DRYING OF CUCUMBER SEEDS BY SOLAR ENERGY FOR PLANTING

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ABSTRACT.

The aim of this research was to study the factors affecting the cucumber seeds drying for planting by using the cabinet dryer, to utilize solar energy with optimum efficiency for drying crops, and to keep the environment free from pollution and save fossil fuel. Modern methods in grain and seeds drying are taken to improve the quality of the product in the process of germination.

Minimum and maximum average of hot-air temperatures in the loaded cabinet ranged between 41 and 50 °C. Relative humidities inside the cabinet of air-forced dryer ranged between 48 and 73 %. The inlet air velocities were 0.51 to 1.12 m/s. Loss moisture content was 7.2 % over one day drying at the layer thickness 5 mm. The highest thermal efficiency was 63.7 % at hot-air temperature of 48 °C.

It was found that the germination ratio of cucumber seeds ranged between 97.1 and 97.4 % at different seed drying-times, temperatures and moisture-contents.

The minimum drying cost of 292 LE/ton was obtained by the dryer with a layer thickness 5 mm.

INTRODUCTION.

Since 1973, energy conflict became eminent. There had been a shortage of fuels in many parts of the world, and their prices increased steeply. It is now clear that the fossil fuel era is gradually coming to an end.

In addition, combustion of fossil fuels causes serious air pollution with harmful effect on the environment. The seriousness of most of the environmental problems had not really been foreseen. Now, alternative sources of energy are sought to conserve the environment.

Solar energy is a very large inexhaustible source of energy. The solar incident energy in Egypt has an average value 3.2-4.9 kWh/m^2 in winter and 7.8-8.8 kWh/m^2 in summer with an average of sun-shine

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duration per day of about 9.2-11 hour **(Saad et al., 1992)**, which is many thousands larger than the present consumption rate on the earth of all commercial energy sources. In addition to its magnitude, solar energy has two other factors in its favor. Firstly, it is an environmentally clean source of energy. Secondly, it is available in adequate quantities in almost all parts of the world, but still needs effective means for utilization.

The use of solar dryers helps to eliminate the air pollution problems caused by fossil fuel dryers. Drying can be done faster, cleaner, and in a controlled fashion. A better quality product is obtained.

Awady et al. (1993) constructed a solar dryer from local materials in the Suez Canal area. The solar collector is composed of two flat panels with absorber plates intercepting the hot air. The flat panels can be separately adjusted to different solar interception angles for maximum air flow and thermal efficiency. The collector had an absorber plate of 0.5 m^2 surface area (1m × 0.5 m) . The absorber plate was formed from aluminum sheet 1mm thick. Its upper face was painted black to absorb the maximum amount of solar energy. Drying chamber was built from material similar to the solar collector for utilizing solar radiation transmitted to it through transparent cover onto the absorber plate. The dryer was mounted on supporting frame to provide a south facing surface at the optimum slope (about 30° with horizontal). They concluded that:

1 - The temperatures of air inside the solar dryer rises from about 17°C to 28°C above the ambient air temperature for grapes, onion and melokhia.

2 - The solar dryer required less time to dry agricultural product with higher moisture removal rate over direct sun, drying and the drying system performance was found to be affected by the inclination of the drying chamber. The maximum values of the drying efficiency were 19.40% for grapes in a column inclination angle of 30° to the horizontal and 35.57%, 13.43% at 90°(vertical) for onion and melokhia respectively.

Tiris et al. (1995) tested a new solar dryer consisting of a solar air heater and a drying chamber. Sultana grapes, green beans, sweet and chili peppers were selected for test samples. The drying time varied between

2 and 5 days. The new solar dryer with integrated collector, which was constructed easily with very simple tools and means, provided better quality and shorter drying periods.

EL-Sahrigi et al. (1999) stated that that structural frame of gable-even-span form had some advantages over the modified Quonset form particularly at night during winter season and at daylight during summer season. During winter season, the gable-even-span form reduced the loss of heat from the greenhouse between 5.15% and 8.59%compared with the modified quonset form, due to influences of curvature surface area on the heat transfer area. During summer , the modified quonset form increased the solar radiation available inside the greenhouse by 13.16% compared with the gable-even-span form because of roof curvature. Consequently, the structural frame of gable-even-span form increased the cucumber fresh yield by 14.64% and 14.73% respectively. The conditioned greenhouses enhanced the rate of vegetative growth, and on the average increasing the cucumber fresh yield by 84.04% and 140.75% for winter and summer crops respectively compared with the unconditioned greenhouses.

