USING SOLAR ENERGY TO DRY EGYPTIAN CLOVER

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ABSTRACT

A solar dryer has been developed and tested for drying high moisture of clover crop (Trifolium alexandrinum) at the Food Technology Research Institute, Agricultural Research Center. The dryer used solar heated air passing by forced convection through a beds of green forage. Three beds were employed to investigate the effect of solar drying of clover on the final quality of hay in comparison with the natural drying method.

The obtained results showed that::

- Clover moisture content decreased from an initial level of 85.67 % (w.b.) to final level of about 12.86 % in 26 and 94 h. for the solar drying and natural sun drying method respectively. This means that solar drying method could reduce the required time for drying clover hay by about 72 % in comparison with sun drying method.

- The thermal efficiency of the dryer approached about 26 %.

- The chlorophyll A and B and carotenoid content of the solar dried clover were slightly higher for solar dried samples in comparison with sun dried samples. Meanwhile the percentage of crude protein, fiber content and ash content increased by 10.18, 3.22 and 4.8 % respectively.

INTRODUCTION

In Egypt, feedstuffs for livestock are insufficient for adequate feeding, where about 13.000.000 tons total digestible nutrients (TDN) per year are required, yet only 9.6 million ton are annually produced providing 75 % of livestock energy requirements and unequal distrution of green forages around the year, specially in summer, where the available feeds (mainly straw and little concentrates) cover only 39 and 37 % of animal requirements for energy and protein, respectively **(Abd El-baki et al., 1998)**. Clover is considered of the most important forage crops in Egypt.

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It is the main source of total digestible nutrients (TDN) for animal feeding. Clover hay is mostly obtained from the third cut of clover crop, when the atmospheric conciliations are quite suitable for converting it to hay by natural drying. The commodity in Egypt is sun dried on ground in the field. During this process the plants loose a high percentage of its leaves which contain the valuable nutrients and crude protein. It was surprising that a questionnaire showed a need to develop this process beside the need for developing other drying processes. Therefore, using of artificial and solar drying methods may help in minimizing the nutrient and crude protein losses usually occur in the ordinary sun drying usually took place by farmers. Egypt is one of the countries, which has solar energy in abundance. It lies within the tropical and sub-tropical regions. It has a value of about 2.2 to 9.4 kW solar energy per square meter per day, and sunshine duration per year extended to about 3000 to 4000 hours **(Abd El-latif, 1989, Awady et al., 1993).** Currently, considerable research and projects are being undertaken in the use of solar energy for drying agricultural crops. Due to the steep increase in the price of energy, alternative energy sources have become more attractive. Solar energy is one of these alternative energy sources. The solar energy applications are dependent upon the development of systems that have optimum performance, good reliability and economic characteristics that compare favorably with conventional energy systems and other energy sources **(Abd El-latif et al., 1993)**. Drying may be achieved by either natural or artificial drying methods. However, there is no easy formula to decide weather the natural or the artificial drying method is profitable for use. In Egypt sun drying is still the most common method to preserve agricultural products. Due to the lack of sufficient preservation methods, farmers have to spread the crop to be dried in thin layers on paved grounds or mats where they are exposed to sun and wind. Considerable losses may occur during natural sun drying due to various influences of rodents, birds, insects, rain and micro organisms **(Kamel, 1999)**. To overcome the existing preservation problems of agricultural crops in Egypt, the introduction of solar dryers seems to be a promising way since the available amount of solar energy is sufficient to provide the heat requirements of the small dryers. The solar drying system for crops drying depends on a temperature rise of only a few degrees in order to dry the crops in an extended period of time. Most of the solar drying systems depend on a forced or natural convection air for reducing the moisture content of the product **(Tayel and Wahby 1989)**. Natural convection type solar dryers offer a means of protecting the crop during the drying process. Also the drying time can be reduced compared with natural drying **(El-Shiatry et al., 1991)**.

