EFFECT OF SOLAR ENERGY AND OTHER DRYING METHODS ON QUALITY OF SOME MEDICINAL PLANTS

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ABSTRACT

The present study was carried out in the two growing seasons (2002-2003) to investigate the effect of solar energy and other drying methods on quality of some medicinal plants. The solar drying (±35°C), natural drying (sun drying ±30°C) and artificial drying (in oven at 45°C) are the three different systems used for drying lemongrass (Cymbopogon citratus), oregano (Origanum vulgare), spearmint (Mentha virdis) and peppermint (Mentha pepperita). The three systems have been constructed and installed at the Agricultural Engineering Research Institute. The results showed that the moisture loss (%) from the four medicinal species was the highest following the oven drying method. The moisture loss (%) was almost the same in case of solar and natural drying methods. The contrary was observed regarding the essential oil content of dried herbs the oven drying resulted in the lowest essential oil content compared with the other methods. Regarding the color of the products, i.e., their chlorophyll contents, were higher due to solar or natural drying than in case of oven drying. The required energy to remove 1cm^3/gm of water from lemongrass, oregano, spearmint and peppermint were 200.4, 176.7, 209.28 and 202.1 watt/m^2 respectively. The efficiency of dryer heat exchanger was 91.6%, 87%, 91.1%, and 92% for lemongrass, oregano, spearmint and peppermint, respectively.

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INTRODUCTION

The post harvest processes are of crucial importance in case of medicinal and medicinal plants. Among these processes, drying determines the quality of the final products in terms of feature and active ingredients content. The natural drying although easy and cheep, however, it is time consuming and does not guarantee clean product. Therefore, several investigations have been, and still, carried out to find the most proper drying methods. Also, due the ever increasing prices of fuel, efforts have been directed towards the use of solar energy in drying.

Ozguven and Tansi (1999) found that in trials on Majorana hortensis (origanum majorana) in Cukurova, Turkey, the highest fresh (1077.2 kg/day) and dried herb yields (492.9 kg/day) and essential oil yield (77.7 litres/day) were obtained at the post-flowering stage. The main components of the oil were gamma-terpinen, P-cymol and terpineol.

Ozguven and Kirici (1999) reported that the total fresh herbage, dry herbage and dry leaf yields in adana ranged from 512.5 to 4053.8 kg/day. 116.5 to 1051.8 kg/day and 34.6 to 431.1 kg/day respectively. M.piperita cv. Bulgaristan 36 gave the highest herbage yield. Total fresh and dry herbage and dry leaf yields in pozant: ranged from 115.6 to 678.1, 57.6 to 322.5 and 17.0 to 133.0 kg/day, respectively. Essential oil contents varied between 1.57% and 6.29?% and were higher than values in the pharmacopoeia because of the high temperature. M.arvensis had the highest menthol contents (66.2 – 72.29%) in both years and locations. The menthol contents of M.piperita cultivars ranged from 6.23% to 40.47%. The carvone content in oil of M.spicata subsp. Spicata ranged from 39.38% to 69.41%.

Seruga and Magdic (1998) pointed that mathematical models were developed to calculate the incoming solar radiation on a solar collector and the amount of this energy which can be used, via a heat exchanger, for preheating drying air. Fuel savings of the main heat source (light oil) was calculated according to waste air temperature after passing through the drier for Camomile (Chamomilla recutita) and mint (Mentha). Results showed that energy savings of 41 – 53% could be obtained for maximum air flow and 56 – 59% for minimum air flow.

Yaskonis and Jaskonis (1990) studied that in 3-year trial with Mentha piperita, 85.5% of the planted rhizomes rooted. The cultivar was vigorous and productive. In the 1st year it produced a dry leaf yield of 39 h kg/ha, and in the 2nd and 3rd years yield of 35.8 and 20.0 h kg/ha, respectively. The essential oil content of the leaves was 2.79% in the 1st year and 2.99 and 3.10% in the 2nd and 3rd years, respectively. The cultivar is recommended for growing commercially in Lithuania.

