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OPTIMUM DRYING CONDITIONS FOR THIN-LAYER DRYING OF SWEET BASIL

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ABSTRACT

The drying characteristics of sweet basil leaves as a medicinal and aromatic plant at initial moisture content of 567%(d.b) were studied and investigated under different drying conditions. Three different drying air temperatures (35, 40 and 45 ^{o}C), three different drying air relative humidities (34, 27.3 and 22.4 %) and three different drying air velocities (1.1, 1.5 and 2.0 m/s) were functioned during this laboratory experiment. Drying equations and the values of corresponding drying constants were determined for different drying conditions. The experiment were carried out in Bhnay village, EL-Bagour center, Minofiea Governorate, Egypt in 2006.The obtained results revealed that, the drying method of sweet basil leaves gave the average drying rates of 43.4, 47.4 and 59.4 % d.b/hr for drying periods of 12,11 and 9 hr, with an average drying air temperatures (35, 40 and 45 ^{o}C) respectively. The total chlorophyll of 84, 64 and 48 % mg/100 gms samples was obtained respectively. The obtained data also showed that, the drying rate increased as the air speed increased, although the effect is not as pronounced when the air speed increased from 1.1 to 2.0 m/s. The volatile oil percentage for the three different drying air temperatures was 88.2, 84.6 and 78.9 %, respectively.

INTRODUCTION

Medicinal and aromatic plants cultivated in all over the world particularly in Egypt for both local consumption and export. The sweet is one of the most important aromatic plants in Egypt. Its area is about 1091 feddans, producing about 1951 ton/year from green plants and 29.262 ton essential oil **(The CAGMC, Annual Stistical Book 2003).** The operation of drying in Egypt is by using natural sun and wind to dry aromatic plants, but low quality and high losses occur because during drying, the aromatic plants are not protected from dust,

Res., Ag. Eng. Res. Institute., Ag. Res. Center.

rain, birds, and insects. Industrial drying by dryers provided a high levels of quality and quantities of aromatic plants. The importance of drying aromatic plants and herbs can be used for ethereal perfumes, beautiful preparation industry, agricultural and animal production, sweet and jam industry as natural materials for taste. They are used also for medicine components and medicine industry, which is used for treatments of diseases of humans and animals. **Hall (1980)** defined drying in agricultural work as the removal of moisture until the moisture content of the produce is in equilibrium with the surrounding air, usually 12 to 14 % (w. b.). **Muller et al. (1989)** used a solar heated drier (capacity 3 ton fresh matterial) developed and tested in aromatic and spice plants production to reduce drying costs and increase profitability. The design, operation and performance of the drier, which is incorporated into a plastic film covered greenhouse structure, were described. Due to modular design, the system is highly flexible and inexpensive as compared with a conventional batch drier. Operation costs are < 0.10 DM/kg, results of drying experiments for mint, sage and hops showed that solar drying was far superior to conventional drying with regard to colour, texture and active ingredient content. **Hazra et al. (1990)** indicated that drying in direct sunlight produced 24 % less vapor than required during distillation. Nedkov and Georgiv (1991) mentioned 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. **Ozguven and Tansi (19991)** found that in trials on Marjoram hortensis (origanum Marjoram) in Cukurova, Turkey, the highest fresh yield was 1077.2 kg/day and dried herb yields 492.9 kg/day and essential oil yield was 77.7 liters/day, obtained at the post-flowering stage. The main components of the oil were gamma-trepinen, p-cymol and terpineal. **Muhidong et al. (1992)** determined the that thin-layer drying rates of Kenaf. The page equation is the appropriate model to describe thin-layer drying of bast and core fibers of Kenaf. The drying constants were affected by drying air temperature and air flow rate. **Okos et al. (1992)** showed that, the constant rate period represents the removal of unbound water from the product. The water acts as if the solids are not present. The surface of the product is very wet at the beginning and the water activity in approximately on. On porous solids, the removed water is supplied from the interior of the solid. The constant rate period continues only as long as the water is supplied to surface as fast as it evaporates. The temperature of the surface is approximately the wet bulb temperature. **Mujumdar (1995)** mentioned that relatively seldom used in the manufacture of final pharmaceutical products, band dryers find wide use in drying of raw materials, especially herbs and medicinal plants, usually several bands in one above another configuration are used. Bands are made of stainless steel screens, or perforated plates. Speed from several centimeters to about 0.5 m/min are used. Band widths vary from as low as 0.5 up to 2 m, drying air temperature in the range 80-100 oC, initial moisture contents of 45-100 %, and drying rate of 5-18 kg/m2 /h are usual in industrial practice. **Pabis et al. (1998)** stated that the dryer selection depends on location, amount of product, variety of products, energy sources, economic condition of farmers, market patterns, farm setting, and time available for drying, other factors that need to be considered are:

1- initial cost per ton of dryer capacity,

2- energy consumption per kilogram of water removed,

3- maintenance costs, and 4- ease of operation.