Khalil (2002) and Chaaban et al. (2002) concluded that:

1 – Moisture content of rice grain decreased to a min. of 11.9 % by the forced-air tray dryer.

2 – Cracking ratio range of 1.0 – 2 % according to moisture content and drying coefficient.

3 - Thermal efficiencies ranged from 5.0 to 70.6 % with the lowest obtained from the natural-convection dryer. Meanwhile, the highest was obtained from forced-air dryer with additional solar collector.

Abu-Habaga et al. (2010) said that the use of the greenhouse type solar dryer with chopping and crushing of the green tops could decrease the drying time of sugar beet tops by about 47 to 59 h in comparison with the traditional drying method which takes about 78 hours. The thermal efficiency of the dryer ranged from 34.12 to 22.96% and the protein content of the dried tops ranged from 12.57 to 14.52% on DM (Drying Method) basis.

Kassem et al. (2011) found that the Gable Even Span solar dryer was the most convenient, since it gave highest removal of water, less moisture content, high gain solar energy, less solar energy and highest efficiency during the two experimental operations:

1- It removes 51.1g water from 60 g onion sample at (SD_1) with rocks which was 47.5 g for drying without rocks.

2- It gains 39.75 and 46.06 kW during the experimental operations without and with rock respectively.

3- It has the highest efficiency of 68% and 72% respectively with rock and without rock.

The objectives of this research were:

- Utilizing the solar energy with optimum efficiency that can be used for drying agricultural products to keep the environment free from pollution and save non-renewable fuel resources.
- Utilizing modern methods in grain drying and seeds to improve the quality of the product in the process of germination.

MATERIALS AND METHODS.

The tested cabinet-dryer.

Cabinet solar dryer designed by Khalil (2002) and Chaaban et al. (2002) was tested to dry cucumber seeds in this research. The cabinet solar dryer was located at 30° latitude.

The tested dryer is shown in figs. 1 and 2. The tested dryer consisted of the following parts:

- *Drying box* : Drying box consists of four double sides that have an insulation layer of 20 mm thickness. The four sides were made of plywood black painted from inside with 18 and 12 mm thickness for outer and inner sheets respectively. The drying box has 585 mm length, 475 mm front width and 835 mm rear width. Each side contained 4-holes of 50 mm diameter for air inlet. The side contains 7-holes of 50 mm diameter for air inlet. The rear side contains two square gates of 155×155 mm used to mount the blower fan. The bottom of drying box has double side of plywood black painted from inside of 18 and 12 mm thickness for outer and inside sheets respectively, and having 1220 mm length, and 625 mm width with an insulation layer of 20 mm thickness.

- **Seeds used in the investigation:** Seeds of cucumber Beta-alpha variety were used.

The experiments were carried out to find parameters affecting drying efficiency and performance of designed dryers. These parameters are :

- **Temperature*:*** Thermocouples with digital thermometer of 5 points (as shown in fig. 3) were used for measuring every hour the temperatures at different points inside and outside of drying plenum (Hot air-temperature "T_1", seeds temperature "T_2", hot-air temperature inlet "T_i", hot-air temperature outlet "T_o" are thermocouple points inside drying box and ambient temperature "T_3".).