Chalchat and Michet (1997) indicated that the results of the studies showed that harvesting at the end of flowering yields an oil richer in menthol harvesting twice a year is possible at the location studied, batches of different qualities can be obtained depending on harvesting time, and predrying of peppermint herbage prior to distillation does not affect chemical composition and allows steam distillation of greater amounts of plant material.

Nedkov and Georgiev (1991) said that M.piperita is a major essential oil plant. Dried leaves are used for various blends of tea which are reputed to have medicinal properties.

Patel and Valand (1994) showed that a number of dried plant materials were tested for their efficacy in protecting stored wheat against Rhyzopertha dominica. The 2 most effective materials were dried mint leaves (Mentha spicata) and powdered seeds of custard apple (Annona squamosa).

Hazra et al (1990) indicated that drying in direct sunlight was 24% less steam than required during distillation.

Buckenhuskes et al. (1996) said that Origanum Majorana harvested in May-July1992 near Gizeh and Benha in Egypt at predried for 6 h in the field were dried in solar greenhouse dryer. Air was sucked absorbing material. The detection of airflow was reversed at the southern eaves and directed over the drying boxes. The drying capacity of this solar greenhouse was up to twice that of traditional sun drying, a daily average of 8 Kg dried shoots/m^2 of drying area being possible. The shoot essential oil content after drying was 98% of that initially. Microorganism count were 50% of those on traditionally dried material.

Paakkonen et al. (1999) carried out some drying experiment on Mentha piperita, Agastache Foeniculum, Petrosselinum crispum and Angelica archangelica (grown in Finland) were conducted using near infrared drying, operating at a product temperature of 35 – 50 °C. and oven drying at 40 °C. The essential oil content, composition and residual water content of the dried herbs were determined. The microbiological quality of fresh and dried material was determined for total bacterial count and coliforms, moulds and yeasts. Fresh material had very poor microbiological quality. Drying method did influence microbiological quality, but no trends were determined. It was concluded that infrared radiation has potential for drying herbs since it is gentle and shortens the processing time compared with oven drying. However, the quality of the fresh material was the major factor determining the quality of dried herbs.

The medicinal plant loss a great quantity of oil content and chlorophyll content during the drying processes for that the research investigate the effect of solar energy and other drying methods on quality of some medicinal plans.

MATERIALS AND METHODS

This experiment was conducted during the two growing seasons; (July 2002 and July 2003). Three drying systems have been designed, constructed and installed at the Agricultural Engineering Research Institute. These methods were compared for drying the fresh herbs of some medicinal plants i.e., lemongrass (*Cymbopogon citratus*), oregano (*Origanum vulgare*), spearmint (*Mentha virdis*) and peppermint (*Mentha pepperita*). These species were cultivated in the Experimental farm belonging to the Medicinal and Medicinal Plant Research Department, Horticulture Research Institute Giza governorate . The chemical analyses have been carried out in the laboratory of the same department. The three used drying systems were solar drying (±35°C), natural drying (±30°C), and artificial drying (oven at 45°C) systems.

a- The solar dryer (Figure 1&2) contained a small gable even Span greenhouse of 2m long and 1m width, and 2.25m height made from 3 x 3 cm iron angle, the roof angle is 31°. The lowest part isolated with isolation material (1.5 inch foam) and the upper part contained a heat changer made from galvanize water iron pipe (0.5 inch diameter) and it is connected with a half inch electric water pump connected with a 200 liter tank to circulate the water from the storage tank to the parabolic solar heater which made from a 1.2m diameter Aluminum dish with 2.1 m^2 area as an absorber plate and fixed around it a 0.12mm diameter copper pipe then, it was isolated by fiber material and covered by wooden box curried by iron currier. The parabolic solar collector connected with another half inch electric water pump and eclectic timer to control the pump timing. Air fan with 0.4m diameter to push air through the heat exchanger with hot water from the storage tank passing through the galvanized water pipe at the same time, so the hot air pass through the fresh green plant material, on a 1m x 2m screen tray by convection air flow to remove the moisture. The dryer greenhouse temperature controlled by electric thermostat adjusted at 35^{o}C, connected with the fan and water pump, which connected with the galvanized water pipe heat exchanger, to push heated water and ambient air when the dryer temperature decreased below 35^{o}C. Electric humidistat adjusted at 40% connected with 15 cm diameter fan to control the relative humidity when it raised than 40%.

b- The second system is a natural dryer made of 1 x 2 m screen tray sited under the sun shin (±30^{o}C).

c- The third system is an oven dryer adjusted at 45^{O}C.