Arafa (2001) studied drying of three types of aromatic plants (M. Pulegium, Marjoram, and Peppermint), at different temperatures of 35, 40,45,50,and 60 ^{o}C and different air relative humidities of 25, 50, 65, and 75 % through fixed temperature (45 ^{o}C) and fixed 1.1 m/s air velocity. The present work adds a new method to enhance drying rate while conserving solitaire oils from being lost.

The aim of the present work is to decrease drying time for sweet basil plants using three different drying temperatures for aromatic plants. Also to reduce the moisture content of aromatic crops to provide a good quality of crops and reduce the volume and mass for easy and low costs of transporting, storage and packing. Moreover to maintain the essential oil (volatile oil) to use when needed. Also to design and construct sweet basil dryer using locally available low-cost materials and simple technology with a view making this drying system easily available to the farmers and determination of drying characteristics of sweet basil and other some aromatic plants.

MATERIAL AND METHODS

A- Materials:

A laboratory dryer show in Fig.(1) which used in the present study was constructed, assembled and manufactured locally at the workshops of Minofia Governorate to be used for artificial drying of aromatic plants(sweet basil). The experiment were carried out in Bhnay village, EL-Bagour center, Minofiea Governorate, Egypt in 2006. The dryer consists of three components; forced air unit, an air heating unit and drying unit.

1- Forced Air unit:

This unit consists of a centrifugal fan driven by variable speed electric motor with maximum power of 1 hp (3/4 kW)at 1200 r.p.m.

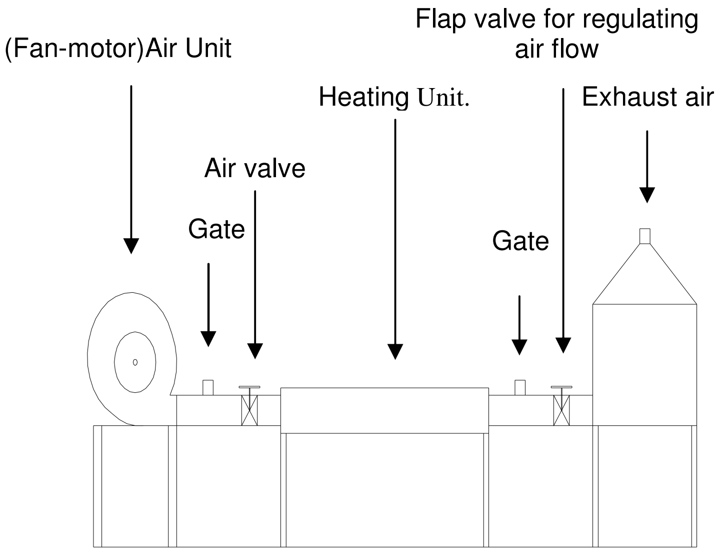

Fig (1): Schematic diagram of experimental dryer.

2-Air heating unit:

It consists of electric heater, electric switch and air heating tunnel

-Electric switch was of variable resistance to control the heating source .it was connected before heater to change the supply of electric current and provide suitable air heating for drying process.

- An electric heater of 1.5 kW, was used to heat air inside the air chamber.

- Air chamber is cylindrical in shape and made of steel sheet. The electric heater was situated in the meddle of the air chamber.

3-Drying unit :

It consists of steel sheets and angles of half-meter long, half-meter wide and one meter high. The frame was covered by double layer of steel sheet that contain in between fiber glass as an insulation material to reduce heat losses from the drying unit.

B-Instrumentation:

1-A turbometer:

A turbometer (Source: U.S.A, type: electronic, model No:5951-75,sensitivity:0.1 m/s.) was used to measure the air velocity during drying experiments.

2-Digital humidity /temperature meter :

It was used to measure the air relative humidity and temperature of drying air during drying process. The instrument has the following specifications: current:consumption approx.7mA,dimension:200x70x36 mm,weight:270 g/including battery, sensor type: humidity-precision thin film capacitance sensor, temperature-solid state-sensor, R.H range:10 to 95 % ,temp. range:0 to 60 ^{o}C .

3-Stop watch: A stop watch was used for measuring the drying time.

