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SOLAR ENERGY UTILIZATION FOR DRYING PEPPERMINT

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ABSTRACT

Experiments were carried out through summer season of 2013 in the rice mechanization center at Meet El-Dyba, Kafr El-Sheik Governorate, Egypt for trying to obtain high quality of dried peppermint with the highest volatile oil percent at least drying time. The experiments were conducted under the following variables of two different drying methods (sun drying and solar greenhouse dryer), two different plant conditions (whole plants and leaves), three different loads (2,4 and 6 kg/m^2) and three different air velocities (0.5, 1 and 1.5 m/sec.) under continuously fan operating system. The moisture content, relative humidity, temperature, volatile oil and total microbes count (TMC) were in the proper best region under the following conditions: Use of solar tunnel greenhouse for drying peppermint. Drying the peppermint as leaves in order to reduce the drying time. Procedure the drying process at air velocity of 1m/s. Loading the greenhouse by about 4 kg/m^2.

Key words: Solar energy, drying methods, peppermint, temperature, moisture content, product quality.

INTRODUCTION

The post-harvest processes are very importance especially, in case of medicinal and aromatic plants. Drying as among of these processes determines the quality of the final products. Peppermint (*Mentha pepperita* L.) is one of the most important aromatic plants because it has a wide range of industrial uses and is widely accepted by the public for its flavoring and pharmaceutical properties. The aromatic oil of peppermint contains many components which are used in manufacturing of pharmaceuticals. The cultivated area with peppermint plants in Egypt amounted to be about 162 faddans and the total value of peppermint plants production in Egypt is 3424 ton (Ministry of Agric., 2012). Sun drying is a traditional drying technique in many countries, produces a product with desirable properties in color, flavor, and texture. However, it also has many disadvantages, such as low drying rate and long drying time, exposure to contamination from dust and insects (Lee *et al.*, 2004). To overcome these problems, solar drying method could be used to dry agriculture products instead of traditional sun drying as the drying process takes place in enclosed structures (El-Sebaii *et al.*, 2002). A greenhouse is essentially an enclosed structure which traps the short wavelength solar radiation and stores the long wavelength thermal radiation to create a favourable micro-climate for higher productivity. A greenhouse heating system is used to increase the thermal energy storage inside the greenhouse during the day or to transfer excess heat from inside the greenhouse to the heat storage area. This heat is recovered at night to satisfy the heating needs of the solar tunnel greenhouse dryer. Thus, the temperature inside the dryer will be increasing steadily, thereby ensuring quicker drying of the products than the open sun drying method. Condori *et al.* (2001). Rocha *et al.* (2011) found that the drying method, velocity and temperature of drying air influence the quantity and quality of the active ingredients present in aromatic and medicinal plants. In spite of all technical developments, the choice of

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the correct drying temperature remains a central economic and ecological criterion in the drying of medicinal plants. Drying air temperatures between 50 and 60°C appear to be feasible for drying large number of medicinal plants. Muller *et al.* (1989) found that, the drying of whole mint in greenhouse solar dryer from initial moisture content of 85% (w.b.) to final moisture content of 10% (w.b.) took 3 days.

The main aim of this research is to study the different factors (solar radiation, air temperature and relative humidity) that affecting the performance of drying process and so, select the optimum conditions for drying peppermint which keep the properties and benefits.

MATERIALS AND METHODS

Experiments were carried out through summer season of 2013 at rice mechanization center of Meet El-Dyba, Kafr El-Sheikh Governorate.

Materials

Plant

Peppermint plant was used under this study. Some physical properties of peppermint plants were determined as shown in Table 1.

Tunnel greenhouse

The tunnel greenhouse as shown in Fig. 1 was used as solar dryer prototype. Three identical greenhouse dryers were constructed and installed at the workshop of Kafr El-Sheikh Governorate. The dryer prototype frames was constructed from iron galvanized pipes of 12.7 mm and installed on the circumference of four walls forming a batch. The pipe frames was covered by a clear plastic film 200μ thick. Black plastic wire net was used as a solar absorber covering the surface of the drying chamber in order to increase the collection efficiency of solar radiation. Wire netting constitutes a floor at the bottom of the batch. Suction fan of air was fixed (active solar drying) and driven by electric motor of 0.37 kW at 3000 rpm. The fan was operated in a continuously operating system. The other side of greenhouse has an open window for air inlet of 350 x 100 mm and a front door of 700 x 450 mm is located at the front side of the dryer for loading and collecting samples of peppermint.

Traditional sun drying

Peppermint was drying using traditional sun drying method by placing the plants in the wooden frames and subjected it to direct sun drying. The dimensions of the used wooden frame were 200 × 500 mm.

Methods

Experimental conditions

Experiments of drying peppermint were conducted under the following variables:

- Two different drying methods (sun drying and solar greenhouse dryer).
- Two different plant conditions (whole plants and leaves).
- Three different loads of (2 , 4 and 6) kg/m^2.
- Three different air velocities of (0.5, 1 and 1.5 m/sec.).

Measurements and determinations

Evaluation of the performance of drying was taking into considerations under the following indicators and measurements:

Solar radiation

The solar radiation was measured by connecting by pyranometer sensor model H-201 to a chart recorder model YEW 3057 in order to convert the voltage single to an equivalent reading in kW.hr/m^2. The solar radiation was measured and recorded during the period started from 8 am to 6 pm.

Temperature and relative humidity

The temperature was recorded to the ambient, dryer and bulk temperature (whole plant and leaves). Thermocouples (type T) were fixed at different locations of the dryer to measure the bulk crop temperatures.

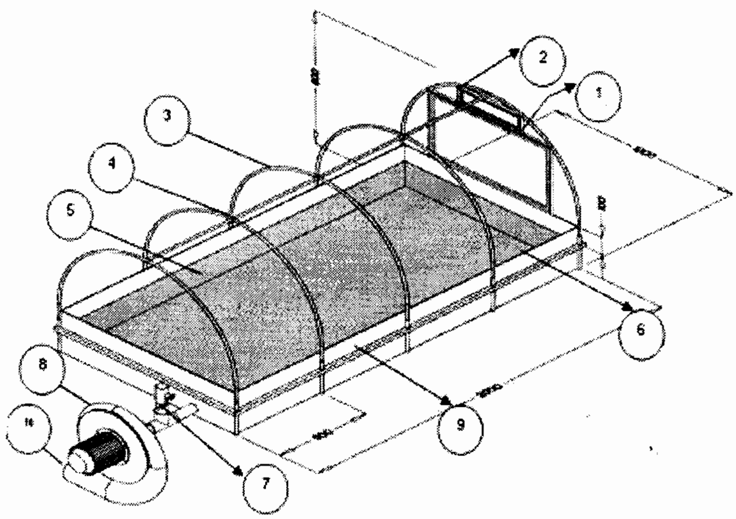
Digital temperature and humidity meter, model Chino (HN-K) was used to measure the air temperatures and relative humidity inside and outside the greenhouse.