Abdellatif and Lieth (1992) developed a computer model of glasshouse planted ornamental crops in order to assess heat requirements for maintaining optimum ambient air temperature glasshouse. They showed that ventilation and infiltration losses are negligible in a wall-constructed greenhouse. The steady state energy balance can be computed from the following equation :-

$$Q_{load} - Q_{loss} - Q_{gain} = 0 \qquad (1)$$

$$Q_{load} = Q_{loss} - Q_{gain}, \text{ Watt} \qquad (2)$$

$$Q_c = U_o A (T_{ai} - T_{ao}), \text{Watt} \qquad (3)$$

$$Q_{inf} = m_o C_p (T_{ai} - T_{ao}), \text{Watt} \qquad (4)$$

Where :-

Q_{gain} = Solar heat gain, (W/m^2).

Q_{loss} = Heat losses, (W/m^2).

Q_{load} = Heat load, (W/m^2).

Q_{inf} = Heat losses due to cold air infiltration (through the structure) from outside to inside of the greenhouse, (W/m^2).

U_o = Overall heat transfer coefficient, (W/m^2/ ^oC).

A = Wall surface area, (m^2).

C_p = Specific heat of air, (J/kg/ ^oC).

m_o = Mass flow rate of air, (kg/h).

T_{ai} = Inside ambient temperature, (^oC).

T_{ao} = outside ambient temperature, (^oC).

The solar heat gain can be estimated by the following equation (ASHRAE, 1983):-

$$Q_{gain} = L_s A_f \lambda$$

Where:-

L_s = Solar radiation flux incident, (W/m^2)

A_f = Floor surfaces area of greenhouse, (m^2)

λ = Effective transmittance of the greenhouse cover, decimal.

Solar dryer receives solar radiation and convert 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_s). It can be calculated according to **Awady et al. (1993)** as follow:-

$$\eta_s = \frac{Q_u}{Q_I} \times 100 \qquad (5)$$

$$Q_u = m_r L + m_p C_p \Delta T$$
$$Q_I = ACI_p \qquad (6)$$

Where:-

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

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

m_p = Mass of agricultural product, (kg/h),

C_p = Specific heat of the agricultural product, taken (0.44 kCal/kg.^oC) for the paddy **(Hall, 1980),**

ΔT = Temperature rise of agricultural product, (^oC),

Ac = Area of collector, (m^2)

Ip = Solar radiation, (W/m^2).