4- Electric balance: the electric balance was used for measuring the weight sample of sweet basil during drying, rang:1 to 5kg, sensitivity: 0.1g

C-Plant used in investigation:

Sweet basil is a bushy half-hardy perennial sub-shrub that is often grown as an annual crop. Sweet basil is 30 to 80 cm tall with descending, multi-branched stems that spill over to create a mound. Since the stems make root where they touch the soil, the mound gradually increases in diameter. If grown in a hanging basket, the stems form a cascade of attractive gray-green foliage. Sweet basil's oval leaves are soft and fuzzy, but a hand lens is needed to see the short fine hairs. They are opposite each other on a square stem which is typical of plants in the mint family. The leaves get up to an 2.5 cm long and have a wonderful, very distinctive, perfumy fragrance when bruised. The flowers are tiny, less than 3 mm long and arranged in burr like heads 12.7mm long.

D-Calculations:

1- Moisture content; dry basis (M.C.db %):

The dry basis moisture content was measured for aromatic plants under test by taking random samples from plants before drying, separated to be ready for drying and drying it in air forced electric heater at 105 ^oC at atmospheric pressure for three hours after measuring its initial moisture content before drying according to **Arafa (2001).** The moisture content was calculated according to the following equation.

$$\mathbf{Mcdb = (Mwet - Mdry) / Mdry \times 100}$$

Where:

Mcdb = Moisture content, dry basis %.

Mwet = Mass of wet samples, g. and

Mdry = Mass of dry samples, g.

2- Moisture ratio:

The data was analysed using the logarithmic model employed by **Henderson and Pabis (1961):**

$$\mathbf{MR= M-Me/Mo-Me=exp(-kt)}$$

Where:

MR = Moisture ratio, dimensionless.

Mo = Initial moisture content, %(d.b).

M = moisture content at any time, %(d.b).

Me = Equilibrium moisture content, %(d.b),at the conditions of the drying air.

k = Drying constant,h-1

t = Drying time, h

3- Drying constant (K):

According to **Hall (1980)**, the data of moisture ratios were plotted on a semi-logarithmic paper versus drying time and fitted to take the form of straight line, thus the drying process of the sweet basil can be described by Lweis equation. The slope of the fitted line represents the drying constant (k).

4- Equilibrium moisture content

Equilibrium moisture content in the previous equation was computed from the collected data using the following equation suggested by **O,Callaghan and Nellist (1971):**

$$Me=(Mi+Mf)-(Mm)2/(Mi+Mf)-2Mm$$

Where:

Me = Equilibrium moisture content, %(d.b).

Mi = Initial moisture contant at time zero, %(d.b).

Mf = Final moisture content,%(d.b).

Mm = Moisture content at half time, %(d.b).

5- Essential oil.

Determinations were conducted at the Horticultural Research Institute, at Medical and Aromatic plants Research Department, Dokki – Giza in 2005. The ratio of specific essential oil quantity (m/100g) of sweet basil plants as distillated from the dried plant to that distillated from the fresh plants was determined.

PROCEDURE

The sample of sweet basil (one kg) which artificially dried was washed to remove the mud and dirt before entering into the drying unit The moisture content was found by the standard oven method i. e. drying the sample of 10 g at 105 ^{o}C for three hour (3h). Three samples each of 10 g were taken to determine the initial moisture content using the procedure suggested by the **ASAE (1983)**. Prior to the start of the drying test, the dryer was allowed to run for 30 min with the selected of air velocities in the range of 1.1 to 2 m/s. The airflow was regulated by operating a flap valve installed between the heating unit and the centrifugal fan. The drying air temperature range was ranged between 30 and 45 ^{o}C . Drying was continued until the moisture content was in equilibrium with the temperature and relative humidity of the drying air. The start of the drying test was recorded using a stop watch. The room air temperature and relative humidity were recorded. Initially at zero time, the inlet and outlet air temperatures and relative humidity were measured. The sample was dried for 12 h during which periodic, weighing was made every 1 hour of the drying. At the end of the drying test, the moisture content of the dried sample was determined as described by **ASAE(1983)**.

RESULTS AND DISCUSSION

Drying characteristics

The collected data were analyzed to investigate the drying of sweet basil (ocimum basilicum) var. basilisum under both ambient and heated air conditions. The effects of air velocity, entry air temperature and relative humidity on drying rate and drying constants of the sweet basil were investigated. The data were analyzed using the logarithmic model employed by **Henderson and Pabis (1961):**

1-Ambient air conditions.

The ambient air at room temperature was forced through the sweet basil at different air velocities.

