excellent way to preserve food and solar food dryers are an appropriate food preservation technology for a sustainable world [1]. In this method of food preservation, we have studied the product as a corn to dry it by indirect type dryers, corn is considered one of the important crops which are drying in some cities and locations in Libya by the natural method , for that we chose Jalo city location (latitude 29° 00' 60.00" N)[2]. as a place for this project because it is one of the oases in the desert and it is a famous for the agriculture products, so this design is used for a small farms for help some people to protect their crops and increase the productivity.

## II. Materials And Methods

**Working Principle:**

Solar energy dryers can broadly be classified into direct, indirect and hybrid solar dryers. The working principle of these dryers mainly depends upon the method of solar energy collection and its conversion to useful thermal energy for drying [3].

**1. Open Sun Drying (OSD):**

Figure 1.shows the working principle of open sun drying by using only the solar energy. The crops are generally spread on the ground, mat, cement floor where they receive short wavelength solar energy during a major part of the day and also natural air circulation. A part of the energy is reflected back and the remaining is absorbed by the surface depending upon the colour of the crops. The absorbed radiation is converted into thermal energy and the temperature of the material starts to increase [3].

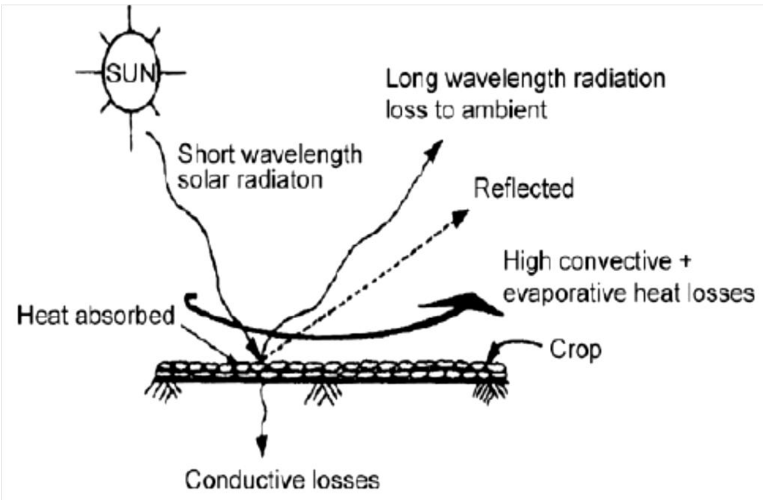


Figure 1.Working principle of open sun drying.

**2. Direct Solar Drying (DSD):**

The working principle of direct solar crop drying is shown in Figure 2, also known as a solar cabinet dryer. Here the moisture is taken away by the air entering into the cabinet from below and escaping through at the top exit as shown in Figure. In the cabinet dryer, of the total solar radiation impinging on the glass cover, a part is reflected back to atmosphere and the remaining is transmitted inside the cabinet. A part of the transmitted radiation is then reflected back from the crop surface and the rest is absorbed by the surface of the crop which causes its temperature to increase and thereby emit long wavelength radiations which are not allowed to escape to atmosphere due to the glass cover [3].

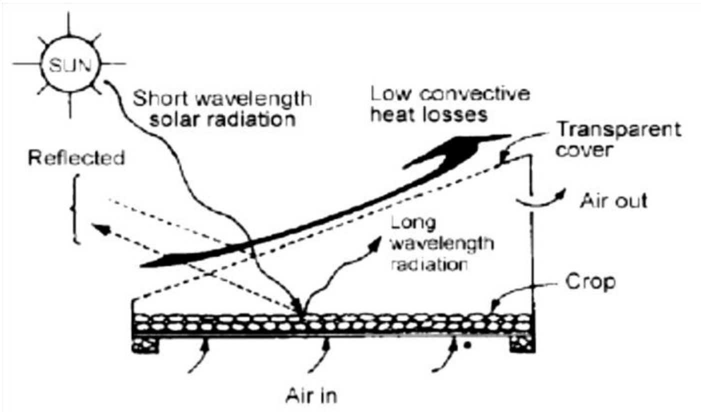


Figure 2.Working principle of direct solar drying

**The advantages of solar drying over open sun drying are as follows:**

a) Simpler and cheaper to construct than the indirect- type for the same loading capacity.
b) Offer protection from rains, dews, debris etc [3].