Ayensu (1997). designed a solar drying system on the principle of convection heat flow. The dryer was constructed from local materials(wood, metals and glass sheet) and used to dry food crops (cassava, papper, okra ground nuts, etc..). The obtained results revealed that, takes about open air sun-drying twice as much time compared to the convective heat flow solar dryer. **El-Kholy, (2003)** mentioned that for rough rice drying in natural convection solar dryer, drying started simultaneously at the top and bottom of the bed while the middle layer dried slowest. The recorded drying times for solar drying with stirred and unstirred bed were 22 and 26 h. respectively as compared with 46 h. for natural sun drying in open mats. **Kassem et al. (2006)** investigated the effect of solar energy and other drying methods on quality of some plants. The required energy to remove 1 cm^3/g of water from Lemongrass (cymbopogon citrates), Oregano (Origanum vulgare), Spearmint (Mentha virdis) and Peppermint (Mentha pepperita) were 200.4, 176.7, 209.2 and 202.1 $watt/m^2$ respectively. The efficiency of dryer heat exchange were 91.6 %, 87 %, 91.1 % and 92. % for Lemongrass (cymbopogon citrates), Oregano (Origanum vulgare), Spearmint (Mentha virdis) and Peppermint (Mentha pepperita)

The present study aims to develop and evaluate a forced convection solar dryer for drying freshly harvested clover. The evaluation basis included, drying time, thermal efficiency of the dryer and final quality of the dried clover.

MATERIALS AND METHODS

A) Materials:

The objective of the present work was to investigate the possibility of drying Egyptian clover (Trifolium alexandrinum) using forced convection solar dryer, under Egyptian climatic conditions.

Samples of clover with initial moisture content of 85.67 % (w. b.) were obtained from the experimental farm of Horticulture Research Institute during harvesting season of 2009 (March-April, 2009) to investigate solar drying of green clover in comparison with the traditional sun drying method. Moisture content, bulk temperature, air temperature and relative humidity, chlorophyll A and B, crude protein fiber content and caroten of Egyptian clover were measured. The properties of clover samples were analyzed at the laboratory of Food Technology Research Institute, Agricultural Research Center.

1-Solar dryer specification and description:

In this investigation a forced convection solar dryer was constructed and tested at the Food Technology Research Institute, Agricultural Research Center, Ministry of Agriculture, Giza, Egypt. The solar drier consists of drying chamber, solar collector, and suction air blower as shown in fig. 1. The overall dimensions are 315 cm for height, 100 cm for width, and 305 cm for length. Details descriptor of the dryer parts can be presented as follows:

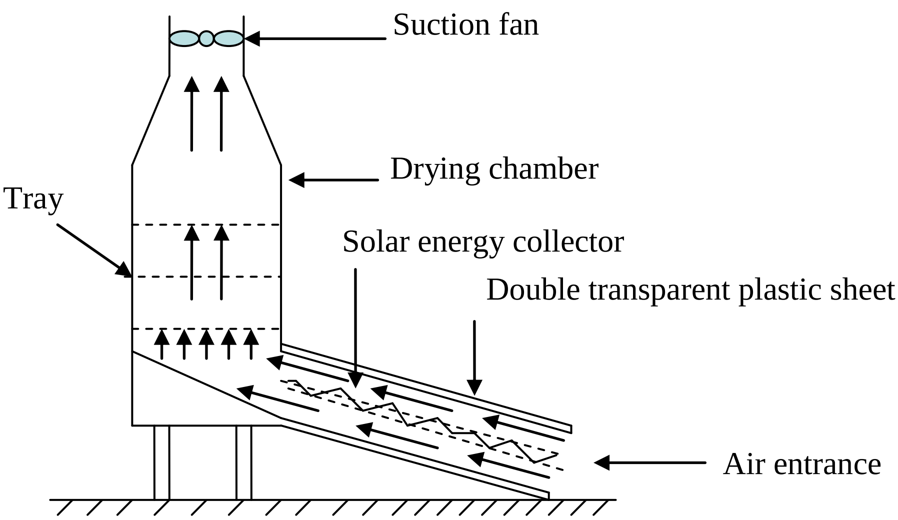

Fig. 1: Sketch of the forced convection solar dryer.