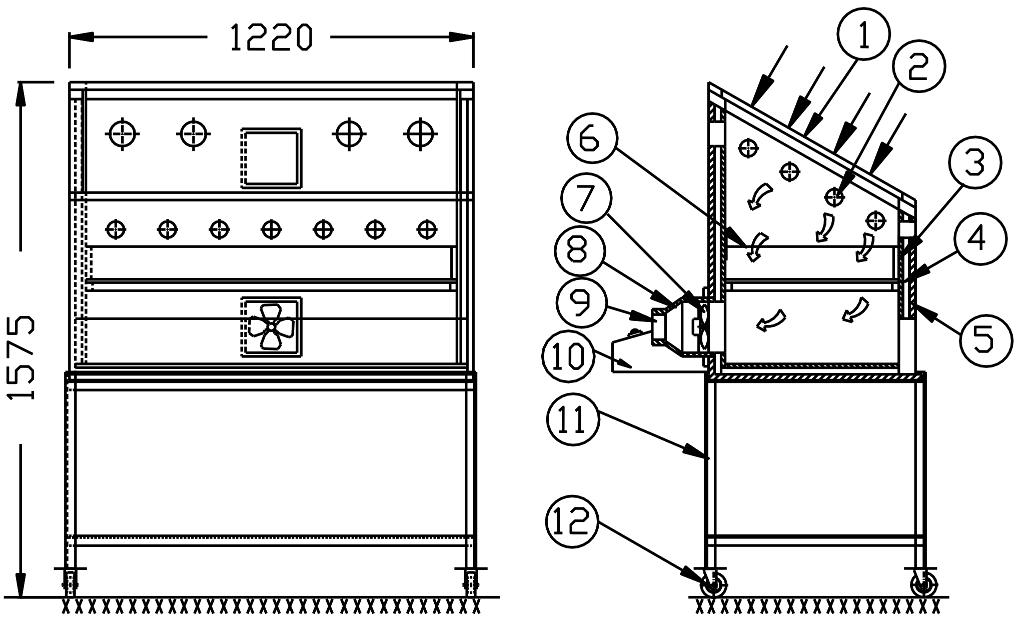


Fig. 1: Elevation and side views for the cabinet dryer.

(1) Transparent cover, (2) Air intake hole, (3) Inside frame, (4) Insulation, (5) Outside frame, (6) Grain tray, (7) Blower, (8) Blower frame, (9)Air exhaust hole, (10) Control box, (11) Drying box stand, and (12) Ground-wheels.

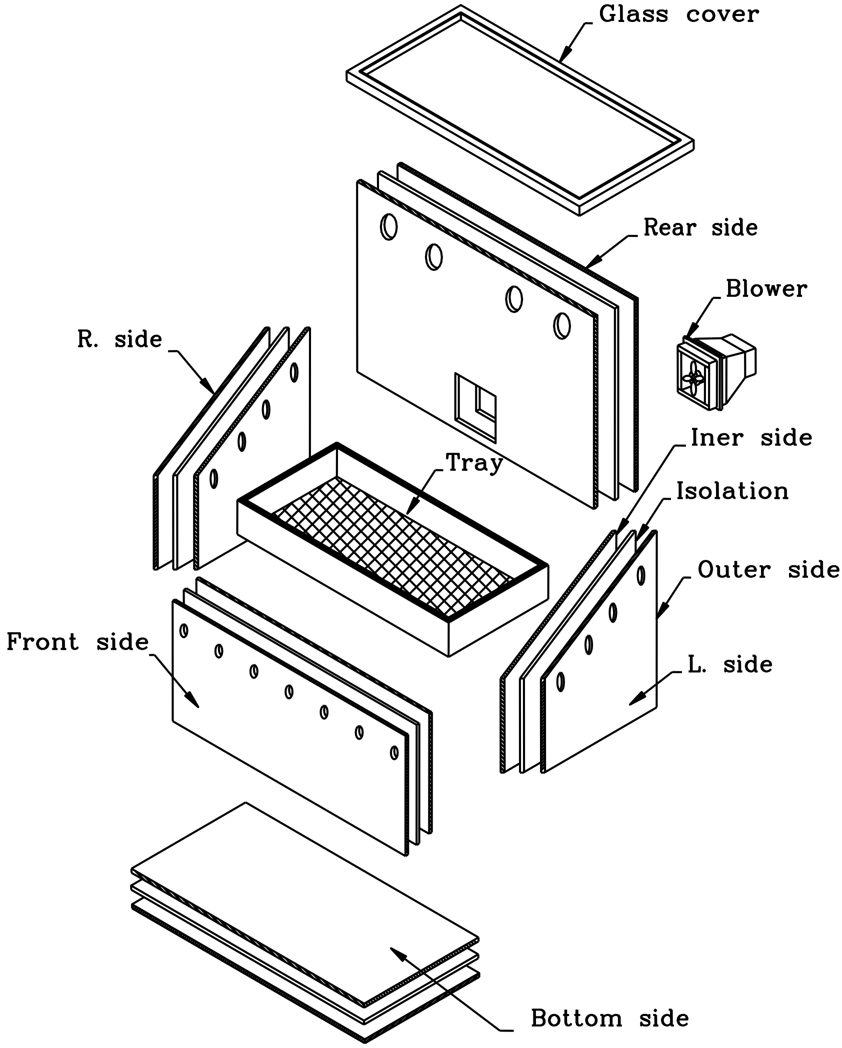


Fig. 2: Isometric and parts of the cabinet dryer.