Moisture content

The moisture content was determined by the standard oven method. Samples were taken before and during the drying and weighted oven dried to constant mass at 105°C up to 24 hr., (AOAC, 1990). The moisture content was calculated as a wet basis (w.b., %) as following:

Table 1. Physical properties of peppermint plants

Physical Properties	Average value
Plant height, cm	27.5
Average leaf area, cm^2	4.0
Thickness of peppermint leaves, mm	0.25
Bulk density of fresh leaves, kg/m^3	30.15
Moisture content of whole plant (%)	84.42
Moisture content of leaves (%)	83.52



All dimensions in mm

No.	Part name	No.	Part name
1	Front door	6	Wall for batch
2	Window	7	Control hand valve
3	Pipe frame	8	Suction fan
4	Plastic cover	9	Air chamber
5	Wire netted floor	10	Air outlet

Fig. 1. Schematic of solar tunnel greenhouse dryer prototype

$$M_c = [(m_w - m_d) / m_w] \times 100$$

Where:

M_c: Moisture content, %

m_w: Wet peppermint mass, g

m_d: Dry peppermint mass, g

Product quality

Volatile oil and TMC were used to determine the quality of dried peppermint as follow:

Volatile oil

The percentage of volatile oil of the dried samples was determined using the method described in British pharmacopoeia (1963).

Total microbes count

Total microbes count (TMC) per gram sample of all treatments was determined using nutrient agar medium according to the procedure described by Merck (1977).

Statistical analysis

Data of volatile oil and total microbes count were subjected to statistical analysis according to Snedecor and Cochran (1990). Means separation was done by LSD at 0.01 and 0.05 levels of probability.

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following heads:

Solar Radiation

Fig. 2 show the measured solar energy flux incident as a function of the daylight time. The average daily of climatic conditions outside and inside the solar tunnel greenhouse were 683.93 and 545.62 W/m^2, 701.25 and 572.49 W/m^2, 653 and 531.59 W/m^2, 659.84 and 548.35 W/m^2 during the first, second, third and fourth days of drying period. At drying day of 3/7, the drying process started with solar radiation of 430 and 331.10 W/m^2 at 8 am., and then, increased through the day to the maximum value of 978.54 and 802.40 W/m^2 at 1 pm., while at the end of drying, the solar radiation was reached to be 282.86 and 223.46 W/m^2 at 6 pm., for outside and inside greenhouse, respectively. This variation in solar radiation during the drying period affected the dryer effectiveness in heating the drying air and thereby, affected the temperature and relative humidity inside and outside the solar greenhouse.

Effect of Different Parameters on the Temperature in the Greenhouse

The variation of temperature under different air velocities of 0.5, 1.0 and 1.5 m/sec. at load of peppermint of 2 kg/m^2 was shown in Fig. 3. It is noticed that increasing the air velocity was followed with a decrease in the temperature inside the greenhouse. This is may be due to insufficient time for the air to be heated inside the solar collector which in turn affects the bulk temperature of both whole plants and leaves. At ambient temperature of 39.20°C at 1 pm., the air temperature in the greenhouse was 55.00, 51.30 and 48.20°C under air velocities of 0.5, 1.0 and 1.5 m/sec., respectively. The temperature was differed through the day; this is referring to the differences in solar radiation.

With regard to the variation of temperatures with relation to different loads under air velocity of 1 m/sec. and continuous fan operating system was illustrated in Fig. 4, results showed that loading the greenhouse by 2 kg/m^2, the highest obtained temperature was 50.10°C under ambient temperature of 36.60°C. By loading 4 or 6 kg/m^2 peppermint, the drying process consumed two days of experimental periods. Added to that the temperature was found in an increment at the first stage of second day (8 am) compared to final reached temperature at the first drying day (6 pm), this is may be due to increase the thermal energy storage inside the greenhouse during the day or to transfer excess heat from inside the greenhouse to the heat storage area and thus, the temperature inside the dryer will be increased according to Condori *et al.* (2001). For drying 4 kg/m^2 to be in a suitable limit, the last obtained temperature was 51.90°C at an ambient temperature of 37°C (1 pm), while the last obtained temperature was 44.30°C at an ambient temperature of 30.50°C (4 pm) for maximum load of 6 kg/m^2. By increasing the crop load in a greenhouse, the temperature was decreased.

Effect of Different Parameters on Relative Humidity

The increase of air velocity, increased the relative humidity. This is due to the temperature was decreased by increasing the air velocity and thus, relative humidity was increased. The daily average of relative humidity was 28.84 %, 30.50% and 31.85% for air velocities of 0.5, 1.0 and 1.5 m/sec, respectively under an average ambient relative humidity of 45.31% as illustrated in Fig. 5. Due to the greenhouse effect, thermal storage, the temperature was increased and thereby, the relative humidity was decreased compared with the ambient relative humidity. The lowest relative humidity was 16.90%, 21.70% and 22.70% at 0.5, 1 and 1.5 m/sec., respectively.

With respect to the variation in relative humidity under different crop loads as shown in Fig. 6; the average daily of relative humidity

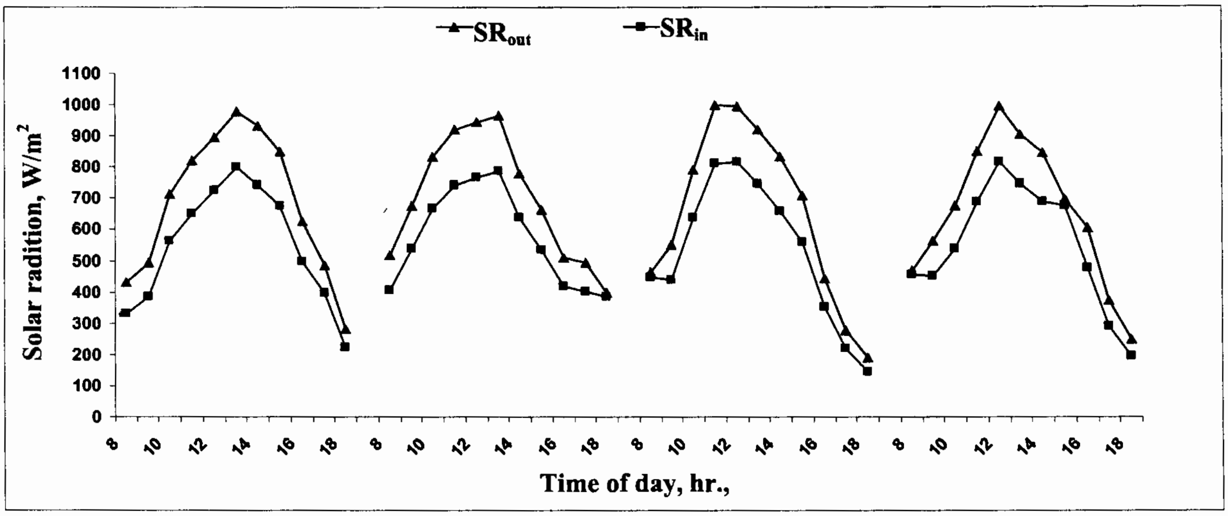


Fig. 2. Average hourly solar radiation outside (SR_{out}) and inside (SR_{in}) the solar tunnel greenhouse during the experimental period