Fig. 1 : The drier solar system

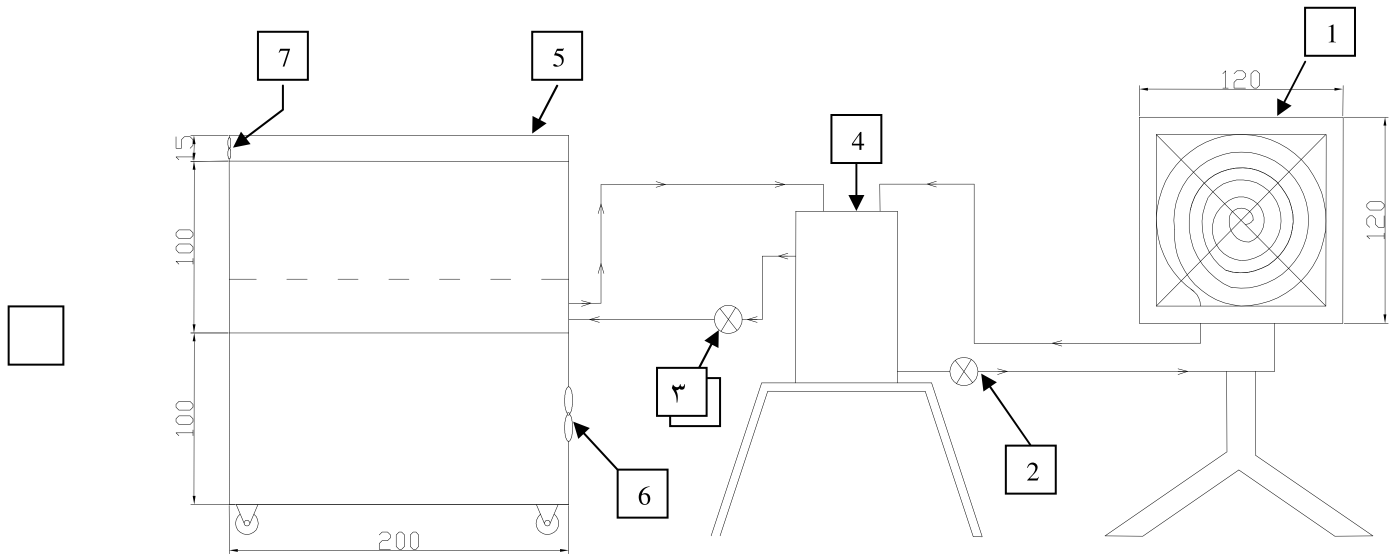

Fig. (2) : Systematic diagram showing the solar dryer system
1- Parabolic solar collector 2,3- Electric pumps 4- Storge tank
5- Even gable spzne greenhouse 6,7- Electric fans

During the experiment work nine (copper, constantan alloy) thermocouples are employed to measure the dry temperature in three different points inside the dryer system and one for each of the ambient air temperature, , the dryer wet temperature, inlet water temperature in the storage tank, outlet water temperature from the storage tank, inlet water temperature in the solar collector, and outlet water temperature from the solar collector. The disk solarimeter was employed to measure the solar radiation flux incident on a horizontal surface outside the dryer. All the pervious sensors are connected into the data logging system in order to read and record data from the sensors.

The essential oil of the herbs was determined according to the method described in the **British Pharmacopoeia (1963)** by using Clavenger's apparatus. Chlorophyll (a) and Chlorophyll (b) contents were determined in the dried plants according to the method mentioned by **Saric *et al* (1967),** as well as the moisture loss (%) was determined due to the drying methods. The collected data which was the means of the two
seasons were statistically analyzed according to **Snedecor and Cochran (1980).**

RESULTS AND DISCUSSION

Effect of day time on energy absorbed from the solar collector:

Figure (3) shows that, the solar energy during day time has been stored inside the 200 liter isolated storage tank by electric circle which connected to electric timer and half horse power water pump. It was turned on at 7:00 O'clock in the morning while turned off at 3:00 O'clock after noon to prevent the energy loss from the isolated storage tank to the outside ambient air again. To control the temperature inside the dryer an electric thermostat was used and adjusted at 35°C, as the average temperature in summer time. At the day time the unit received the direct sunshine and energy but, at night time when the ambient air inside the dryer decreased, the thermostat gave a signal to another water pump to push the hot water which stored at the isolated storage tank to the heat exchanger to raise the dryer ambient air again by convection air flow. The average energy requirement during fourteen hour for drying lemongrass, oregano spearmint and peppermint are 708.23, 853.88, 967.1 and 950.0 watt/m^2 respectively. After drying 250 g sample of each herb, the dry matter percentages were 34.85, 25.61, 21.70 and 20.63, respectively.

During the period between 7:00 am and 6:00 pm, the heat exchanger was stopped and the drying depended on the direct energy inside the dryer so at this period of time the energy take off from the heat exchanger.

The energy requirement for drying herbs using natural drying:

The average energy requirement during fourteen hour for drying lemongrass, oregano spearmint and peppermint were 614.4, 608.4, 691.0 and 606.17 watt/m^2, respectively. After drying 250 g sample of each herb, the dry matter percentages were 37.97, 27.87, 22.07 and 19.72%, respectively.