**The limitation of a cabinet dryer:**

a) Liability to over- heat locally, causing crop damage.
b) Poor vapour removal rates leading to relatively slow overall drying rates.
c) Small capacity limits it to small scale applications.
d) Discoloration of crop due to direct exposure to solar radiation.
e) Moisture condensation inside glass covers reduces its transmissivity [3].

**3. Indirect Solar Drying (ISD)**

These differ from direct dryers with respect to heat transfer and vapor removal. Figure 3 describes the working principle of indirect solar drying. The crops in these indirect solar dryers are located in trays or shelves inside an opaque drying cabinet and a separate unit termed as solar collector is used for heating of the entering air into the cabinet. The heated air is allowed to flow through/over the wet crop that provides the heat for moisture evaporation by convective heat transfer between the hot air and the wet crop. Drying takes place due to the difference in moisture concentration between the drying air and the air in the vicinity of crop surface [3].

**The advantages of indirect solar drying are:**

a) Offers a better control over drying and the product obtained is of better quality than sun drying.
b) Caramelization and localized heat damage do not occur as the crops are protected and opaque to direct radiation.
c) Can be operated at higher temperature, recommended for deep layer drying.
d) Highly recommended for photo- sensitive crops.
e) Have inherent tendency towards greater efficiency than direct solar drying [3].

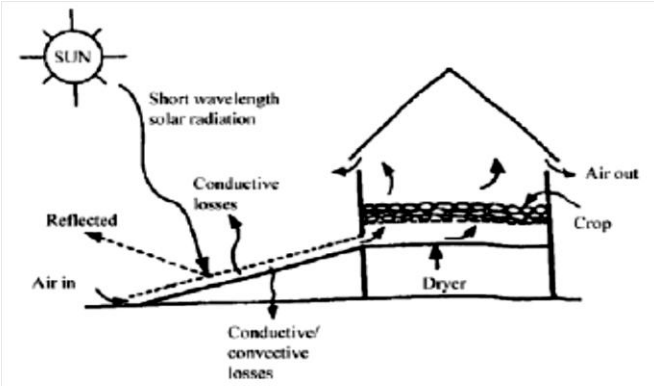


**Figure 3.**Working principle of indirect solar drying system

## 4. Hybrid Solar Drying (HBD)

The hybrid solar dryers combine the features of the direct and indirect type solar energy dryers. Here the combined action of incident direct solar radiation on the product to be dried and air pre- heated in a solar collector heater produces the necessary heat required for the drying process [3].

**Table 1:** Estimated Energy Requirement For Drying Of Some Crops

| Crops | initial moisture content (%) wb | final moisture content (%) wb | water removed (kg/t of dried product) | Energy Requirement $10^6$ kj/t |
|---|---|---|---|---|
| Wheat, barley, rye, oats, paddy, corn | 20-25<br>25-45 | 14-16<br>12-14 | 50-147<br>147-600 | 0.30-0.88<br>0.80-3.60 |
| peas, beans Potatoes onion, garlic carrot, beets, cabbage, tomatoes | 60-70<br>65-85<br>70-80<br>80-90<br><br>90-95 | 5-10<br>14<br>5-10<br>5-10<br><br>5-10 | 1250-2157<br>1458-4733<br>2000-3750<br>3500-8500<br><br>8000-3300 | 7.50-13.00<br>8.75-28.40<br>12.00-22.50<br>21.00-51.00<br><br>48.00-108.00 |
| apples, apricots, peaches Prunces, grapes figs, banana | 75-80 | 14-23 | 2080-3300 | 12.48-19.80 |
| hay grass, alfala | 40-60<br>80-90 | 10-14<br>10-14 | 433-1250<br>3300-8000 | 2.60-7.50<br>19.80-48.00 |

## III. Drying terminology

**Percent moisture content, dry basis:**

The moisture content is calculated from the mass ratio of water to dry solid.

$$\mathrm{M\ (wet)} = \frac{\mathrm{W-d}}{\mathrm{d}} \times 100\% \text{———} (1)$$

Where W is the wet mass
d is dry mass of the product.