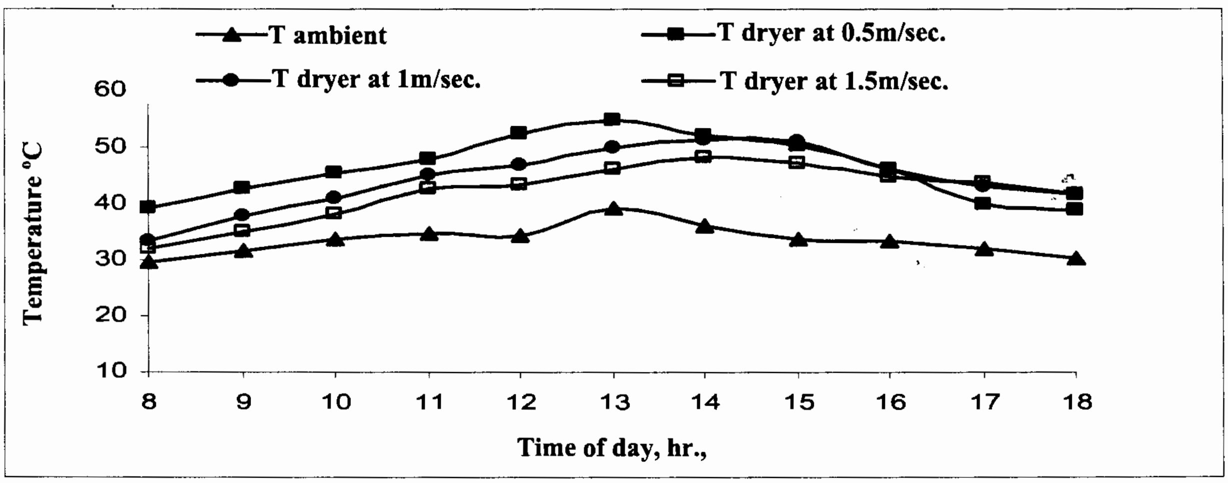


Fig. 3. Variation of ambient temperature and drying air temperature with time under different air velocities at load 2 kg/m^2

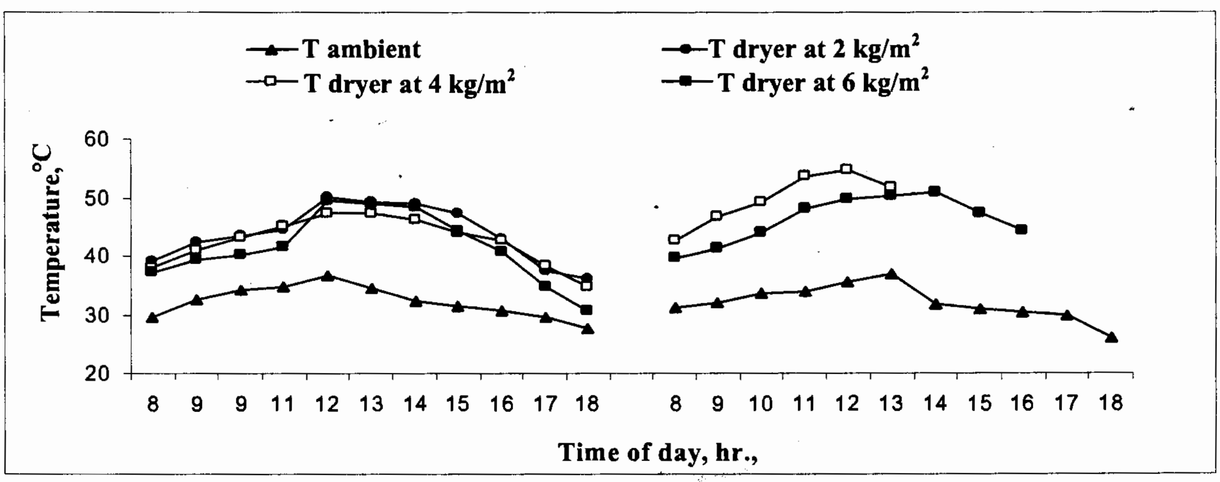


Fig. 4. Variation of ambient temperature and dryer air temperature with time under different loads at air velocity 1m/sec.

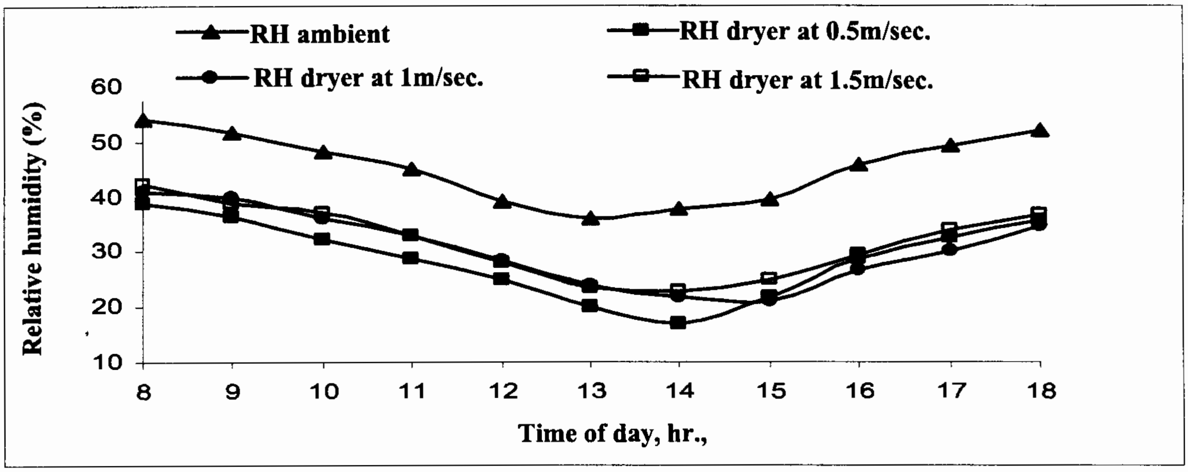


Fig. 5. Variation in ambient relative humidity and drying air relative humidity with time at different air velocities and load 2 kg/m²