Fig.(2, 3 and 4) shows the effect of air velocity using ambient air on drying of sweet basil. The results indicate that velocities in the range of 1.1 to 2 m/s affected the drying rate during the initial periods and its effect diminished as the drying process proceeded. The diminished effect of air velocity during the later steps of drying indicated that it did not affect the value of equilibrium moisture content. The air velocity had very little effect on the sweet basil final moisture content when the sweet basil was dried for 12,11 and 9 h.at ambient air conditions.

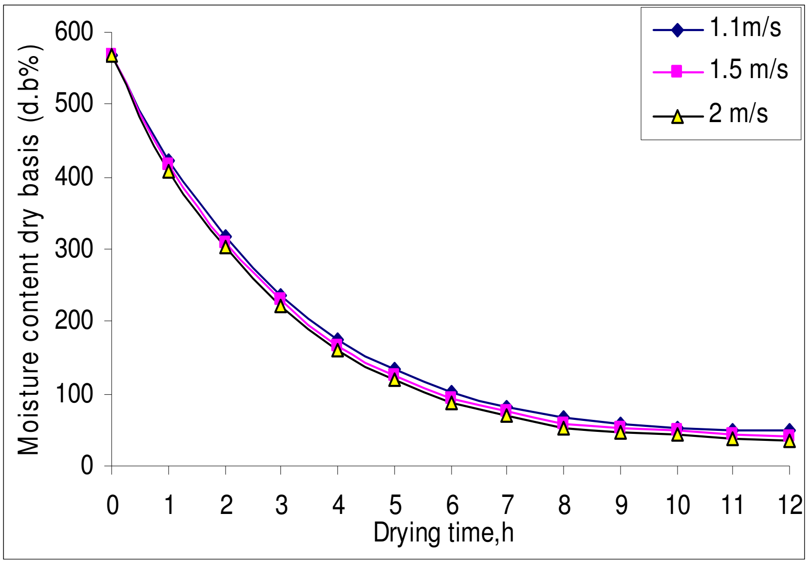

Fig.(2):Moisture content dry basis(d.b%) against drying time at 35 ^{o}C air temperature for different air velocities.

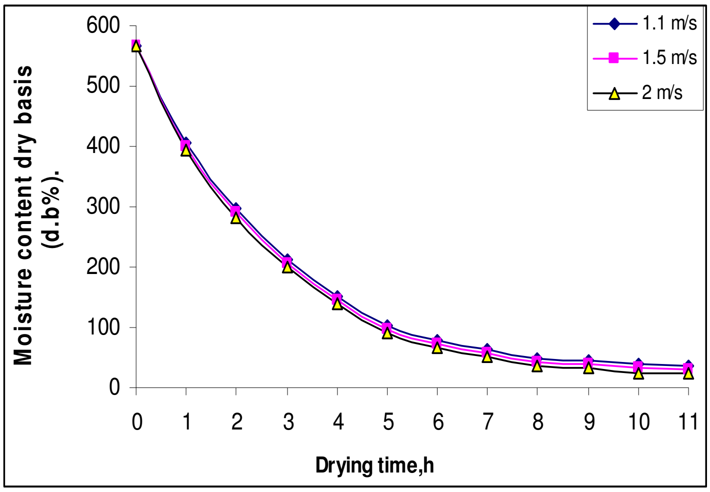

Fig.(3):Moisture content dry basis(d.b%) against drying time at 40 °C air temperature for different air velocities.

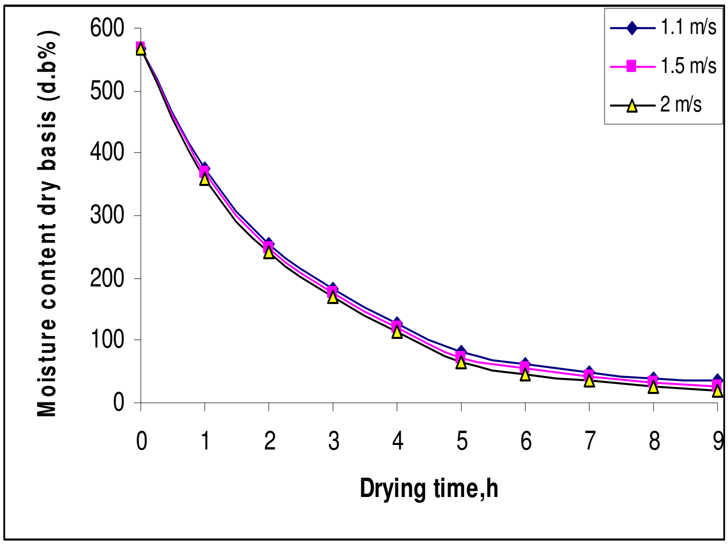

Fig.(4):Moisture content dry basis(d.b%) against drying time at 45 °C air temperature for different air velocities.