Dryer efficiency:

Figure (4) shows that the average of the efficiency of heat exchanger was 91.6%, 87%, 91.1% and 92% for lemongrass, oregano, spearmint and peppermint, respectively. The efficiency varied according to the ambient temperature, with the lower ambient temperature the heat exchanger efficiency increased. The dryer efficiency decreased as the day time increase, the maximum efficiency was found at early morning and declined as day time increased. The minimum efficiency for drying was found at mid night.

Effect of solar drying on moisture loss (%) from plants during day time:

Figure (5) shows that, the percentage of water released from the plant material increased by increasing the day time for all the species under investigation. The maximum water loss was 79.37% for peppermint while the minimum value of 65.15% for lemongrass. The required energy to remove 1g of water from lemongrass, oregano, spearmint and peppermint were 200.4, 176.7, 209.28 and 202.1 watt/m^2, respectively.

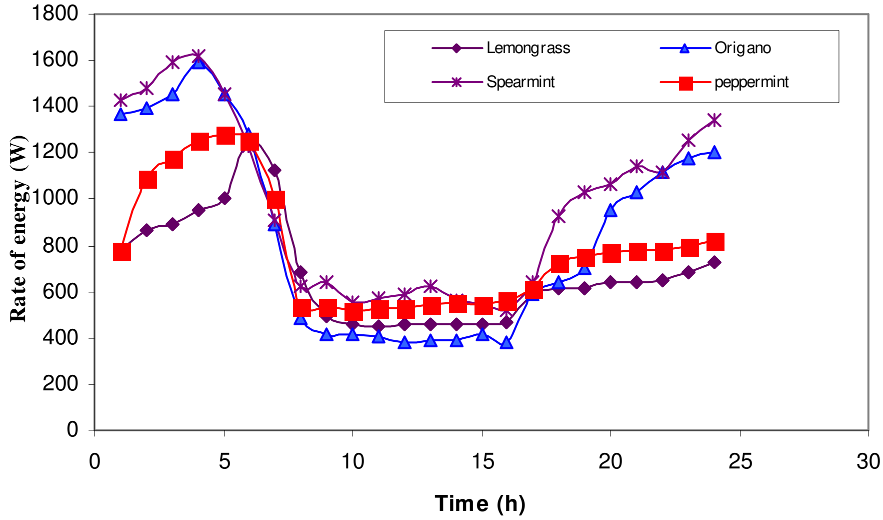

Fig. 3: Hourly average rate of energy added to the drier during the drying period.

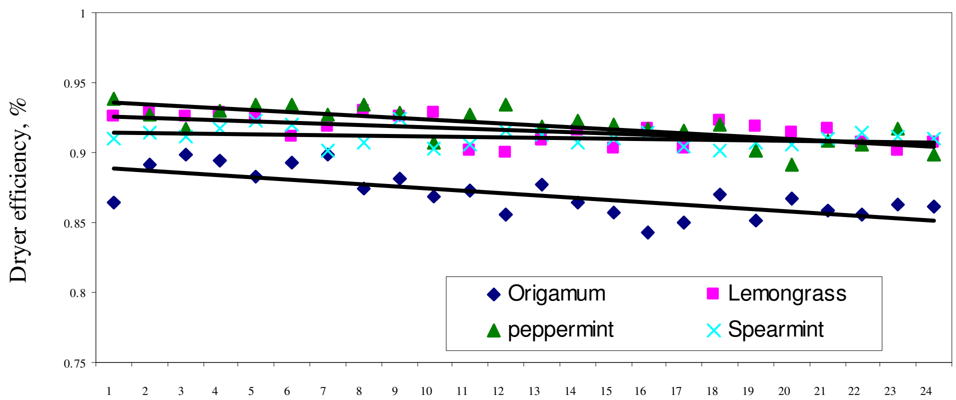

Fig (4): drier efficiency.