- **Air velocity:** This was measured during the drying process at both intake and exhaust ports, every hour, to determine the mean values.
- **Humidity:** The relative humidity was measured inside the dryer in the exhaust air every hour.
- **Solar radiation :** The solar radiation data were collected from weather station (Weather Lab Center – Min. of Agr.).
- **Seeds moisture-content :** It was measured every hour before drying process from each sack of cucumber seeds and after drying process. Samples were taken from different layers (bottom, top and middle).

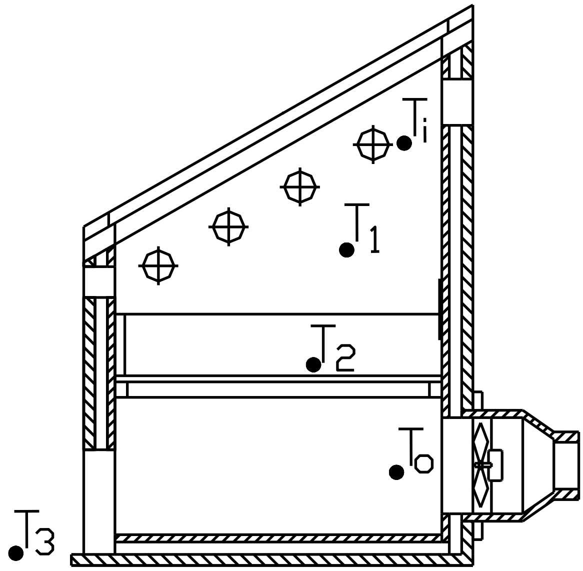


Fig. 3: Distribution of 5 thermocouple points inside and outside drying box.

- **Thermal efficiency:** The thermal efficiency of collector is calculated according to **Sato, 1994**, as follows:

$$\eta_{th} = \frac{m^{\cdot}\ C_p\ (T_1 - T_3)}{A_c\ I_p} \times 100$$

$$m^{\cdot} = a * S * \rho_{air}$$

where:

η_{th} : thermal efficiency of collector, $m^{\cdot}$: mass flow rate of air (kg s^{-1}), C_p : specific heat of air (J kg^{-1} $°C^{-1}$) = 1.047, T_1 : hot air temperature in the cabinet (°C), T_3 : ambient air temperature (°C), A_c : area of collector (m^2), I_p : solar radiation (W/ m^{-2}), a : area of duct (m^2), S : mean air velocity in duct (m/s), and ρ_{air} : specific weight of air (kg/m^3) = 1.2.

- **Drying efficiency:** Solar dryer receives solar radiation and converts it into useful heat to evaporate moisture from the agricultural products. The ratio of the useful heat (Qu) to the incident radiation (QI) is defined as the efficiency of solar drying system (η_d). It can be calculated according to **Awady et al., (1993)** as follows:

$$\eta_d = \frac{Qu}{QI} \times 100$$

$$Qu = m_r\, L + m_P\, C_p\, \Delta T$$

$$QI = A_c\, I_p$$

where :

m_r = mass of moisture removed (kg/h),

L = latent heat of water , taken (539 kCal / kg),

m_P = mass of agricultural product (kg/h),

C_P = specific heat of the agricultural product, taken (0.45 kCal / kg. °C) for the cucumber seeds (Food and Foodstuff, 2013),

ΔT = temperature rise of agricultural product (°C),

A_c =area of collector (m2), and

I_P = solar radiation (W/ m2).

- **Economic feasibility:** The operation cost by using the dryer at optimum condition of cucumber seeds drying was calculated according to a modified form of the equation by **Awady, 1978**. This equation is :

$$C = (P/H)(1/y + i/2 + t + m) + e + (s/144)$$

where:

C: total hourly cost, P: initial price or capital of dryer (L.E.), y: estimated life-expectancy of dryer in years, H: estimated yearly-operating hours, I: investment or overhand rates, t: taxes and overhead rates, m: maintenance and repairs ratio to capital head, e: electric-energy cost (L.E.), s: monthly salaries, and 144: estimated working hours per month.

RESULTS AND DISCUSSION.

1 - Temperature.

Fig. 4 shows the relations between drying time, layer seed thickness and temperature (T_1: hot-air temperature, T_2: seeds temperature and T_3: ambient temperature).