**Percent moisture content, wet basis:**

The mass fraction of water in the commercially dry solid [4].

$$\mathrm{M\ (wet)} = \frac{\mathrm{W-d}}{\mathrm{W}} \times 100\% \text{———} (2)$$

## IV. Design parts

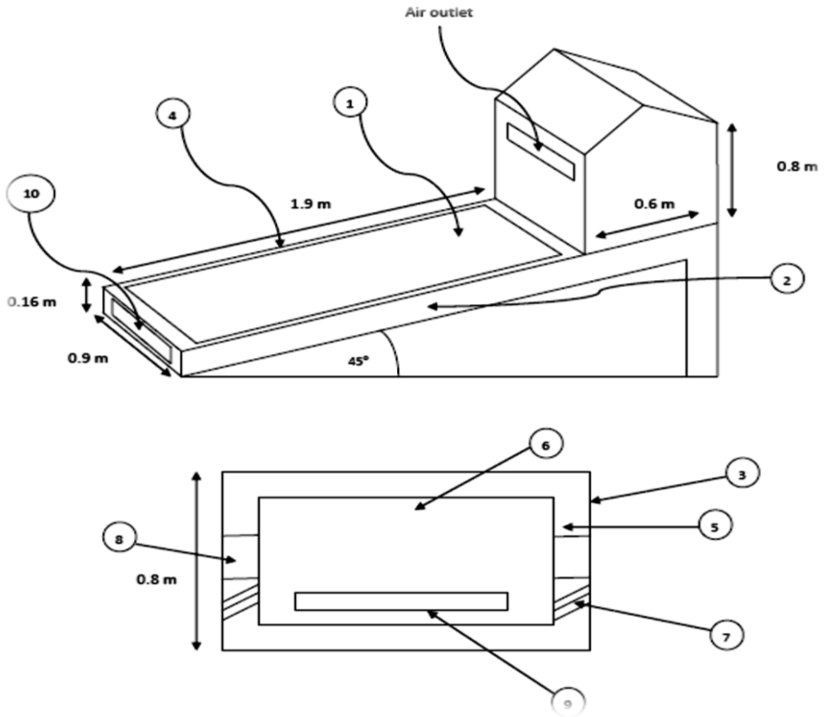


**Figure 4:** multiple views of the application solar food dryer [1].

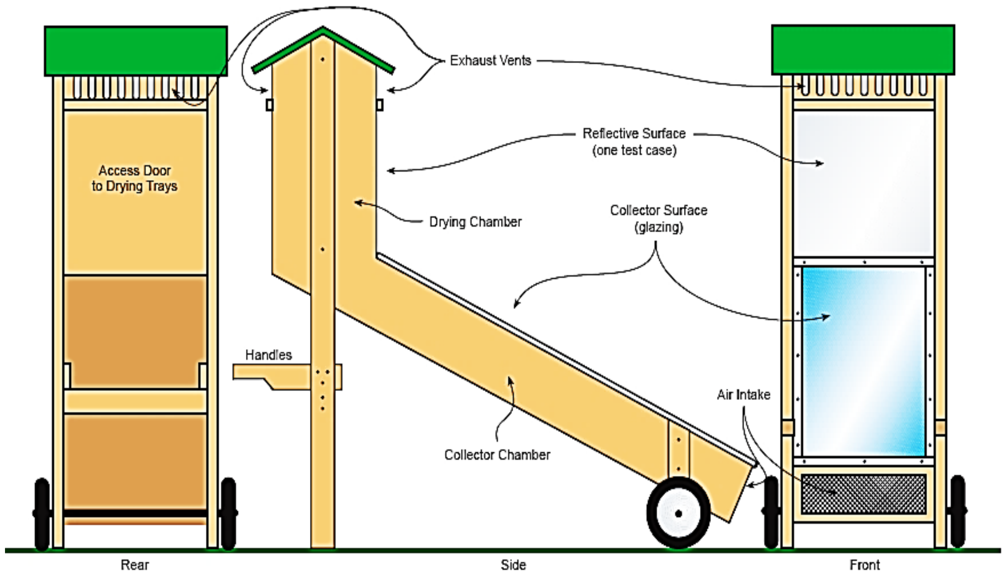


**Figure 5:** A schematic diagram, details, and dimensions of the drying system.

**Table 2:** Components of design

| | |
|---|---|
| 1- Glass cover | 2- Thermal insulation (fiber glass) |
| 3- Exterior aluminum plate | 4- Absorber plate |
| 5- Interior aluminum plate | 6- Screened drying tray |
| 7- Rock wool insulation | 8- Vents |
| 9- Hot air outlet | 10- Air inlet |