2-Effect of entering air temperature and relative humidity on drying.

Fig.(5). reveals the combined effect of inlet air temperature and relative humidity on drying a then-layer of sweet basil at air velocity of 1.1 m/s. As anticipated the higher the air temperature and the lower relative humidity the lower was the final moisture content.

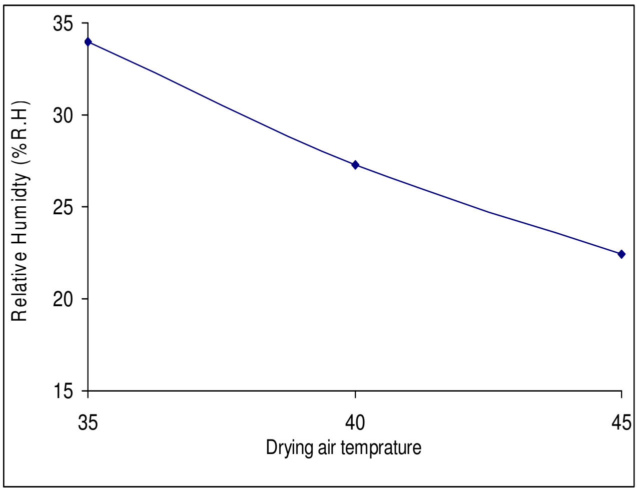

Fig.(5):Relation between drying air temperature and relative humidity.

3-Outlet air temperature as affected by drying .

Fig.(6).Shows the difference between the inlet and outlet air temperature for various inlet air temperatures. The difference between the entry and exit air temperatures was higher at zero time, then it decreased until it reached a minimum value at the end of the drying process. Initially, most of the heat of the drying air was used to evaporate water from the sweet basil resulting in lowering the air temperature.

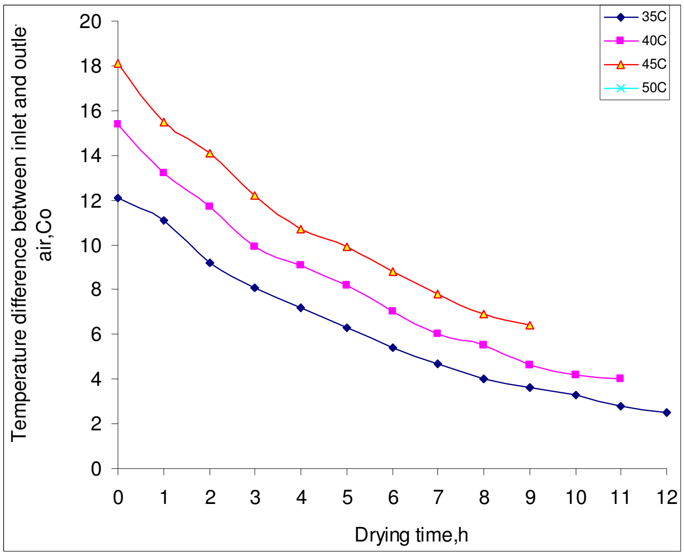

Fig.(6):Difference between inlet and outlet air temperatures against drying time for sweet basil.

As the drying process progressed less water was removed and the temperature of the drying air was slightly lowered. At the end of the drying process the outlet air temperature approached to the inlet air temperature.

4- Outlet air relative humidity as affected by drying.

Fig.(7). Shows that the outlet air relative humidity against drying time. initially, at the beginning of drying a large quantity of water was removed from the sweet basil and added to the outlet air resulting in high air relative humidity. At the end of the drying process water removed was at minimum level resulting in slight increase in outlet air relative humidity