The hot-air temperature ranges were between 39 and 50 °C in days of 13 sunshine hours and solar intensities between 435 and 675 W/m^2 for all the thickness layers. The highest temp. was 50 °C ai the thickness layer 5 mm.

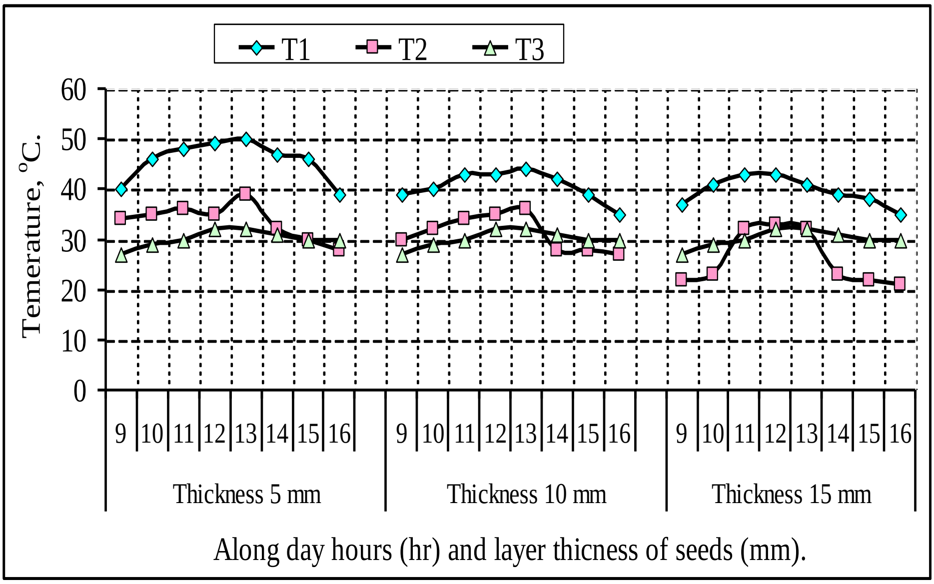


Fig. 4: Effect of drying time and layer thickness of cucumber seeds on the temperature (T_1: hot-air temperature, T_2: cucumber seeds temperature and T_3: ambient temperature).

2 - Relative humidity.

Fig. 5 shows the relations between drying time, layer seed thickness, hot-air temperature "T_1" and relative humidity.

The minimum and maximum relative humidites for air from loaded dryer were 48 and 73 % in days of 13 sunshine hours. The relative humidities for the dryer at load condition were higher due to presence of agricultural product and thickness layers.

3 - Air velocity.

Fig. 6 shows the effect of drying time, layer seed thickness on the air velocity.

The minimum and maximum air-velocity with load were 0.51 and 1.12 m/s in day of 13 sunshine hour at temperature 41 and 50 °C at the same hour. The inlet air-velocity increasing in the dryer by increasing hot temperature and decreasing thickness of layers due to decreasing of air density.