Drying chamber:

A drying chamber with charging and discharging door was made of iron frame covered with high transmittance plastic sheets to help for collecting the solar energy. The drying chamber consisted of three beds vertically arranged in sequence of (top, middle and bottom). The dimensions of each bed were 300 cm for length and 100 cm for width and they were made of perforated galvanized iron sheets with thickness of 1.5 mm. The distance between beds was 25 cm.

A conical frame covered with transmittant plastic sheet was also fixed at the top of the drying chamber to allow for air discharge using an axial flow fan.

Solar collector:

The solar collector consists of double transmittant plastic sheet fixed on an iron frame. A corrugated heat absorption plate made from 1.5 mm thick black painted aluminum sheets was fixed at the center of the solar collector frame to increase the absorption area. The collector was attached from one side to the vertical drying chamber at slope of 30^0. The dimensions of the collector were 305x160x20 cm.

Air suction fan:

The ambient air was succed from the solar collector using an axial flow fan fixed at the top of the conical part of the drying chamber. The fan assembly consists of six radial blades, driven by electric motor of 1.5 hp (1.125 k.W) at 1500 r.p.m.

2- Test procedure and Measurements:

2-1 Test procedure:

Freshly harvested Egyptian clover (Trifolium alexandrinum) was used for the experimental work. The initial moisture content of the clover samples was 85.67 % (w. b.). The experimental work was carried out during (March-April, 2009). Prior to each experimental run, an equal amount of clover samples (about 90 kg) was transferred to the dryer and spread over the beds surfaces at thickness of about 15 cm. Similar amount of clover samples was spread on the ground beside the tested dryer as a control sample and it was treated in the traditional method of clover drying usually practiced by the farmers. For the solar drying method, the suction fan was operated at the maximum air flow rate of the fan reflected in an air velocity of 2.75 m/s. The clover moisture content, bulk temperature, air temperature and relative humidity inside and outside the dryer were measured at two hour intervals for the solar dryer and at 6 hour intervals for the natural sun drying method, while the chemical analyses of the clover sample were conducted at the start and the end of each experimental run.

2-2 Measurements:

Moisture content:

The moisture content of clover samples was measured by using a hot air drying oven set at 105 ^{o}c until constant weight as recommended by **(Abd El-latif and Helmy, 1993)**. The moisture content was expressed in wet basis unless otherwise specified.

Solar energy measurements:

The solarimeter with a portable recorder model (Y3057-11) was employed to measure the solar energy flux incident on a horizontal surface outside the dryer.

Air flow rate:

A hot wire anemometer model (Kanomax 24-6111) was used to measure the air velocity at different points to represent the air movement through the dryer.

Bulk clover and air temperatures:

The universal measuring system (Model Kaye Dig. 12) connected to 16 scanning box with thermocouples was used to hourly measure the bulk temperature of clover and the air temperature at different points inside and outside the dryer.

Air relative humidity:

The relative humidity meter (Model HN-K) was used to measure the air relative humidity at adjacent points of temperature measurements.

3- Chemical analysis:

Chlorophyll A, B and carotenoids:

The photosynthetic pigments were extracted from the dried clover samples by pure acetone according to **(A.O.A.C., 1970)**. The optical densities were measured spectrophotometrically using (Spectronic-20) at wave lengths 662, 6444 and 440.5 um. The pigment concentrations were calculated as follows:

Chlorophyll, A= (9.784 x E662) – (0.99 x E644) mg/L **---------(1)**

Chlorophyll, B= (21.426 x E644) – (4.65 x E662) mg/L **---------(2)**

Carotenoids = (4.695 x E440.5) – (0.268 "chl. A+B") mg/L **---------(3)**

The pigments content were then expressed in mg/g dry weight of the forage.

Crude protein (C.P):

Crude protein was determined by micro Kjeldahl method of **(A.O.A.C., 1970)**.

Ash content:

Ash was determined using furnace at 600 ^{o}c for one hour according to **(A.O.A.C., 1970)**.

RESULTS AND DISCUSSION

1-Moisture content:

Figs. (2) and (3) present the change in moisture content as related to drying time during solar and sun drying methods of clover respectively.