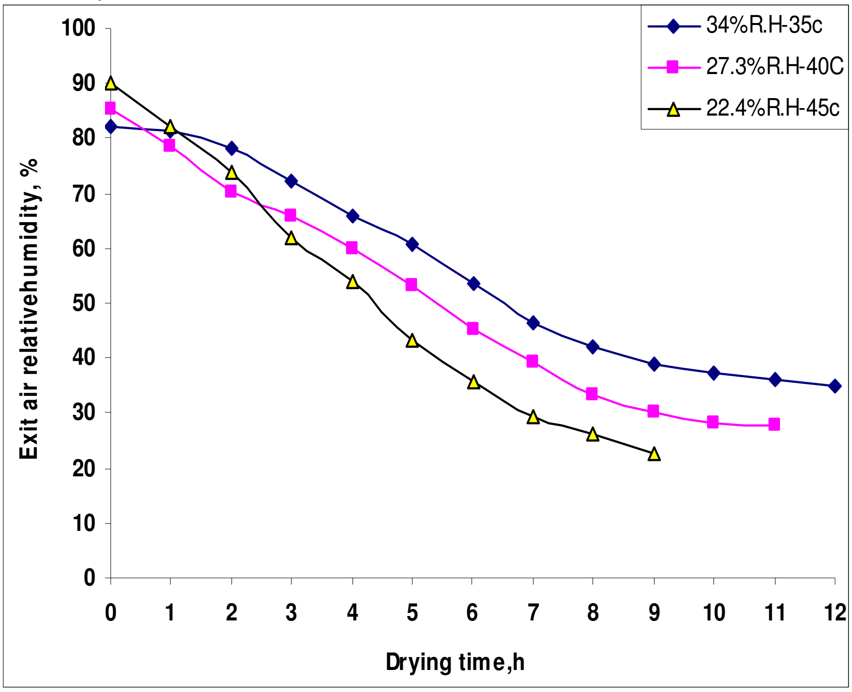

Fig.(7):Outlet air relative humidity against drying time during drying process at 1.1m/s air velocity.

5- Equilibrium moisture content.

Fig.(8):shows the equilibrium moisture contents against drying air temperature.

The equilibrium moisture contents of sweet basil were 23.39, 18.44 and 12.58 % (d.b) at 35, 40 and 45 ^{o}C respectively. Therefore, the equilibrium moisture content of sweet basil decreased with the increase of air temperature. As known the air relative humidity of the drying air decreases as its temperature increases. This decrease in relative humidity causes to reach the equilibrium moisture content at lower levels. The variation in air velocity from 1.1 m/s to 2 m/s was not affected on the equilibrium moisture content of sweet basil.

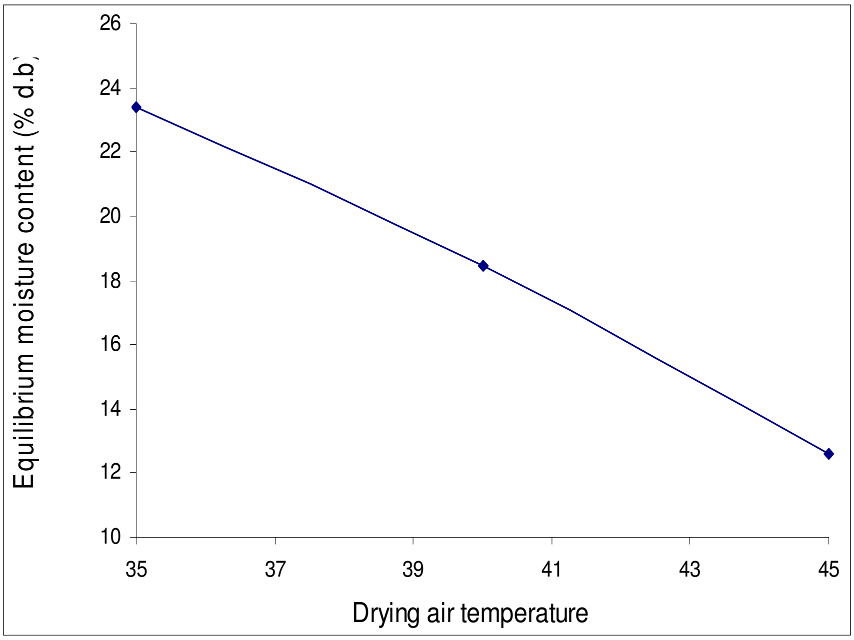

Fig.(8):Relation between drying air temperature and equilibrium moisture content of sweet basil.

6- Drying rate.

The drying rate was expressed as the percentage moisture dry basis removed per unit time (%M/h).Fig.(9), Shows the drying rate(%M/h) versus time (h) using air velocity of 1.1 m/s. The drying rate was high at the first hour compared with any period during the drying process. It decreased until it reached its minimum value at the end of the drying process.