**Table 3:** Design conditions, and assumptions

| Items | Condition or assumption |
|---|---|
| Location | Jalo (latitude 29° 00' 60.00" N) |

| | |
|---|---|
| Crop | corn |
| Drying period | 10 hr |
| Initial moisture content (moisture content at harvest), Mi | 30 % |
| Final moisture content (moisture content for storage) , Mf | 8 % |
| Ambient air temperature, Tam | 26 $^{o}$C |
| Maximum allowable temperature, Tmax | 80 $^{o}$C |
| glass cover temperature $T_g$ | 45 $^{o}$C |
| Incident solar radiation, I | 900 w/m$^2$ at 12 o'clock |
| Wind speed | 4 m/s |
| mass flow rate of air | 0.6 kg/s |
| back temperature Tb | 348 k |
| absorber temperature Tp | 353 k |

**Table 4:** Details and dimensions of the collector

| | |
|---|---|
| collector long | 1.9 m |
| collector wide | 0.9 m |
| collector high | 0.16 m |
| depth of air channel | 0.06 m |
| thick of glass cover | 3.5 mm |
| thick of gap | 20 mm |
| fiber glass insulation thick at the back | 0.08 m |
| fiberglass insulation thick at the edges | 0.03 m |

**Table 5:** The collector emissivity [5]

| | |
|---|---|
| emissivity of absorber $\varepsilon_p$ | 0.92 |
| emissivity of glass $\varepsilon_g$ | 0.88 |
| emissivity the back $\varepsilon_b$ | 0.92 |
| effective of collector Tα | 0.90 |

## V. Calculation of energy and heat balance

The collector overall-loss coefficient (UL) W/m$^2$.K is the sum of top and bottom and edge loss coefficients [6].

$$U_L = U_t + U_b + U_e \quad \text{———} (3)$$

$U_t$= top heat loss coefficient W/m$^2$.K
$U_b$= bottom heat loss coefficient W/m$^2$.K
$U_e$= edges heat loss coefficient W/m$^2$.K
First assume the glass cover temperature $T_g$ to save time about 45$^o$c (318k)

$$U_{top} = \left(\frac{1}{h_{c_{p-g}} + h_{r_{p-g}}} + \frac{1}{h_{c_{g-a}} + h_{r_{g-a}}}\right) \quad \text{———} (4)$$

$h_{r_{p-g}}$ The radiation heat transfer coefficient between absorber plate and glass cover [8].

$$h_{r_{p-g}} = \frac{\sigma( T_p + T_g)\,( T_p^2 + T_g^2 )}{\left(\frac{1}{\varepsilon_p}\right) + \left(\frac{1}{\varepsilon_g}\right) - 1} \quad \text{———} (5)$$

$h_{r_{g-a}}$ The radiation heat transfer coefficient between the glass cover and the ambient [8].

$$h_{rg-a} = \varepsilon_g \sigma\left(T_g + T_a\right)\left(T_g^2 + T_a^2\right) \text{———} (6)$$

The following properties of air obtained for $0.5\left(T_P + T_g\right)$
V=19.51 x 10$^{-6}$ m
Pr = 0.701
K = 0.0288 $\frac{W}{M^2}$.k
The Rayleigh number, Ra can be obtained by this equation [11].

$$Ra = \frac{g\grave{\beta}P_r}{v^2}\left(T_p - T_g\right)L^3 \quad \text{———} (7)$$

$\grave{\beta}$=1/$T_{main}$ [12]
($h_{c_{p-g}}$ ) The convection heat transfer coefficient between absorber plate and glass cover, can be estimated from correlations for Nusselt number13].