As shown in figs. (2) and (3) clover moisture content decreased from an initial level of 85.67 % (w.b.) to final level of about 12.86 % in 26 h. for the solar drying method and in 94 h. for the natural sun drying method. This means that solar drying method could reduce the required time for drying clover hay by about 72 % in comparison with sun drying method. Meanwhile, as shown in fig. (2) the bottom bed facing the air entrance from the collector showed higher drying rate followed by the top bed, while the middle bed was the slowest in drying rate. The higher drying rates of the bottom and the top beds in comparison with the middle bed are attributed to exposure of the bottom bed directly to the heated air blown from the solar collector and the exposure of the top bed to the solar flux incident through the upper conical part of the dryer.

In general, the mean values of moisture content of the three beds, at any time would sufficiently represent the moisture content of clover.

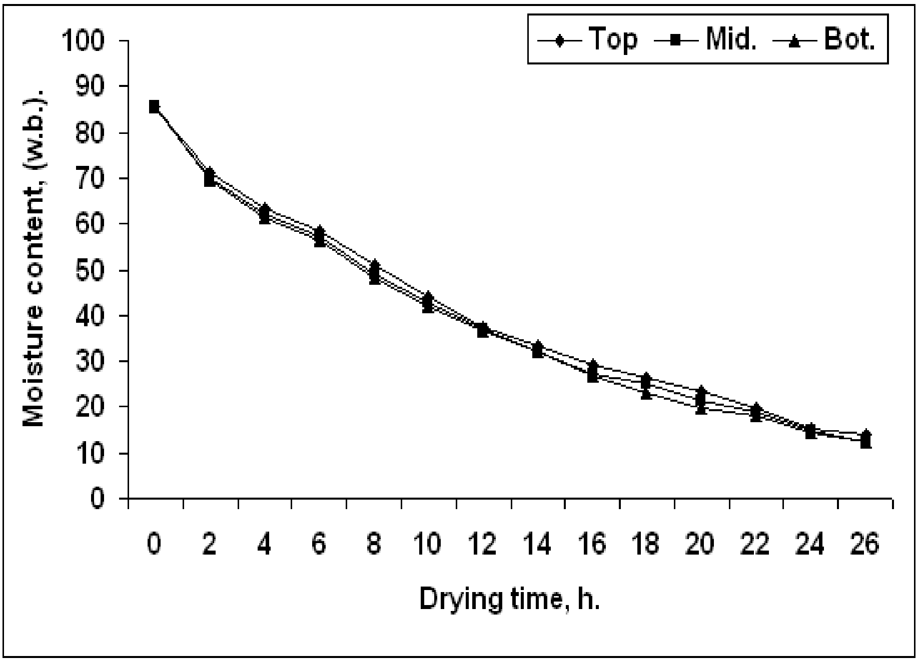

Fig. 2: Clover moisture content as related to drying time during solar drying of clover.

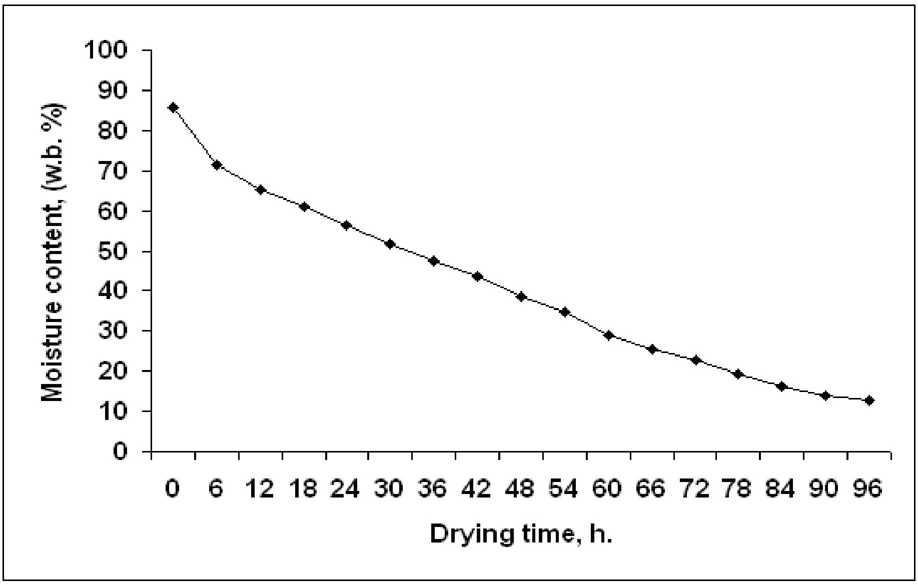

Fig. 3:Clover moisture content as related to drying time during natural sun drying of clover.