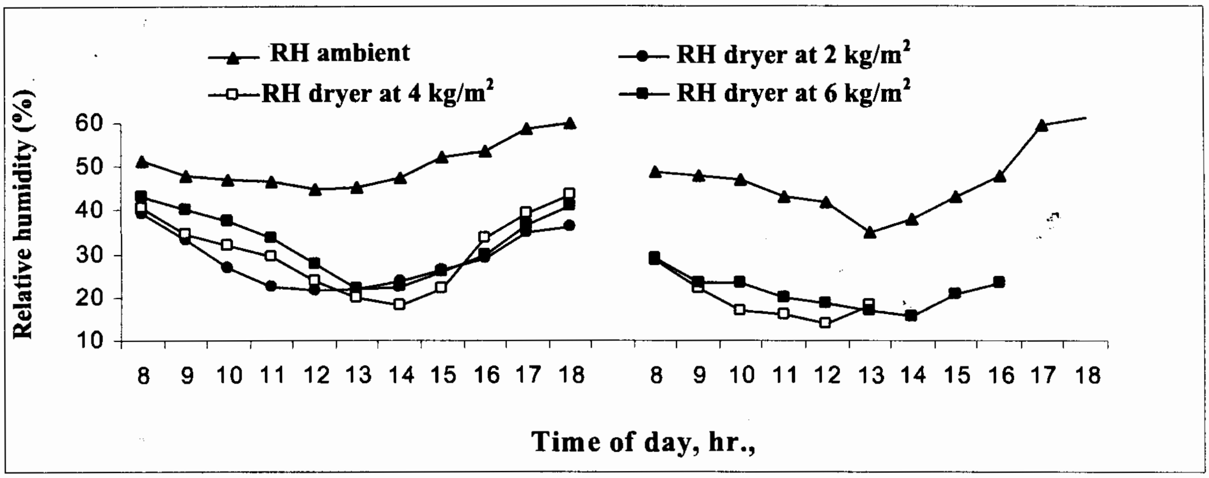


Fig. 6. Variation in ambient relative humidity and drying air relative humidity with time under different crop loads and air velocity of 1m/sec.

was 28.77%, 30.60% and 32.77% for 2, 4 and 6 kg/m^2 at the first day of experiment, while the product mass of 4 and 6 kg/m^2 extended to the next day for completing the drying in order to reach them to the optimum limits. The average daily of relative humidity was 19.82% and 21.20%for 4 kg/m^2 and 6 kg/m^2 in the second day. It was observed that the decrement in relative humidity at the beginning stage of drying in the next day compared to the recorded last relative humidity at the day before, this is may be the increase in temperature according to Condori *et al.* (2001) and thus, decrease in relative humidity. Increasing the crop load, the relative humidity was increased, because of by increasing the product mass, the total humidity was increased and then, occurred transferred to the humidity between the plants and the air inside the greenhouse to be in equilibrium relative humidity level.

Effect of Different Parameters on Moisture Content (w.b. %)

Solar tunnel greenhouse

Effect of different air velocities on moisture content of whole plants and leaves were shown in Fig. 7 under crop load of 2 kg/m^2. It was noticed that the increase of air velocity, decreased moisture content up to 1 m/sec. and then, increased with increasing air velocity. The drying times of peppermint as whole plants and

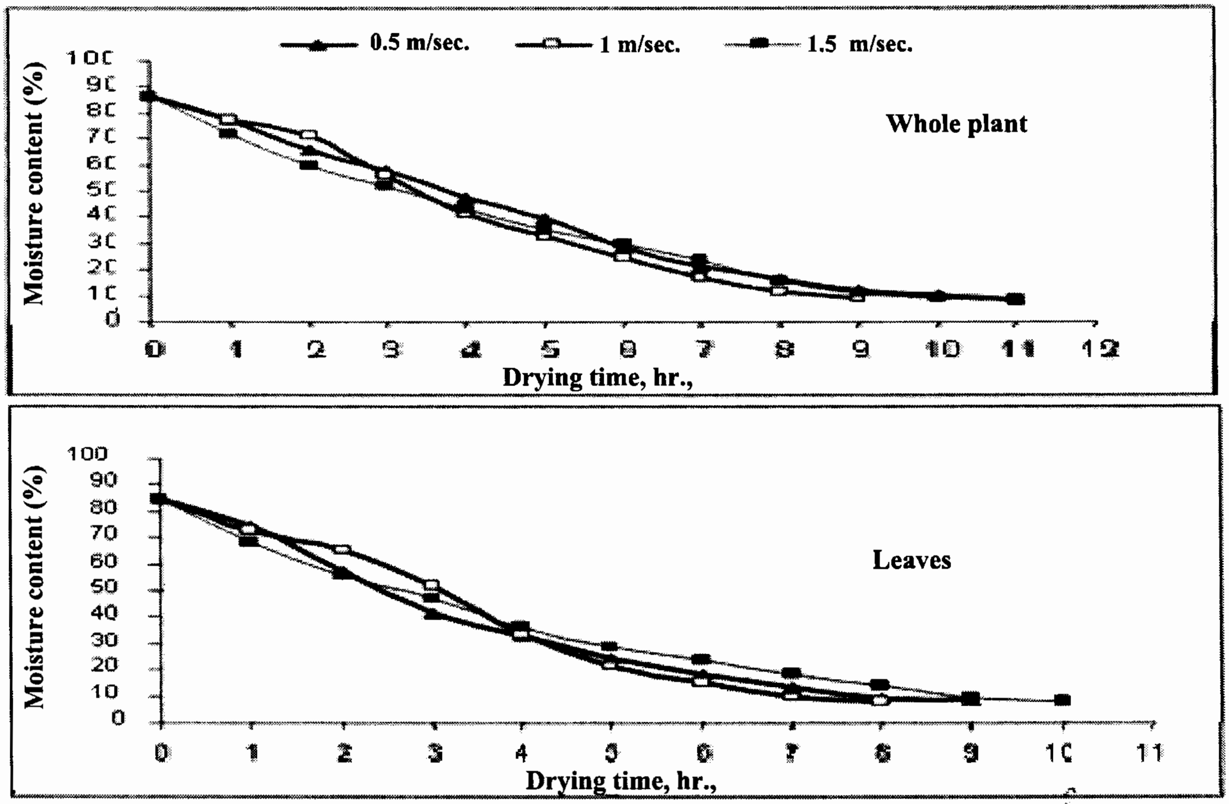


Fig . 7. Variation of moisture content (w.b.%) of peppermint in a greenhouse at different air velocities under load of 2 kg/m^2

leaves were (11 and 9 hr.), (9 and 8 hr.) and (11 and 10 hr.) at 0.5, 1, 1.5 m/sec., respectively. The increase in drying time with air velocity of 1.5 m/sec., this may be due to insufficient time for passing the air through the product. The moisture content in whole plants was higher than leaves, that was in agreement with Fatouh *et al.* (2006), so the whole plants took more time for drying than leaves and this is also due to the projected area of leaves for air thereby, accelerate the drying time for leaves than whole plants. Using the air velocity of 1 m/sec., decrease the drying time by 18.18% (for whole plants and 11.11% and 20% for leaves) compared by air velocities of 0.5 and 1.5 m/sec., respectively.