$$h_{c_{p-g}} = \frac{k}{L}\left[\left(1 + 1.446\left(1 - \frac{1708}{Ra \times \cos\theta}\right)\right)\right] \times \left[1 - \left(\frac{1708\,[\sin(1.8\theta)]^{1.6}}{Ra \times \cos\theta}\right)\right] + \left[\left(\frac{Ra \times \cos\theta}{5830}\right)^{0.333} - 1\right] \quad (8)$$

The convection heat transfer coefficient from glass to the ambient is the wind loss coefficient ($h_w$)

$$h_{c_{g-a}} = h_w = \frac{8.6\, v^{0.6}}{L^{0.4}} = \frac{8.6\,(4)^{0.6}}{(1.9)^{0.4}} \quad (9)$$

$U_{top}$ Can be calculated from Eq.

$$U_{top} = \left(\frac{1}{h_{c_{p-g}} + h_{r_{p-g}}} + \frac{1}{h_{c_{g-a}} + h_{r_{g-a}}}\right) \quad (10)$$

$U_b$ = bottom heat loss from tables fiber glass insulation conductivity K =0.038 w/m.°c[6].

$$U_b = \frac{1}{\frac{t_b}{k_b}} \quad (11)$$

$U_e$ =edges heat loss [6].

$$U_e = \frac{1}{\frac{t_e}{k_e}} \quad (12)$$

By the empirical Eq [7].

$$Ut = \frac{1}{\dfrac{Ng}{\dfrac{C}{Tp}\left[\dfrac{Tp - Ta}{Ng + f}\right]^{0.33}} + \dfrac{1}{hw}} + \frac{\sigma\,(Tp^2 + Ta^2)\,(Tp + Ta)}{\dfrac{1}{\boldsymbol{\varepsilon_{p} + 0.05\, Ng\,(1-\varepsilon_p)}} + \dfrac{2\,Ng + f - 1}{\varepsilon_p} - Ng} \quad (13)$$

$$f = (1 - 0.04\, h_w + 0.0005\, h^2{}_w)\,(1 + 0.091\, Ng) \quad (14)$$

$$C = 365.9(1 - 0.00883\beta + 0.0001298\,\beta^2) \quad (15)$$

$$U_t = 5.799 \cong 6 \frac{w}{m^2}.k$$

$$T_{main} = \sqrt[3]{\frac{(Tp + Tb)\,(Tp^2 + Tb^2)}{4}} \quad (16)$$

From tables at $T_{main}$. The following properties can be obtained
μ=2.075 x 10-5 kg/m.s
K = 0.03003 w/m.oc
$C_p$ = 1009 j/kg.K
$h_{r_{p-b}}$ The radiation heat transfer coefficient from the absorber to the back plate [8].

$$h_{rp-b} = \frac{\sigma(T_p + T_b)(T_p^2 + T_b^2)}{\left(\frac{1}{\varepsilon_p}\right) + \left(\frac{1}{\varepsilon_b}\right) - 1} \quad (17)$$

From fluid mechanics the hydraulic diameter of the air channel is [9].

$$D = 4\left(\frac{\text{flow cross} - \text{sectional area}}{\text{Wetted perimeter}}\right) = 4\left(\frac{Ws}{2W}\right) = 2S \quad (18)$$

The values of Nusselt number, Nu, for turbulent and lamina flows, where Re and Pr are Reynolds and Prandtl numbers, respectively [7].
The Reynolds number is given by:

$$Re = \frac{\dot{m}D}{A\mu} \quad (19)$$

Therefore Nusselt number is given by:

$$Nu = 0.0158\,(Re)\,0.8 \times \frac{K}{D} \quad (20)$$

Convection heat loss coefficient, absorber-ambient is equal to convection heat loss from back- ambient.

$$\therefore h = h_{C_{p-a}} + \frac{1}{\left(\frac{1}{h_{C_{b-a}}}\right) + \left(\frac{1}{h_{r_{p-b}}}\right)} \quad (21)$$

The collector efficiency factor (Ḟ) [14]:

$$\acute{F} = \frac{1/U_L}{\left(1/U_L\right) + \left(1/h\right)} = \frac{h}{h + U_L} \quad \text{———}(22)$$

The absorber solar radiation (S).