2- Clover bulk-temperature:

Figs. (4a) and (4b) present the change in clover bulk temperature as related to drying time for the solar and the natural sun drying methods respectively. As shown in figures (4a) and (4b), the average clover bulk temperatures were 35.44, 35.5 and 36.2 ^{o}c for bottom, middle and top beds respectively, while it was about 28.65 ^{o}c for the natural sun drying method. The above-mentioned results revealed that for both drying methods, the change in clover bulk-temperatures were affected by the temperature of drying air and the changes in clover moisture-content during the drying process.

3- Air temperature and relative humidity:

Figs. (5) and (6) present the air temperature and relative humidity profiles at different positions across the solar dryer. The air relative humidity inside the dryer was found to be a very important factor affecting the drying rate of clover.

As shown in fig. (5) the ambient air temperature (out-side) the dryer fluctuated between 26.15 and 32.21 ^{o}c with an average of 27.15 ^{o}c, while the air temperature inside the dryer fluctuated between 32.6 and 42.8 ^{o}c with an average of 38.02 ^{o}c.

As shown in fig. (6), the air relative humidity outside the dryer fluctuated between 57.6 and 67.2 % with an average of 62.87 %, while the air relative humidity inside the dryer fluctuated between 49.6 and 52.8 % with an average of 51.2 %.

These results mean, that the solar collector of the dryer could increase the average air temperature inside the plenum chamber of the dryer by about 10.87 ^{o}c and decrease the air relative humidity by about 11.67 %.

4- Solar radiation:

To study the thermal performance of the solar dryer, it was imperative to consider the amount of solar radiation flux incident during the drying process. The hourly average solar radiation available during first and second days of experiments is illustrated in fig. (7). The hourly average available solar radiations were about 605 and 658 W/m^2.h. for the first and second days of experiments respectively. The figure also shows that the solar radiation gradually increased from sunrise till it reached the maximum value at noon, it then decreased gradually until reaching the minimum value at sunset.

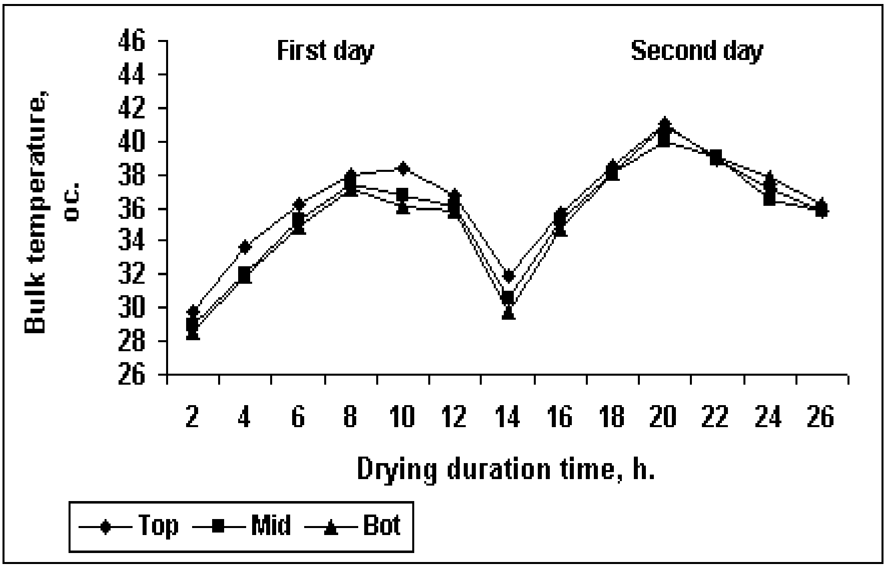

Fig. 4a: Average bulk temperature as related to drying duration time for the solar drying method.