Regarding to the variation in moisture content of whole peppermint plants and leaves under different crop loads and air velocity of 1 m/sec. were illustrated in Fig. 8. Increasing the crop load, the consumed drying time was increased. Dry whole plants and leaves to be in a suitable limit of moisture content, the consumed time for drying 2 kg/m^2 from 83.37 to 8.5% and 83.09 to 8.40% moisture content was 10 and 9 hr., while the drying from moisture content 83.37 to 8.90 and 83.09 to 8.30% of 4 kg/m^2 and from moisture content 83.37 to 8.74% and 83.09 to 8.41% of 6 kg/m^2, the consumed time was 17 hr., and 15 hr., for 4 kg/m^2 and 18 hr., and 16 hr., for 6 kg/m^2, respectively. Whole plants consumed more time for drying than leaves, this is consistent with Fatouh *et al.* (2006) who found that the required drying time increases with increasing surface load and also, small size herbs without stem need low drying time.

Traditional sun drying

Fig. 9 show the differences in moisture content under traditional sun drying of different loads 2, 4 and 6 kg/m^2. To reach the final moisture content of whole plants and leaves, the drying time has been taken (26 and 21 hr.), (27 and 23 hr.) and (27 and 31 hr.) for 2, 4 and 6 kg/m^2, respectively. It was observed that drying plants under traditional sun drying took more time than greenhouse under the same ambient temperature. The whole plants of 2, 4 and 6 kg/m^2 to final moisture content, the drying took three days. While, drying leaves consumed two days for 2 and 4 kg/m^2 and three days for 6 kg/m^2, this is a compatible with Muller *et al.* (1989).

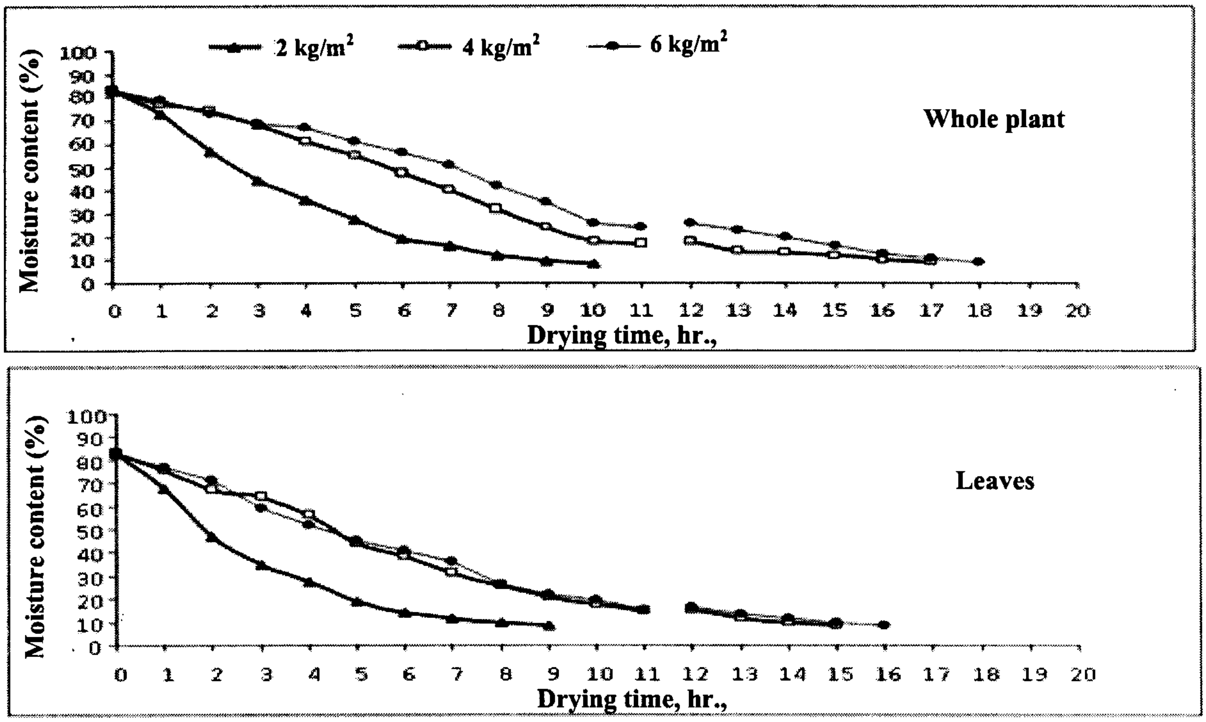


Fig. 8. Variation of moisture content (w.b.%) of peppermint in a greenhouse at different crop loads and air velocity of 1 m/sec.