$$S = Gt\,(T\alpha) \quad \text{———}(23)$$

The outlet air temperature ($T_o$) [14]

$$T_0 = T_i + \frac{1}{U_L}\left[s - U_L(T_i - T_a)\right]\left[1 - \exp\left(-\frac{A_c U_L \acute{F}}{\dot{m} C_p}\right)\right] \text{———}(24)$$

The removal efficiency factor ($F_R$) [6].

$$F_R = \frac{\dot{m} C_p}{A_c U_L}\left[1 - \exp\left(-\frac{A_c U_L \acute{F}}{\dot{m} C_p}\right)\right] \text{———}(25)$$

$Q_u$ In steady state, the performance of a flat-plate solar collector can be described by the useful gain from the collector [10].

$$Qu = A_c F_R\left[S - U_L(Ti - Ta)\right] \quad \text{———}(26)$$

$\eta_c$ The solar collector efficiency is defined as the ratio of the useful heat gain over any time period to the incident solar radiation over the same period [10].

$$\eta_c = \frac{Qu}{A_c G_t} \quad \text{———}(27)$$

From tables at $T_o$=36°c the $h_{fg}$ =2415.8 KJ/Kg

So to dry 25Kg of Corn, then mi=25Kg, $M_i$ initial moisture content and $M_F$ final moisture content

The quantity of moisture evaporated from the dried material may be calculated from the following relation [4].

$$MF = \frac{(M_W - mi\,Mi)}{(M_W - mi)} \quad \text{———}(28)$$

## VI. The performance of solar collector

This date is collected during a day on 15 of June. The initial weight of the Corn 25Kg, and moisture content is 30% (Mi), to calculate (Mf) and the performance for this tables with this date and use it to know all information about the design work.

**Table 6:** relationship between solar radiation intensity and time

| Time | Ta oc | Gt w/m$^2$ |
|---|---|---|
| 8 | 28 | 250 |
| 9 | 30 | 400 |
| 10 | 32 | 600 |
| 11 | 34 | 800 |
| 12 | 35 | 900 |
| 13 | 34 | 800 |
| 14 | 32 | 600 |
| 15 | 30 | 400 |
| 16 | 28 | 250 |
| 17 | 26 | 150 |

To analysis this date using this equation:

$$\eta_c = \frac{Qu}{A_c G_t} \text{——} (29a)$$

$$Q = \dot{m}\, C_p\, (T_o - T_i) \text{———}(29b)$$

$$\therefore Qu = \eta \times A_c \times G_t \quad \text{———}(30)$$

$$T_o = \frac{Q}{\dot{m}\, C_p} + T_i \quad \text{———}(31)$$

$$M_w = \frac{Qu}{h_{fg}} \quad \text{———}(32)$$

**Table 7:** explain all the results which have been collected of date

| Time | Ta $^{O}C$ | Gt $w/m^2$ | $T_O$ $^{O}C$ | Qu W | hfg KJ/Kg | Mw Kg | Mi % | Mf % |
|---|---|---|---|---|---|---|---|---|
| 8 | 28 | 250 | 30.7 | 166.7 | 2430 | 0.24 | 0.30 | 0.29 |
| 9 | 30 | 400 | 34.4 | 266.7 | 2420.5 | 0.39 | 0.29 | 0.27 |
| 10 | 32 | 600 | 38.6 | 400.14 | 2411 | 0.59 | 0.27 | 0.25 |
| 11 | 34 | 800 | 42.8 | 533.52 | 2401.4 | 0.79 | 0.25 | 0.22 |
| 12 | 35 | 900 | 44.9 | 600.21 | 2396.6 | 0.90 | 0.22 | 0.19 |
| 13 | 34 | 800 | 42.8 | 533.52 | 2401.4 | 0.79 | 0.19 | 0.16 |
| 14 | 32 | 600 | 38.6 | 400.14 | 2411 | 0.59 | 0.16 | 0.13 |
| 15 | 30 | 400 | 34.4 | 266.7 | 2420.5 | 0.39 | 0.13 | 0.11 |
| 16 | 28 | 250 | 30.7 | 166.7 | 2430 | 0.24 | 0.11 | 0.10 |
| 17 | 26 | 150 | 27.6 | 100 | 2437.2 | 0.14 | 0.10 | 0.08 |