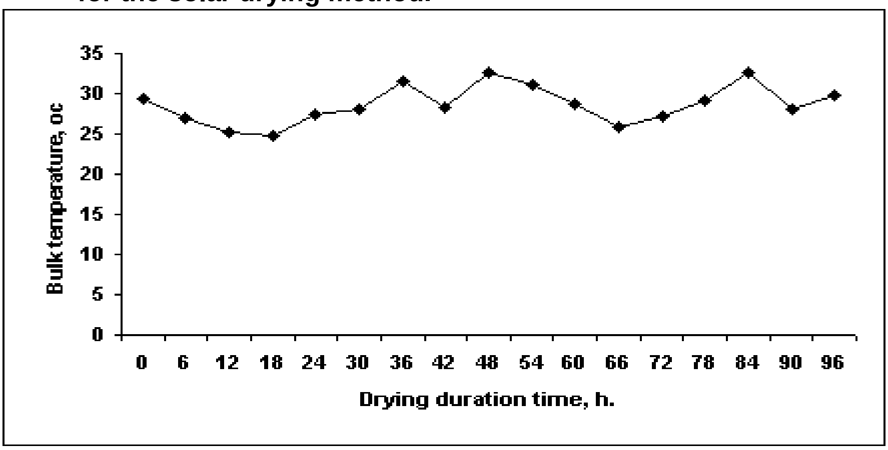

Fig. 4b: Average bulk temperature as related to drying duration time for the sun drying method.

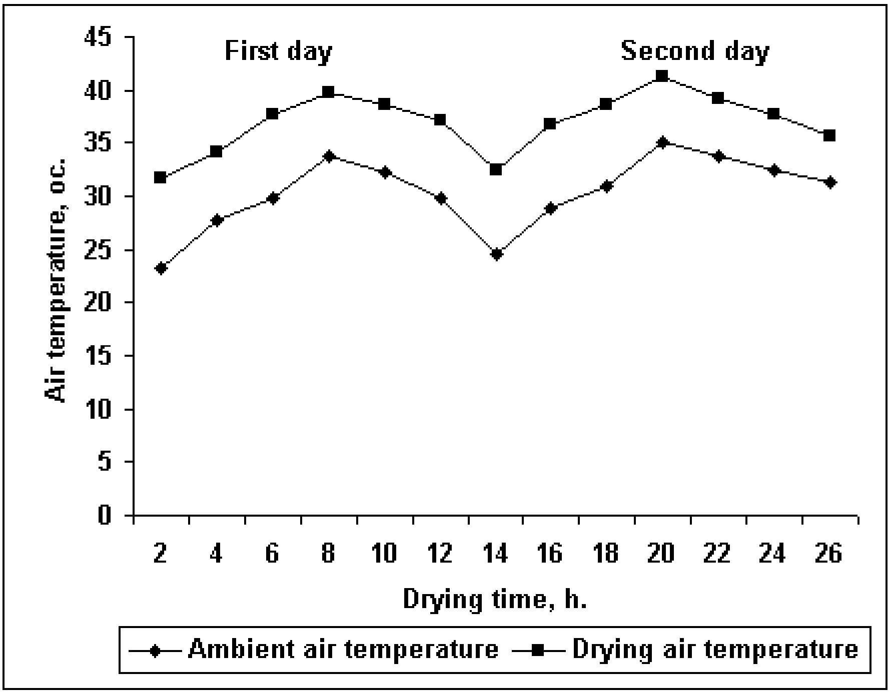

Fig. 5: Temperature of air inside and outside the dryer plenum chamber.