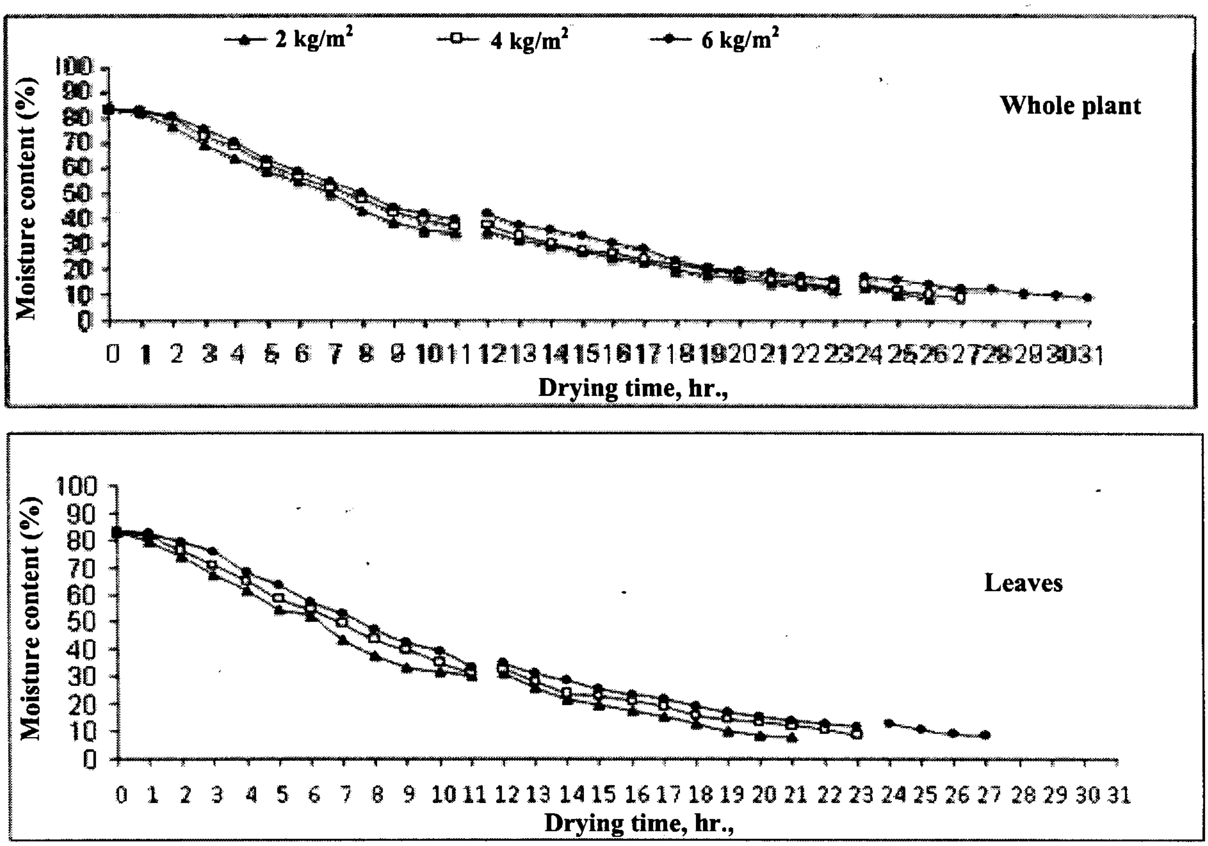


Fig. 9. Variation of moisture content (w.b.%) of peppermint at different crop loads under traditional sun drying

By using the solar tunnel greenhouse for drying whole peppermint plants and leaves at air velocity of 1m/sec., reduced the drying time by (61.53% and 57.14%), (37.03%and 34.78%) and (41.93%and 40.74%) compared with traditional sun drying for 2, 4 and 6 kg/m^2, in that order. This may be due to the greenhouse effect associated with transparent plastic films.

Effect of Different Parameters on Product Quality

The quality of dried product was determined by volatile oil content of peppermint and total microbes count.

Volatile oil percentage

Greenhouse

Fig. 10 show the effect of different air velocities on volatile oil content in whole plants and leaves at crop load of 2 kg/m^2. Results clarified that the highest percent of volatile oil was recorded at air velocity of 1 m/sec., it was 0.90% for whole plants and 1.52% for leaves. While, the lowest percentage was found to be 0.81%for whole plants and 1.34% for leaves at air velocity of 0.5 m/sec. It was found that the leaves had the highest percent of volatile oil compared with whole plants.

Regarding the volatile oil content in whole plants and leaves under different loads and air velocity of 1 m/sec., were illustrated in Fig. 11. The statistical analysis showed high significant differences in volatile oil percentage under using different product loads. The volatile oil content was 0.84%, 0.76% and 0.63% for whole plants, while it was 1.54%, 1.49 % and 1.37% for leaves under 2, 4 and 6 kg/m^2, respectively.

Traditional sun drying

Fig. 12 explained the effect of traditional sun drying on drying whole peppermint and leaves under different crop load of 2, 4 and 6 kg/m^2. In whole plants, the volatile oil content was 0.83%, 0.65% and 0.48 % for 2, 4 and 6 kg/m^2, respectively, while the percentage in leaves was 1.49%, 1.33% and 1.15% under the same previous conditions.

From obtained results, using the greenhouse for drying whole peppermint plants increased the volatile oil percent by 1.2%, 16.9% and 31.25%, while for drying leaves it was increased by 3.35%, 12.03% and 19.13% for 2, 4 and 6 kg/m^2, in that order comparing with traditional sun drying.

Total microbes count (TMC)

Greenhouse

Fig. 13 show the effect of different air velocities on TMC in whole plants and leaves at crop load of 2 kg/m^2. It was not significant differences in TMC between air velocity of 1m/sec., and 1.5m/sec. TMC in leaves was lower than whole plants. The lowest obtained average TMC was 1.60 million/g for whole plants and 1.43 for leaves under using air velocity of 1 m/sec. While, the highest level of TMC was1.63 million/g for whole plants and 1.52 million/g for leaves under using air velocity of 0.5 m/sec. Data showed that TMC in leaves was lower than whole plants.

With regard to the effect of different loads on TMC at air velocity of 1 m/sec., Fig. 14 show that the lowest obtained limit of TMC was 1.61 million/g for whole plants and 1.43 million/g for leaves under crop load of 2 kg/m^2 While, the highest level was 1.91 million/g for whole plants and 1.59 million/g for leaves under load of 6 kg/m^2.

Traditional sun drying

The effect of using traditional sun drying for peppermint under different crop loads was shown in Fig. 15. Results show that the highest levels of TMC were obtained under drying by traditional method. TMC values were 5.77, 5.75 and 6.17 million/g for leaves and 7.2, 7.09 and 7.96 million/g for whole plants under 2, 4 and 6 kg/m^2, respectively.

From results, it was clarified that using tunnel greenhouse reduced the level of TMC of leaves by 303.49%, 304.92% and 288.05% for 2, 4 and 6 kg/m^2, respectively compared with traditional sun drying under the same ambient conditions.

Conclusion

The experimental results reveal that drying time, relative humidity, temperature, volatile oil and total microbes count (TMC) were in the optimum region under the following conditions

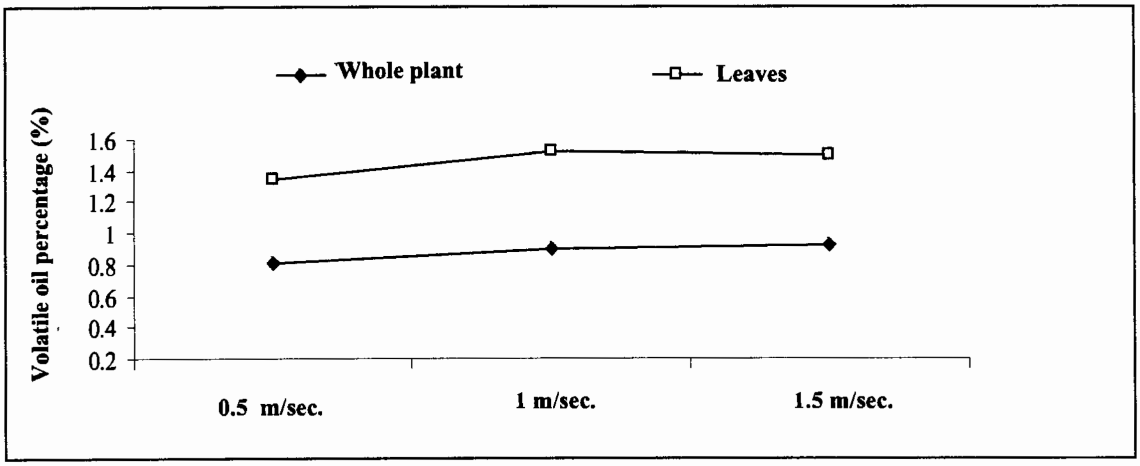


Fig. 10. Effect of air velocity on volatile oil of peppermint in a greenhouse under different air velocities and load 2kg/m^2