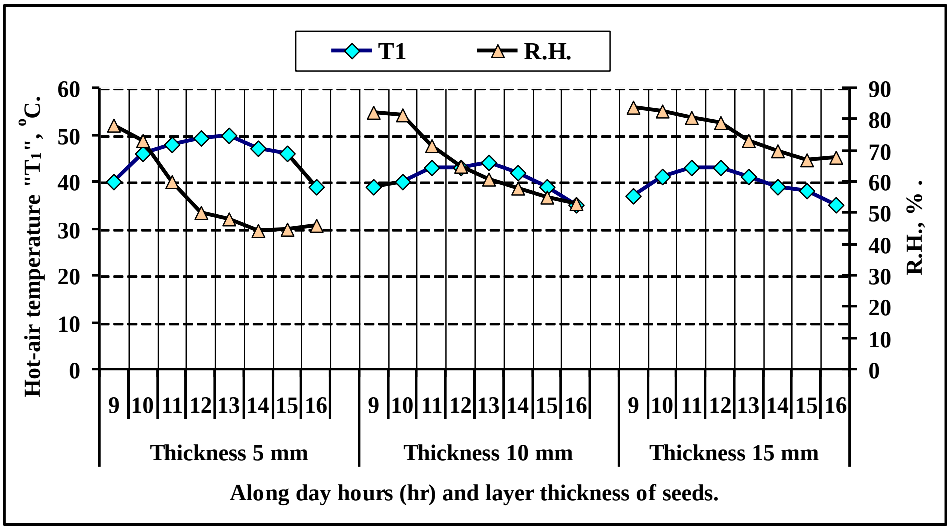
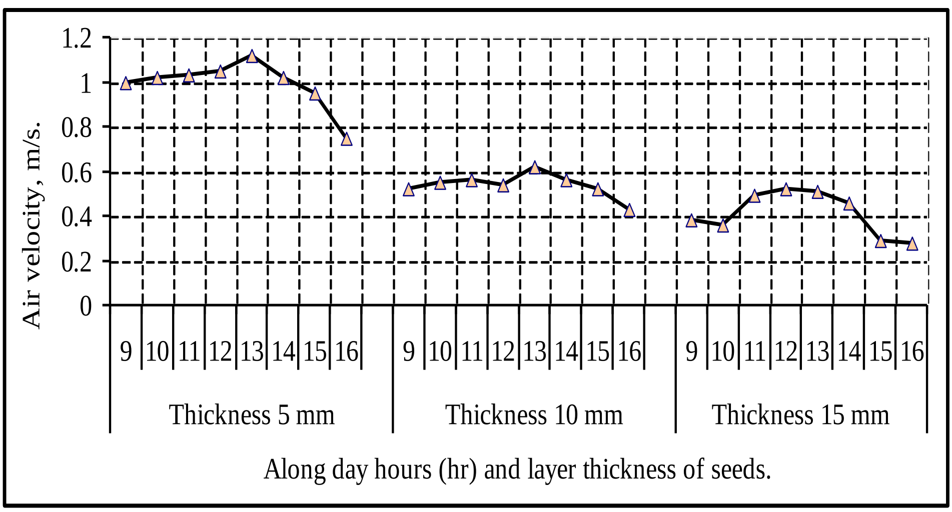


Fig. 5: Effect of drying time, layer thickness of cucumber seeds and drying hot-air temperature "T_1" on relative humidity of air "R.H.".



Figs. 6: Effect of drying time, layer cucumber seeds thickness on the air velocity.

4 - Moisture content.

Fig. 7 shows the relations between drying time, layer seed thickness, Hot-air temperature "T_1" and moisture content.

The moisture content of cucumber seeds in solar dryer decreased by increasing hot-air temperature and increasing of air velocity at the day hours. .

The minimum and maximum moisture contents with load were 11.6 % and 18.9 % in day of 13 sunshine hour at temperature 41 and 50 °C and layer thickness of cucumber seeds 5 mm and 15 mm respectively. Less moisture content was 7.2 % over the day drying at the layer thickness 5 mm.

5 – The thermal efficiency.

Fig. 8 shows the relations between drying time, layer seed thickness, Hot-air temperature "T_1" and thermal efficiency "η_{th}".

The highest thermal efficiency was 63.7 % at hot-air temperature 48 °C. The highest thermal efficiency is due to increase hot-air temperature difference and ambient temperature.