To calculate the productivity of the system (P) Kg .
The mass of water removed can be estimated by [15]:

$$m_w = \frac{m_i(M_i - M_f)}{100 - M_f} \times 100 \qquad (34)$$

To calculate the productivity, which is equal to the weight of corn in the drying chamber minus the amount of water removed, which can be calculated from the following equation:

$$P = m_I - [(M_I - M_F)m_I] \qquad (35)$$

The efficiency of the drying cabinet ($\eta_d$) [4].

$$\eta_d = \frac{P \times h_{fg}}{(G_t A_c)t} \qquad (36)$$

**Table 8:** the final results of the equations

| **prefix** | **Result** | **Prefix** | **result** |
|---|---|---|---|
| $h_{r_{p-g}}$ | 7.02 $w/m^2.k$ | D | 0.12 m |
| $h_{r_{g-a}}$ | 5.86 $w/m^2.k$ | Re | 6425.7 |
| $R_a$ | 15157.4 | $h_{C_{p-a}}$ | 4.399 $w/m^2.k$ |
| $h_{c_{p-g}}$ | 3.01 $w/m^2.k$ | H | 7.280 $w/m^2.k$ |
| $h_{c_{g-a}}$ | 15.283 $w/m^2.k$ | Ḟ | 0.459 |
| Ut | 6.807 $w/m^2.k$ | S | 812 $w/m^2$ |
| $U_b$ | 0.475 $w/m^2.k$ | To | 309 k |
| $U_e$ | 1.266 $w/m^2.k$ | FR | 0.434 |
| UL | 8.548 $w/m^2.k$ | Qu | 602.6 w |
| f | 0.516 | $h_{fg}$ | 2430 KJ/Kg |
| C | 316 | $\eta c$ | 39% |
| Ut empirical | 6.807 $w/m^2.k$ | Mw | 0.897 kg |
| $T_{main}$ | 350 k | $m_w$ | 5.5 kg |
| $h_{r_{p-b}}$ | 8.325 $w/m^2.k$ | P | 19.5 kg |
| | | $\eta_d$ | 84% |