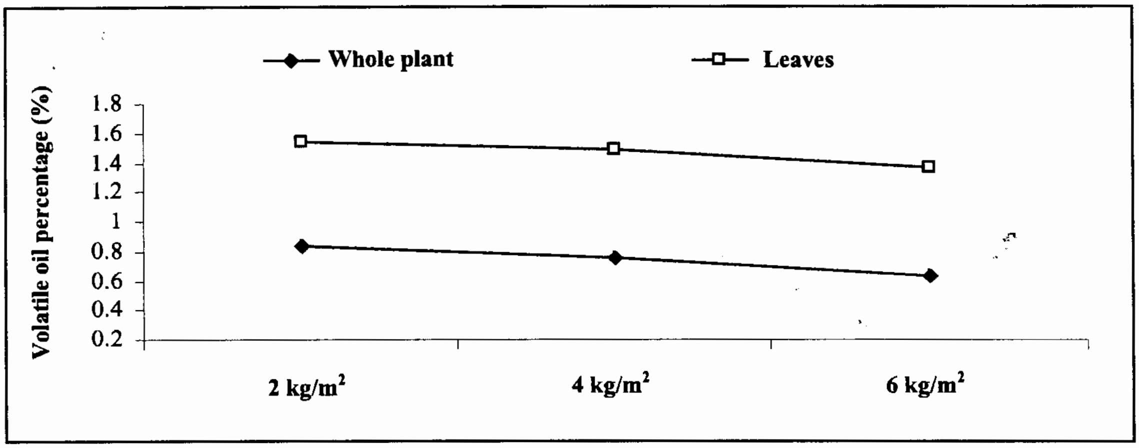


Fig. 11. Effect of peppermint load on volatile oil content of peppermint in a greenhouse at air velocity 1m/sec.

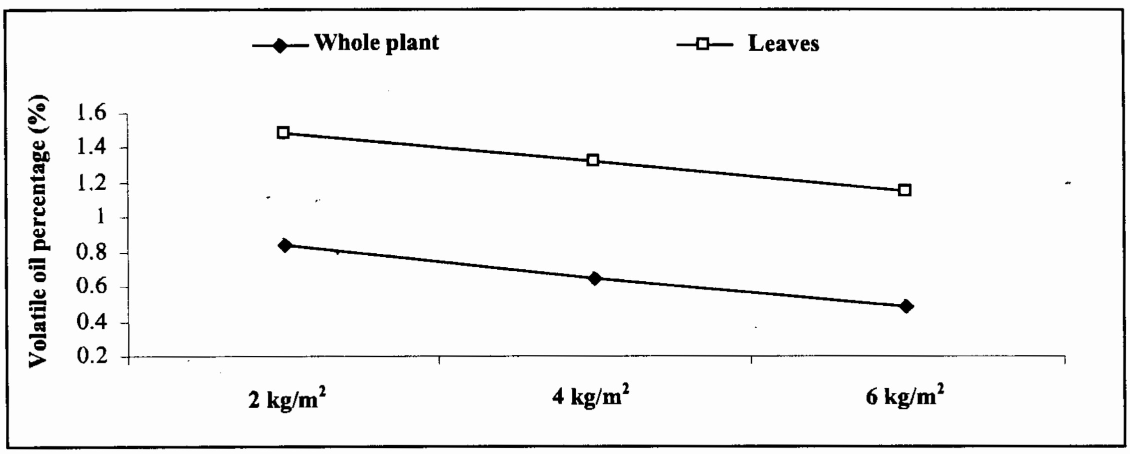


Fig. 12. Effect of peppermint load on volatile oil content of peppermint under traditional sun drying

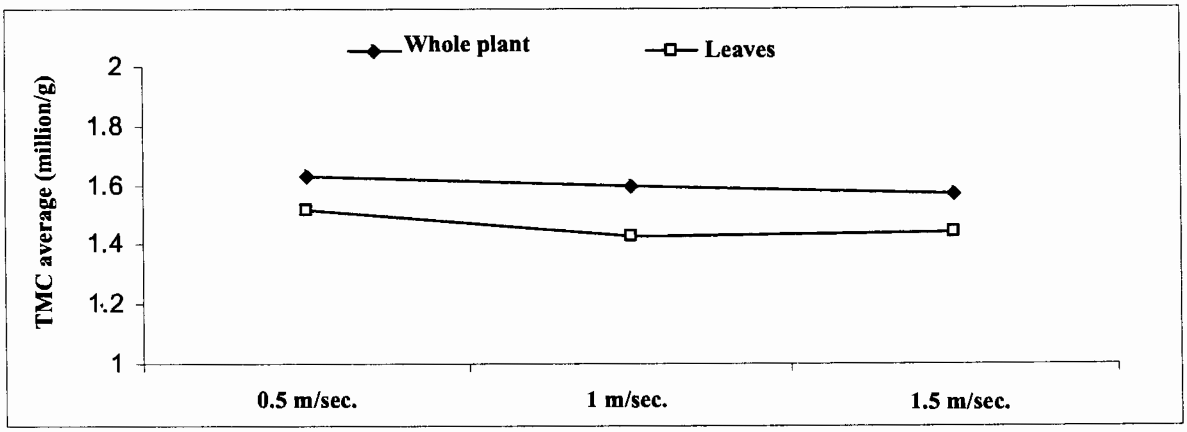


Fig. 13. Effect of air velocity on TMC of peppermint in a greenhouse under different air velocities and load 2kg/m^2