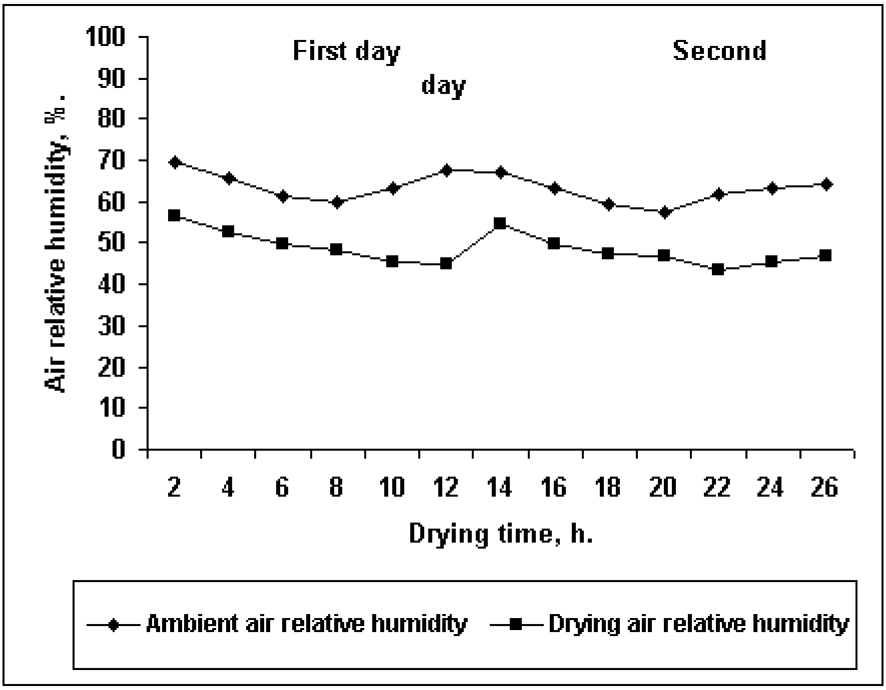

Fig. 6: Relative humidity of air inside and outside the dryer plenum chamber.

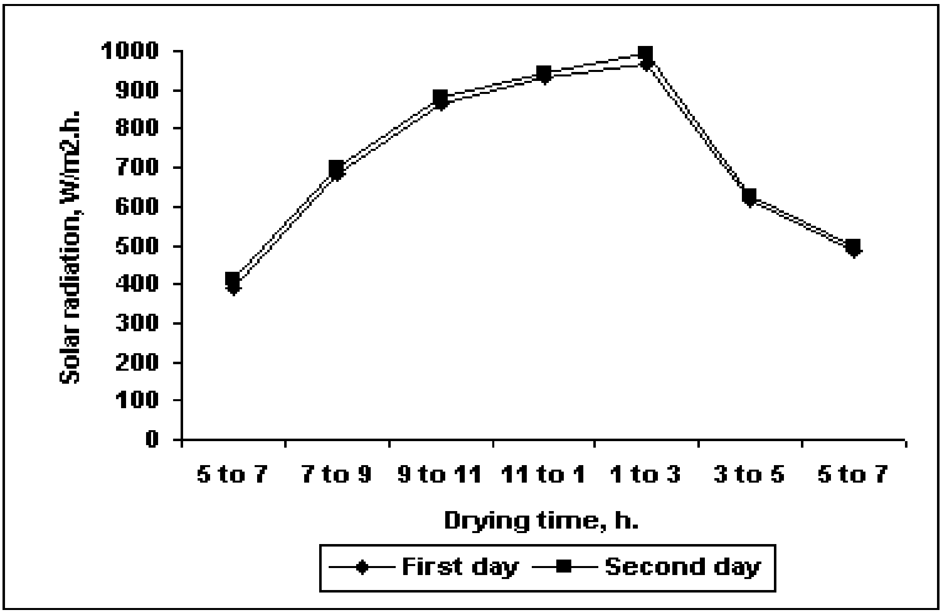

Fig. 7: Solar radiation flux incident as related to drying time.

5- Thermal efficiency of the dryer:

Thermal efficiency of the dryer was considered as the heat of evaporation for the moisture removed from the clover divided by the heat gained by the solar radiation incidient on the dryer during the drying process. The equation of (**Jindal and Reyes, 1987**) was used for thermal efficiency calculation as follows:

$$\eta = \frac{W_w \; x \; L}{Q \; x \; 3600} \; x \, 100 \quad \text{---------------------------(4)}$$

Where:

η = thermal efficiency, %,

W_w= water evaporated from the clover (65.529 %),

L = latent heat of vaporization of water, (2668.25 kJ/kg) and

Q = total energy flux indcident on the dryer during the drying period, (185.62 kW).