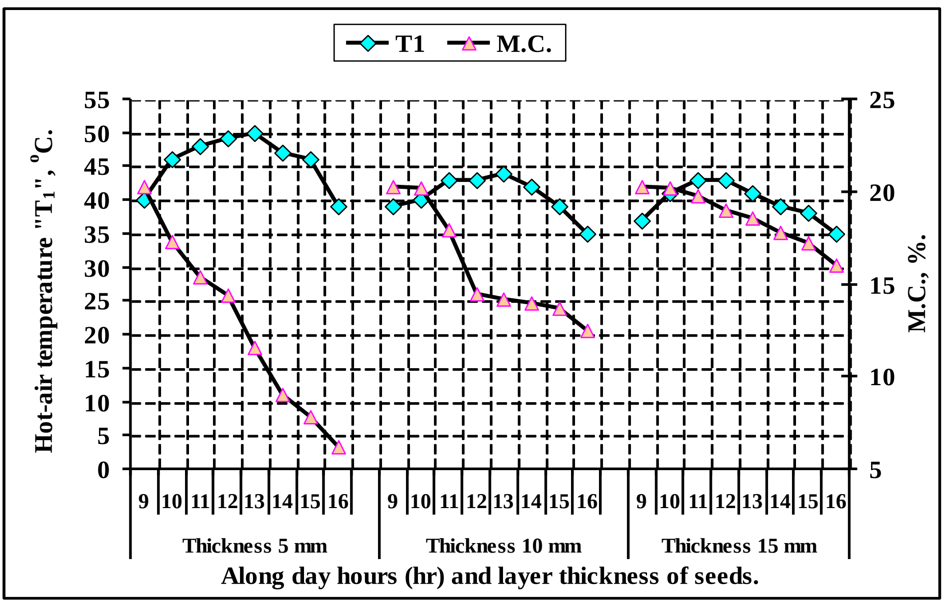


Fig. 7: Effect of drying time, layer thickness of cucumber seeds and drying hot-air temperature "T_1" on moisture content "M.C.".

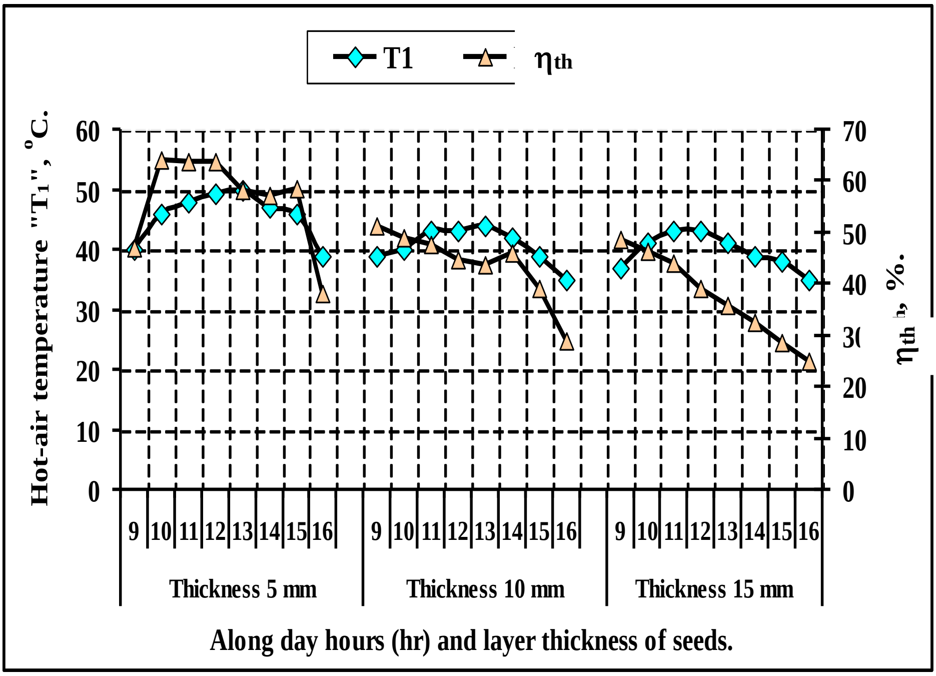


Fig. 8: Effect of drying time, layer thickness of cucumber seeds and drying hot-air temperature "T1" on the thermal efficiency "η_{th}"

6 – Drying efficiency.

Table 1 shows the effect of drying time, hot-air temperature outlet "T_o", hot-air temperature inlet "T_i", and solar intensities "I_P" on drying efficiency "η_d".

It was found that the efficiencies solar drying ranged between 6.4 % at 3 PM and 39 % at 11 AM respectively. Average value is 32.3 % for all-day time.

Solar-system drying efficiency tended to decrease as time passes during the early period of drying. This is due to reduced moisture potential in product. Efficiency remains constant for a while, and drying efficiency starts to catch up again. Catching up may be due to reduced heat input which is denominator of the efficiency ratio while some heat energy is still stored in the product.

Table 1: Effect of drying time, hot-air temperature outlet "T_o", hot-air temperature inlet "T_i", and solar intensities "I_P" on drying efficiency "η_d" (layer seeds thickness of 5 mm).

Time (hr).	T_o, °C.	T_i, °C.	$\Delta T = T_o - T_i$	I_P W/m².	η_d %
9	30	31	-1	524	
10	30	33	-3	563	
11	30	30	0	582	39
12	33	32	1	621	37
13	33	32	1	675	37.2
14	33	33	0	601	42
15	32	31	1	582	6.4
16	30	30	0	435	

7 – Effect of cucumber seeds temperature and moisture content (by using layer seeds thickness of 5 mm) on germination.