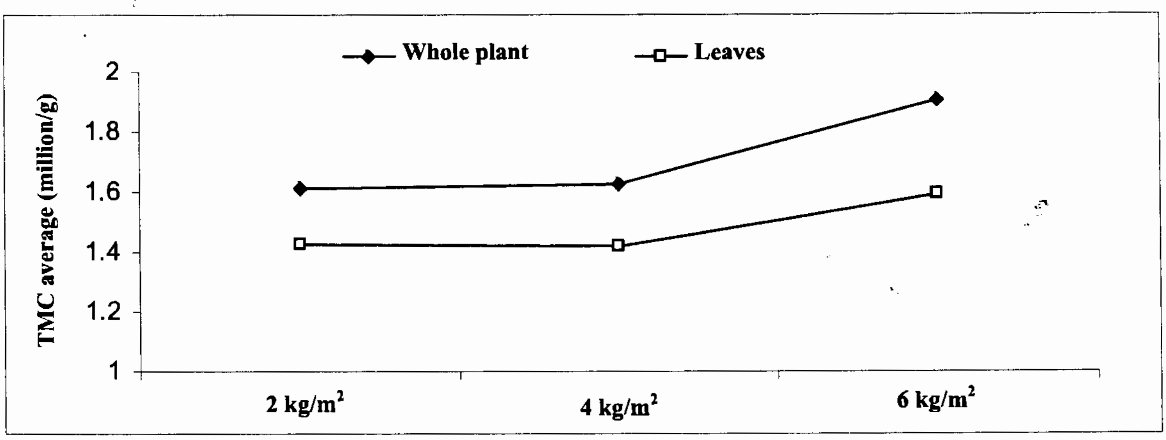


Fig. 14. Effect of peppermint load on TMC of peppermint in a greenhouse at air velocity 1m/sec.

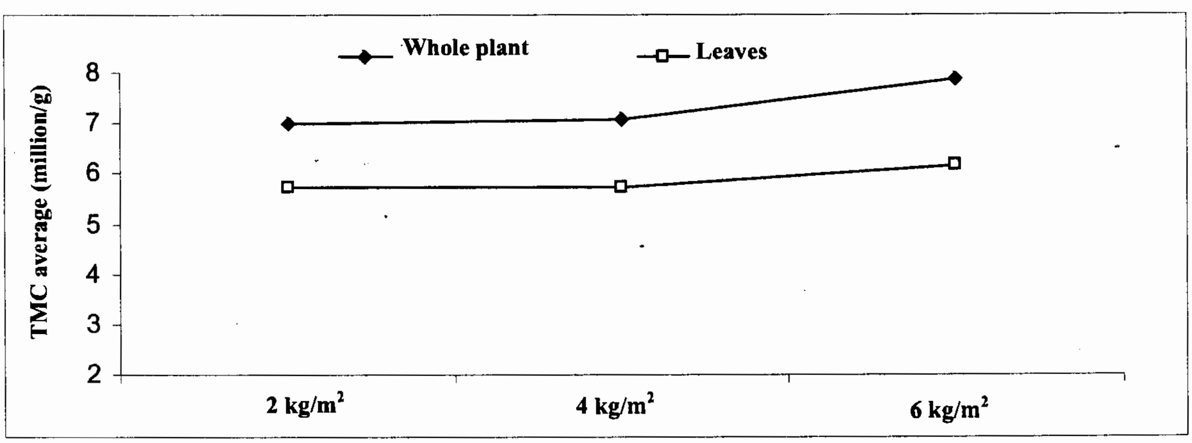


Fig. 15. Effect of peppermint load on TMC of peppermint under traditional sun drying

use solar tunnel greenhouse for drying peppermint which increase volatile oil by 1.2%, 16.9% and 31.25%, while for drying leaves it was increased by 3.35%, 12.03% and 19.13% for 2, 4 and 6 kg/m^2, in that order comparing with traditional sun drying. Drying the peppermint as leaves in order to reduce the drying time by 12%. Procedure the drying process at air velocity of 1m/sec., that record highest volatile oil (1.52%) and lowest total microbes count (1.49 million/g). Loading the greenhouse by about 4 kg/m^2.

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تعتبر عمليات ما بعد الحصاد من العمليات الهامة وخاصة للنباتات الطبية والعطرية، من أحد هذه العمليات عملية التجفيف، حيث تعتبر احد الطرق المستخدمة فى حفظ المواد الغذائية عن طريق خفض ما تحتويه من رطوبة تحت ظروف ملائمة من حيث درجة الحرارة ودرجة الرطوبة النسبية وسرعة الهواء مما يؤدى إلى نقص ما تحتويه المواد المجففة من رطوبة إلى الحد الذى يقف عنده نمو معظم الأحياء الدقيقة مع عدم الأضرار كلما أمكن بصفات المادة الغذائية مثل اللون أو القيمة الغذائية، تم إجراء الدراسة على نباتات النعناع كأحد أهم النباتات الطبية والعطرية والتى تدخل فى العديد من الاستخدامات الصناعية والدوائية، تهدف هذه الدراسة إلى اختيار أنسب الطرق لتجفيف النعناع الفلفلى للمحافظة على نسبة الزيوت الطيارة وتقليل المحتوى الميكروبى الكلى وذلك من خلال دراسة تأثير بعض العوامل التشغيلية المختلفة على عملية التجفيف باستخدام طرق التجفيف المختلفة (الصوبة الزراعية والتجفيف الشمسى التقليدى)، تم إجراء التجارب بمحطة ميكنة الأرز – مركز ميت الديبة – محافظة كفر الشيخ خلال شهر يوليو لعام ٢٠١٣ وتم دراسة سلوك عملية التجفيف لنبات النعناع (المجموع الخضرى) وكذلك الأوراق تحت تأثير المتغيرات الآتية: طريقتين للتجفيف (التجفيف الشمسي باستخدام الصوب الزراعية على شكل أنفاق - التجفيف الشمسى التقليدى) – ثلاث سرعات مختلفة للهواء (٠,٥ – ١ – ١,٥) م/ث – ثلاث أحمال مختلفة للمحصول (٢ – ٤ – ٦) كجم / م٢، وقد تم دراسة أثر هذه المعاملات على كل من: درجة الحرارة – الرطوبة النسبية – المحتوى الرطوبى – نسبة الزيوت الطيارة – المحتوى الميكروبى الكلى، ومن أهم النتائج المتحصل عليها يمكن التوصية بالآتى: استخدام البيوت المحمية لتجفيف النعناع حيث أنه يزيد نسبة الزيوت الطيارة بنسبة ٢,١%، ١٦,٩%، ٣١,٢٥% بالنسبة للنبات الكامل وبنسبة ٣,٣٥%، ١٢,٠٣%، ١٩,١٣% للأوراق مقارنة بالتجفيف الشمسي التقليدي ويقلل من المحتوى الميكروبى الكلى، تجفيف النعناع كأوراق وذلك لتقليل الوقت المستغرق فى التجفيف بنسبة ١٢%، إجراء عملية التجفيف تحت سرعة هواء ١ م/ث حيث سجلت أعلى محتوى من الزيوت الطيارة (١,٥٢%) وأقل محتوى ميكروبي كلي (١,٤٩ مليون/جرام)، تحميل الصوبة بـ ٤ كجم/م^{2}.

المحكمــــون:

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