The results show that the overall thermal efficiency of the dryer is about 26.16 % during the period of experimental work.

6- Clover final quality (Chemical analysis):

Chemical analysis of clover samples dried by sun and solar drying methods are represented in table (1).

Table (1): Chemical analysis of dried clover using sun and solar drying methods

Items	Chlorophyll		Crude protein (%dry weight)	Fiber content (% dry weight)	Carotenoids (mg/g)	Ash content (% dry weight)
	A	B				
Sun drying	0.525	0.389	11.69	22.80	0.135	12.42
Solar drying	0.773	0.475	21.87	26.02	0.249	17.22

As shown in the table, chlorophyll A and B and carotenoid content of the solar dried clover were slightly higher for solar dried samples in comparison with sun dried samples. Meanwhile the percentage of crude protein, fiber content and ash content increased by 10.18, 3.22 and 4.8 % respectively.

The obvious variation in percentage of crude protein between the solar and the natural sun drying method can be attributed to the loss of leaves which contain the highest percentage of crude protein during the sun drying method. These results are in agreement with those obtained by **(Abd El-latif and Helmy, 1993)**.

CONCLUSION

The obtained data showed that:

1- Clover moisture content decreased from an initial level of 85.67 % (w.b.) to final level of about 12.86 % in 26 and 94 h for the solar drying and natural sun drying methods respectively. This means that solar drying method could reduce the required time for drying clover hay by about 72 % in comparison with sun drying method.

2- The thermal efficiency of the dryer approached about 26 %.

3- The chlorophyll A and B and carotenoid of the solar dried clover were slightly higher for the solar drying than the sun dried samples. Meanwhile the percentage of crude protein, fiber content and ash content increased by 10.18, 3.22 and 4.8 % respectively.

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الملخص العربى

استخدام الطاقة الشمسية لتجفيف البرسيم المصرى

احمد فؤاد عبدالمطلب، محمد طة عبيد، بهاء الدين حميدة عبدالموجود

هذا البحث يهدف الى تجفيف البرسيم فى الفترات الحرجة من انتاجة باستعمال المجففات الشمسية مع مقارنتها بالتجفيف الآرضى العادى من حيث المحافظة على القيمة الغذائية والبيولوجية لمحصول البرسيم المصرى.

<u>وأظهرت النتائج المتحصل عليها مايلى:-</u>

-أظهرت نتائج التجارب الحقلية أن الفترة الزمنية اللازمة لتجفيف البرسيم الأخضر من المحتوى الرطوبى الابتدائى (٨٥,٦٧ %) الى المحتوى الرطوبى النهائى (حوالى ١٢,٨٦ %) قد وصلت الى حوالى ٢٦ ساعة، ٩٤ ساعة باستخدام المجفف الشمسى والطريقة التقليدية على الترتيب. وهذا يعنى بأن طريقة التجفيف باستخدام المجففات الشمسية يمكن أن تخفض الزمن المطلوب لتجفيف البرسيم الأخضر بحوالى ٧٢ % بالمقارنة بالطريقة التقليدية.

- وصلت الكفاءة الحرارية للمجفف الشمسى الى حوالى ٢٦ %.

- أظهرت نتائج التحليل المعملى لخصائص جودة محصول البرسيم الأخضر فى نهاية عملية التجفيف ارتفاع جودة البرسيم المجفف باستخدام المجفف الشمسى بالمقارنة بالطريقة التقليدية. حيث نجد أن عملية تجفيف البرسيم بالمجففات الشمسية تحافظ على أعلى نسبة من الآوراق فى الدريس الناتج بعكس التجفيف الطبيعى الذى يؤدى فقد الآوراق التى تحتوى على أعلى نسبة من البروتين، حيث ارتفع البروتين الخام والآلياف والمحتوى الرمادى للبرسيم فى حالة استخدام المجفف الشمسى عند مقارنتة بالطريقة التقليدية.

باحث أول بمعهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – الدقى -الجيزة – مصر.