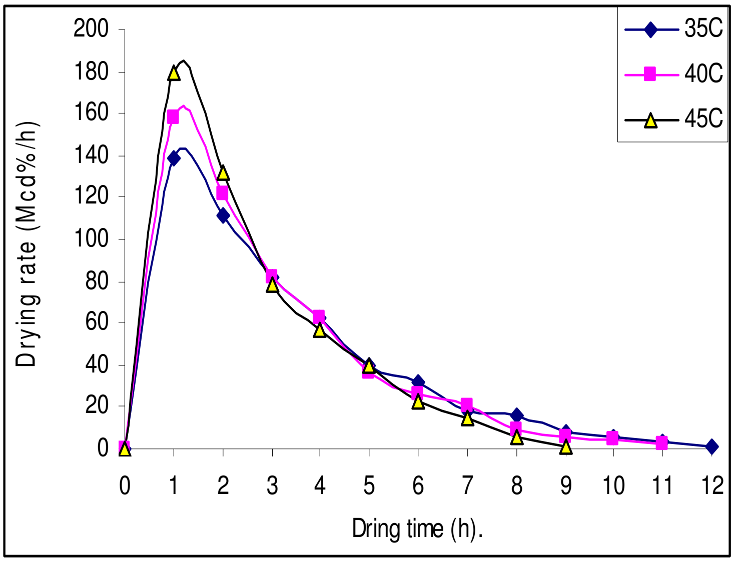

Fig.(9):The relation between drying time and drying rate at different temperatures.

7-The effect of temperature on moisture content of dry basis (d.b%).

Fig(10):illustrates the relation between the drying time and moisture content on vet basis (M.c.d %) at three drying air temperatures of 35,40 and 45 ^{o}C for sweet basil. The moisture content decreased with time for all temperatures. The moisture content decreased with the increase of air temperature at each time.

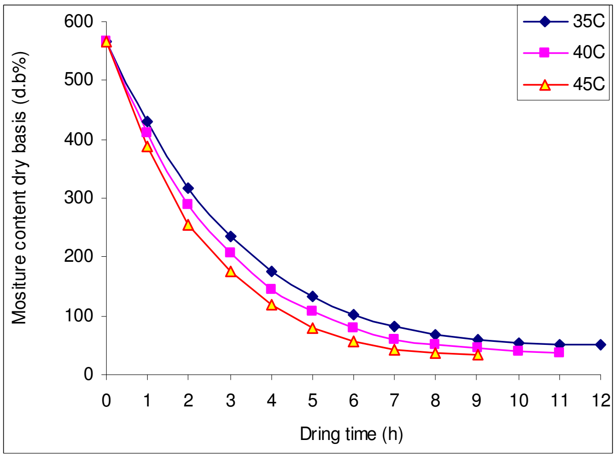

Fig.(10):The relation between drying time and moisture content dry basis(d.b%) at different temperatures.

8- Drying constants.

The logarithms of moisture ratio, MR vs. drying time are plotted in Fig.(11) which shows that except for an initial period of drying, the relationship between Log MR and drying time is linear and that the slope of the straight line is the drying constant, k.

Various values for the drying constants (k) were obtained for various entering air conditions. The best results were obtained when Ln (Mo-Me) was regressed on 0 giving coefficient of determination (r2) of values ranging between 0.985 and 0.995. Drying constants were found to be affected by the initial moisture content, and the entering air temperature and relative humidity. Using drying air at high temperature and low relative humidity resulted in numerically higher values for the k constant.

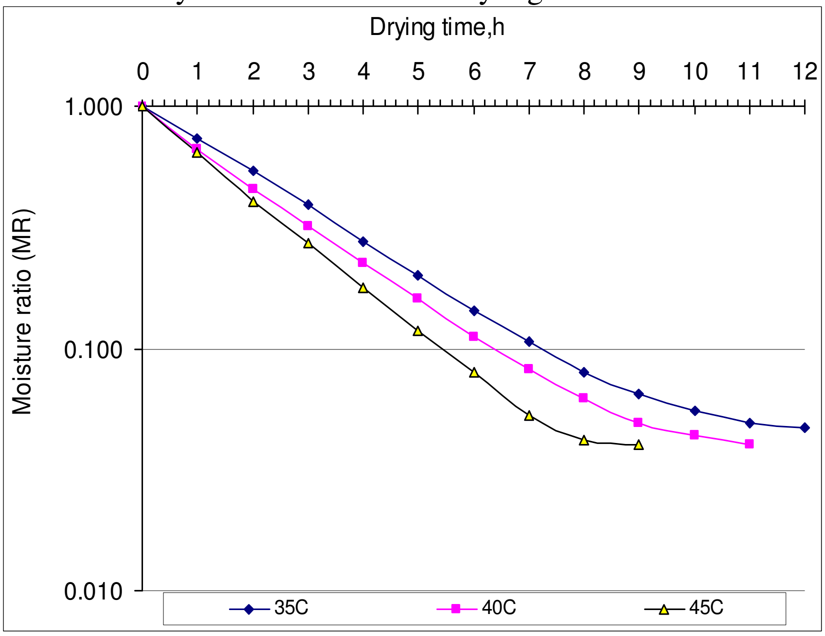

Fig.(11):Moisture ratio (MR)vs drying time, h for 1.1 m/s air velocity at different temperatures

Table (1):show relation between temperature and the drying constant of sweet basil

Temperature	Drying constant(k)
35	0.454
40	0.485
45	0.588

9- Effect of temperature and drying time on essential oil ratio for bsail plant.