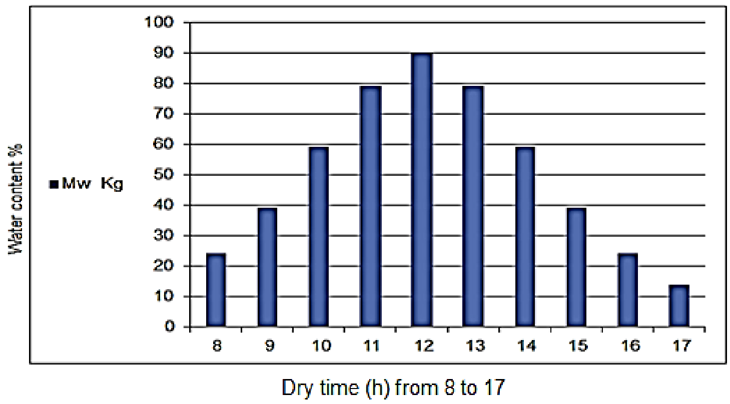


**Figure 6**: Variation of water content with time

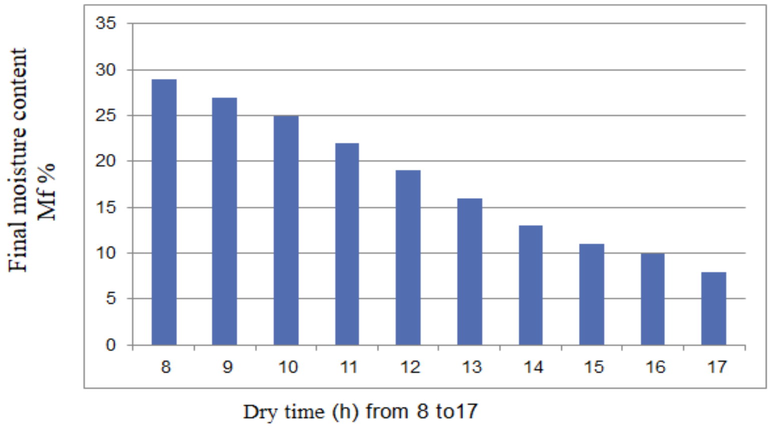


**Figure 7:** Variation of final moisture content with time

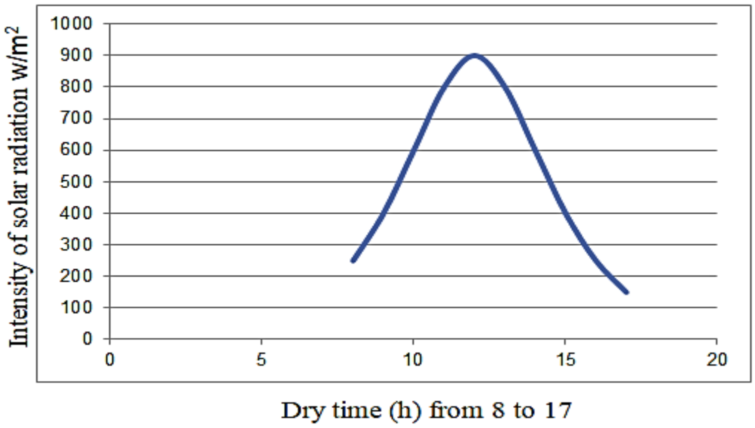


**Figure 8**: Variation of the intensity of solar radiation with time

.

## VII. Conclusion

The solar dryer was designed and built based on the investigations for drying corn. Where the dryer designed with a collector area of 1.71m$^2$ was expected to dry 25kg of corn from 30% to 8% under the conditions surrounding, the harvest period which starts on June 15$^{th}$ from 8 am to 17 pm, and the productivity is estimated of 19.5 kg. The results are good and largely satisfactory.

## References

[1]. Dennis Scanlin. (1997). The Design, Construction, and Use of an Indirect, Through-Pass, Solar Food Dryer.
[2]. https://latitude.to/articles-by-country/ly/libya/247658/jalo-oasis
[3]. G. L. Visavale. (2012). Principles, Classification and Selection of Solar Dryers.
[4]. Abdul Jabbar N, Khalifa[1] Amer M, Al-Dabagh[2] and W, M, Al-Mehemdi[2].(2012). An Experimental Study of Vegetable Solar Drying Systems with and without Auxiliary Heat.
[5]. Richard Halla, John Blowera. (2016). Low-emissivity transpired solar collectors.
[6]. Ho-Ming Yeht and Tong-Tshien Lin.(1995). Efficiency Improvement Of Flat-Plate Solar Air Heaters.
[7]. Michael Gareth Muthini Kituu. (2011). Application of Genetic Algorithms in the Optimization of a Solar Tunnel Fish Dryer Design and Performance.
[8]. [1]S. Thiao, [2]C. Mbow and [1, 3I]. Youm. (2014). Heat Transfer Analysis of a Flat-plate Solar Collector Running a Solid Adsorption Refrigerator.
[9]. BAA Yousef, NM Adam. (2008). Performance analysis for flat plate collector with and without porous media.
[10]. Hasson S. Hamood[1], Badran M. Salim[2], Nabeel M. Abdulrazzaq[3]. (2014). Theoratical Analysis Of Flat Plate Solar Collector Placed In Mosul City By Using Different Absorbing Materials And Fluids.
[11]. Suresh Kumar *, S.C. Mullick. (2012). Glass cover temperature and top heat loss coefficient of a single glazed flat plate collector with nearly vertical configuration.
[12]. M.A. Karim and Z.M. Amin. (2015). Mathematical Modelling and Performance Analysis of Different Solar Air Collectors.
[13]. Anand Bisen, P.P.Dass, Rajeev Jain. (2011). Parametric studies of top heat loss coefficient of double glass flat plate collector.
[14]. Koua Kamenan Blaise [1,2,*], Koffi Ekoun Paul Magloire[1], Gbaha Prosper1. (2019). Thermal performance evaluation of an indirect solar dryer.
[15]. Wengang Hao [1], Shuonan Liu [1], Baoqi Mi [1] and Yanhua Lai [1, 2,*]. (2020). Mathematical Modeling and Performance Analysis of a New Hybrid Solar Dryer of Lemon Slices for Controlling Drying Temperature.