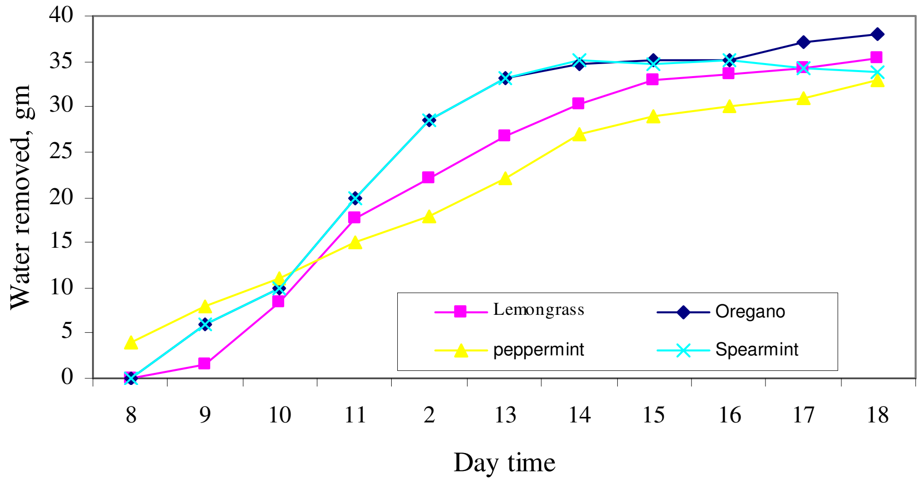

Fig (5): Effect of day time on the percentage of the water loss.

Effect of drying methods on the moisture loss (%) of the studied plants:

It is obvious from the data in Table (1) that the percentage of water loss from a given species depends on the used drying method, as well as the nature of the herb. Regardless of the drying method, the water loss was the lowest from lemongrass herb (68.16%), followed by oregano (74.07%), spearmint (79.20%) while the peppermint was the highest one (82.05%). On the other hand, the water loss from the investigated herbs was the highest after oven drying (80.21%) followed by the solar drying (74.53%), then the lowest in case of natural drying (72.87%). The difference in water loss seems to be insignificant between solar and natural drying methods, however remarkable significant difference could be seen between these two methods from one side and the oven drying from the other side.

Table (1): Effect of drying methods on the moisture loss (%) of the studied plants:

Drying method	Moisture Loss %				
	Lemongrass	Oregano	Spearmint	Peppermint	means
Solar	65.15	74.39	78.30	79.37	74.53
Natural	62.03	72.13	77.93	80.28	72.87
Oven	77.29	75.68	81.38	86.49	80.21
Means	68.16	74.07	79.20	82.05	
LSD	9.73	NS	1.63	3.70	

Table (2): Effect of drying methods on the essential oil (%) of the studied plants:

Drying Method	Lemongrass	Oregano	Spearmint	Peppermint
Solar	1.26	1.56	1.96	1.34
Natural	1.03	1.38	1.24	1.06
Oven	0.98	0.94	0.77	0.78
Means	1.09	1.29	1.32	1.06
LSD	0.21	0.35	0.25	0.24

Effect of the drying methods on the essential oil content of the studied plants:

Regarding the influence of the drying method on the essential oil content (%) of the dried herb, the data in Table (2) indicate that the oven drying was the most harmful method in this regard. All herbs dried by this method lost a remarkable portion of their essential oil content. On the other hand, the solar drying method proved to be the most proper one in this regard followed by natural drying.

Effect of the drying methods on the chlorophylls a and b contents of the studied plants:

It could be seen from table (3) that, the chlorophylls content (a&b) of the all dried herbs was higher due to solar or natural drying methods than in case of oven drying. Insignificant difference could be noticed between the solar or natural drying methods regarding their effect on the chlorophyll content.