Table 2 shows the effect of cucumber seeds temperature and moisture content on germination ratio.

It was found that the germination ratio of cucumber seeds ranged between 97.1 – 97.4 % at different seed drying temperatures and moisture contents. There is no effect of seeds temperature and moisture content on germination ratio because the drying temperature range is acceptable (28 – 39 °C).

Table 2: Effect of cucumber seeds temperature and moisture content on germination ratio (layer seeds thickness of 5 mm).

Time, hr.	M.C., %.	Seeds temperature "T_2", °C.	Germination ratio, %.
9	20.3	34	97.2
10	17.3	35	97.3
11	15.9	36	97.1
12	14.4	35	97.3
13	11.6	39	97.2
14	9	33	97.4
15	7.8	30	97.2
16	7.2	28	97.2

8 - Cost analysis.

The drying costs by using layer thickness of 5 mm was 292 LE/ton.

CONCLUSIONS.

It is recommended to use the cabinet solar grain dryer for small farmer because it gives the hot-air temperature ranges between 41 and 50 °C This dryer gave the minimum drying cost (292 LE/ton of cucumber seeds) by using the layer thickness of 5 mm.

The following variables among conditions of experiments were obtained:

- The minimum and maximum air-velocities with load were 0.51 and 1.12 m/s in day of 13 sunshine hours at temperatures of 41 and 50 °C at the same hour.
- The minimum and maximum moisture contents with load were 11.6 % and 18.9 % in a day of 13 sunshine hours at temperatures of 41 and 50 °C and thickness of 5 mm and 15 mm. The least moisture-content was 7.2 % over the day drying at the layer thickness 5 mm.
- The highest thermal efficiency was 63.7 % at hot-air temperature of 48 °C.
- It was found that the efficiencies of solar drying ranged between 6.4 % at 3 PM and 39 % at 11 AM respectively. Average value was 32.3 % for all-day time
- The minimum and maximum air-velocities with load were 0.51 and 1.12 m/s in a day of 13 sunshine hours at temperatures of 41 and 50 °C at the same hour.
- It was found that the germination ratio of cucumber seeds ranged between 97.1 – 97.4 % at different seeds temperatures and moisture contents.

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الملخص العربى

تجفيف بذور الخيار كتقاوى بالطاقة الشمسية

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يهدف هذا البحث إلى دراسة بعض العوامل المؤثرة على تجفيف بذور الخيار كتقاوى بإستخدام مجفف شمسى يعمل بمروحة لسحب الهواء من اسفل المنتج بأقصى كفاءة ممكنة، وذلك فى مجال تجفيف المحاصيل الزراعية للحفاظ على البيئة من التلوث، و الاستفادة من الأساليب الحديثة في تجفيف الحبوب والبذور لتحسين جودة المنتج في عملية الإنبات.

تتلخص النتائج الرئيسية لهذه الدراسة فى التالى :

- تراوح الحد الأدنى والحد الأقصى لدرجة الحرارة داخل المجفف فى أثناء وجود المنتج بين ٤١ ، ٥٠°س على الترتيب.
- تراوحت الرطوبة النسبية للهواء داخل المجفف فى أثناء وجود المنتج بين ٤٨ – ٧٣ ٪ وسرعة الهواء الداخل للمجفف تراوحت بين ٠,٥١- ١,١٢ متر / ثانية.
- وتم الحصول على أقل محتوى رطوبى للبذور ٧,٢ ٪ على مدار اليوم للتجفيف في طبقة بذور سمك ٥ مم.
- وكانت أعلى كفاءة حرارية ٦٣,٧ ٪ في درجة حرارة الهواء الساخن ٤٨°س .
- وقد وجد أن كفاءة التجفيف الشمسي تراوحت بين ٣٩ ٪ و ٦,٤ ٪ من الساعة ١١ صباحاً حتى الساعة ٣ مساءاً على التوالي. وكان متوسط قيم كفاءة التجفيف لبذور الخيار هي ٣٢,٣ ٪ طوال اليوم.
- وقد وجد أن نسبة إنبات بذور الخيار تراوحت بين ٩٧،١ - ٩٧،٤ ٪ في مختلف درجات الحرارة ومحتويات الرطوبة للبذور.
- تم الحصول على الحد الأدنى من تكلفة التجفيف (٢٩٢ جنيه / طن) بواسطة مجفف مع طبقة سمك ٥ مم.

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