Data in table(2): shows the effect of temperature (^oC) on drying time (h), essential oil ratio and chlorophyll ratio for sweet bsail plant.

Table (2): Effect of temperature on drying time, essential oil ratio and chlorophyll ratio.

Temperature (^oC)	Drying time, (h)	Essential oil ratio	Chlorophyll ratio
35	12	88.2	84
40	11	84.6	65
45	9	78.9	48

Table(2): shows that drying time decreased from 12 to 9 h by increasing temperatures from 35 to 45 ^oC. However, the essential oil ratio decreased from 88.2 to 78.9% and 84 to 48 % This ratio refers to the oil and chlorophyll lost from the plant with high temperatures.

CONCLUSION

From the previous results the following conclusions are derived:

1-The initial moisture content were 566.67% (d.b) or 85% (w.b) for sweet basil.

2-There is an inversely relation between the different temperatures used (35, 40and 45 ^oC) and relative humidity of air (34, 27.3, and 22.4 %) respectively.

3-The variation in air velocity from 1.1 to 2 m/s was not affected on the drying rate, equilibrium moisture content and final moisture content.

4-The drying constant and drying rate increase linearly with the increase of drying air temperature for sweet basil drying.

5-The moisture ratio, the moisture content, equilibrium moisture content total drying time and the essential oil decreased linearly with the increase in drying air temperatures of sweet basil drying.

6-At the start of drying process, the relative humidity of outlet drying air was higher while it decreased at the end of drying process.

7-The difference between the inlet and outlet air temperatures was higher at zero time, then it decreased until it reached a minimum value at the end of the drying process.

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الملخص العربى

الظروف المثلى لتجفيف طبقة رقيقة من نبات الريحان

د/ جمال كمال عرفه

تم تصميم وانشاء مجفف تجريبى لتجفيف نبات الريحان وتم دراسة خصائص التجفيف عند درجات حرارة متحكم فيها (35 ، 40 ، 45 م5) علي التوالى مع رطوبة نسبية (34 ، 27.3 ، 22.4%) على التوالى وسرعة هواء (1.1 ، 1.5 ، 2م/ث) على التوالى .ونفذت هذه التجارب فى قرية بهناى مركز الباجور منوفية فى عام 2006 م.

وكانت اهم النتائج المتحصل عليها كالتالى :

- المحتوى الرطوبى الابتدائى لنبات الريحان 556.7% على اساس جاف و 85% على اساس رطب .
- هناك علاقة عكسية بين درجة الحرارة والرطوبة النسبية للهواء الداخل للمجفف حيث تقل الرطوبة النسبية للهواء من 34% الى 22.4% عندما تزداد درجة الحرارة من 35 الى 45م5 .
- لا تؤثر سرعة الهواء من 1.1 الى 2م/ث بتأثير يذكر على المحتوى الرطوبى المتزن والمحتوى الرطوبى النهائي عند نهاية عملية التجفيف.
- يوجد علاقة عكسية بين درجات الحرارة وقيم كل من المحتوى الرطوبى المتزن والمحتوى الرطوبى النهائى حيث يقل المحتوى الرطوبى المتزن من 23.39 الى 12.58% والمحتوى الرطوبى النهائى من 48.67 الى 34% على اساس جاف بزيادة درجات الحرارة من 35 الى 45 درجة مئوية .
- يزداد كل من معامل التجفيف ومعدل التجفيف بزيادة درجة الحرارة .
- يوجد فرق بين درجات الحرارة الداخلة والخارجة لهواء التجفيف ويكون الفرق اكبر ما يمكن عند بداية عملية التجفيف تم يتناقص حتى يصل الى اقل ما يمكن عند نهاية عملية التجفيف .
- أعلى قيمة للرطوبة النسبية الخارجة لهواء التجفيف يكون عند بداية عملية التجفيف وتقل أثناء التجفيف حتى تصل الى أقل قيمة لها عند نهاية عملية التجفيف حيث تقترب قيمة الرطوبة النسبية الخارجة والداخلة لهواء التجفيف .
- تقل نسبة الزيت الطيار و نسبة الكلوروفيل بارتفاع درجة الحرارة.

باحث – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – دقى – جيز