Table (3): Effect of the drying methods on the chlorophylls a and b contents (mg/g) of the studied plants:

Drying method	Chlorophyll a	Chlorophyll b
Lemongrass		
Solar	3.296	0.393
Natural	4.859	0.577
Oven	2.896	0.371
LSD	0.950	0.301
Oregano		
Solar	7.123	3.569
Natural	7.922	4.081
Oven	5.831	2.541
LSD	0.972	0.359
Spearmint		
Solar	4.161	1.397
Natural	4.539	1.898
Oven	2.447	0.906
LSD	1.358	0.3972
Peppermint		
Solar	6.994	3.217
Natural	7.297	3.529
Oven	3.08	1.267
LSD	0.889	0.403

CONCLUSION

It could be concluded that the solar drying method is comparable with the natural drying regarding the percentage of water loss from the plant material, however the solar drying is supposed to be faster than the natural drying. Plants dried by this method kept their essential oil content as high as possible. From the qualitative point of view, the solar drying method also provides isolated atmosphere that minimize the contamination of the plant material. Also, this method was comparable or even better than natural drying regarding the chlorophylls content in the dried herb, meaning giving the same green color of the final product. From the previous result found that the solar system is more suitable for drying the medicinal plant.

The energy required to removed 1g of water from Oregano, Lemongrass, Spearmint and peppermint are 176.7, 200.4, 209.28 and 202.1 watt/m^2, respectively.

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<u>الملخص العربي</u>

تأثير الطاقة الشمسية و بعض طرق التجفيف الأخرى على جودة بعض النباتات الطبية

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أجريت هذه الدراسة أثناء موسمى نمو متتاليين (٢٠٠٢ -٢٠٠٣) لدراسة تاثير الطاقة الشمسية و بعض طرق التجفيف الأخرى على جودة بعض النباتات الطبية. و كانت هذه الطرق هى التجفيف باستخدام الطاقة الشمسية (± ٣٠ م°) و التجفيف الطبيعى (الشمسى ± ٣٥ م°) و التجفيف الصناعى (فرن عند٤٥ م°). و قد أستخدمت الطرق الثلاثة لتجفيف حشيشة الليمون (*Cymbopogon citratus*) و الأورجانو (*Origanum vulgare*) و النعناع البلدي (*Mentha virdis*) و النعناع الفلفلي *Mentha pepperita*). و قد تم تصميم وتشغيل هذه النظم الثلاثة في معهد بحوث الهندسة الزراعية و أوضحت النتائج أن أعلى فقد في النسبة المئوية للرطوبة كان في طريقة التجفيف الصناعي (فرن التجفيف). بينما كانت نسبة الفقد فى حالة أستخدام الطاقة الشمسية و التجفيف الطبيعى متقاربة. أما بالنسبة للزيوت الطيارة كانت أقل نسبة عند أستخدام الفرن بالمقارنة بالطرق الأخرى. أما بالنسة لصبغات الكلوروفيل(أ،ب) كانت أعلى نسبة باستخدام التجفيف بالطاقة الشمسية أو التجفيف الطبيعى بالمقارنة بالتجفيف الصناعي.

كما أثبتت النتائج أن كمية الطاقة اللازمة لنزع ١سم^{3} /جم من المحتوى المائى فى حشيشة الليمون و الأوريجانو و النعناع البلدي و النعناع الفلفلي هي ٢٠٠,٤ ، ١٧٦,٧ ،٢٠٩,٢٨، ٢٠٢,١ وات /م^{2} كما أن كفاءة التجفيف كانت ٩١,٦% ،٨٧%، ٩١,١% ، ٩٢% لجميع النباتات حشيشة الليمون (*Cymbopogon citratus*) و الأورجانو (*Origanum vulgare*) و النعناع البلدي (*Mentha virdis*) و النعناع الفلفلي *Mentha pepperita*). على التوالي. , و من هنا نجد أن التجفيف باستخدام الطاقة الشمسية مناسب لتجفيف النباتات الطبية لاستهلاكه أقل طاقة وتحقيق نتائج طيبة و جودة عالية وذلك طبقا للنتائج السابقة .

- باحث بمعهد بحوث الهندسة الزراعية.
- رئيس بحوث بمعهد بحوث الخضر قسم بحوث النباتات الطبية و العطر