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Evaluation of Different Drying Methods of Sage Leaves, Bioactive Compounds Content and Its Utilization as A Natural Additive to Flatbread

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Abstract: Medicinal and aromatic herbs require a special drying for reduce the moisture content without affecting their quality for medicinal use and improvement of food properties. In this work, the sage (*Salvia officinalis* L.) leaves were dried using five drying methods; shade, traditional sun and solar green house as natural drying methods with three load levels (2, 4 and 6 kg/m^2). In addition, electric oven with three temperature levels (45, 50 and 55°C) and microwave with three power levels (400, 640 and 800W) or power densities (4, 6.4 and 8W/g) as artificial drying methods under load 4kg/ m^2. Furthermore, three concentrations (1, 1.5 and 2%) of dried sage leaves powder were added during the preparation of flatbread to improve its properties. Drying methods were evaluated by evaluating drying rate, drying efficiency, essential oil content, phytochemicals, antioxidant activity and total microbial load for dried leaves and desirable flatbread properties. Data revealed that optimal sage leaves drying conditions at solar greenhouse dryer at load level of 4 kg/ m^2 compared to other natural drying methods (average drying rate of 0.0048 g_w/g_d.min, drying efficiency of 31.32%, essential oil content of 3.07%, chlorophyll a+b content of 0.317 mg/g d. wt., antioxidant activity of 88.98 % and total bacterial count of 2.32 log CFU/g). While, in artificial methods, the optimal essential oil content was obtained at drying with electric oven under temperature level of 50°C (average drying rate of 0.0057 g_w/g_d. min, drying efficiency of 18.76% and essential oil content of 3.03%). Whereas, the highest total phenolic content, total flavonoid content, antioxidant activity and lowest microbial load obtained by microwave oven at power of 640 W (average drying rate of 0.341 of g_w/g_d. min, drying efficiency of 45.16%). GC-MS for essential oil of dried sage leaves revealed twenty-nine constituents were identified with different drying methods with 1,8 cineole (30.73-43.97%), (+)- camphor (14.45-17.58%) and *β*-caryophyllene (1.73- 8.34%) as major constituents. The highest percentage of 1,8 cineole (43.97%) was obtained in dried leaves with solar drying method. Addition of dried sage leaves has a positive effect on flatbread properties. Results showed that different concentrations of dried sage added to flatbread, led to decrease hardness, staling rate and water activity. Therefore, flatbread with 1.5% of dried sage leaves by solar greenhouse dryer was favorable as overall acceptability and have healthier properties.

Key words: Sage (*Salvia officinalis* L.), solar greenhouse dryer, traditional sun, drying in shade, electric oven, microwave, volatile oil, microbial load, chemical composition, and food properties

INTRODUCTION

Sage (*Salvia officinalis* L.) is a medicinal and aromatic herb, the famous of genus *Salvia* which consider the largest genus of the *Lamiaceae* family (**Jahani *et al.*, 2022**), spread throughout many countries in South-East Asia, Central America, and the Mediterranean region (**Farhat *et al.*, 2013**). It cultivated in Egypt, which grows rapidly in the light yellow lands, especially in Sinai region.

Sage plant is well-known traditionally used in folk medicine to treat different conditions such as fever, bronchitis, gout, seizures, rheumatism, inflammation, tremor, diarrhea as well as nervous diseases, ulcers and hyperglycemia. Therefore, sage plant has been subjected to many studies in the last years to indicate its pharmacological actions, including antioxidant, antibacterial, hypoglycemic, anti-dementia, and anticancer properties (**Kamatou *et al*., 2008** and **Sharma *et al.*, 2019**), also it used in, perfumes, dyes, biopesticides, and food additives. It is also riches in essential oil reached to 1.85% (**Abbas *et al*., 2016)**. The main components of the oil, 1.8-cineole (16.70 - 38.70 %), camphor (8.32- 12.09 %), β caryophyllene (7.02-13.88%) and α-terpineol (4.67 -7.64%) (**Mohammed *et al*., 2021).** As well as, it contains phytoconstituents as terpenes, phenolic compounds, alkaloids, fatty acids, carbohydrates, glycosidic derivatives, flavonoids, polyacetylenes, steroids, and diterpenoids (**Kadhim *et al*., 2016** and **El-Rafie *et al*., 2022).**

All beneficial sage compositions are based on the quality of plant material, which is dependent on many factors including post-harvest treatments (**Başer and Buchbauer, 2016**) such as the drying process, which considered the most common preservation procedure (**Chua *et al.*, 2019**).

Drying is a process defined as decrement in the plant moisture content, aimed at inhibiting enzymatic and microbial activity, and consequently preserving the product (**Rocha *et al*., 2011).** The most common drying methods are shade and sun drying. However, there are many limitations such as slow drying rate, elevated risk of contamination, inadequacy of drying, and the effect of the surrounding weather conditions (**Udomkun *et al*., 2020).**

Solar drying is considered a good option as it is effectiveness, clean, renewable, less expensive source, sustainable technology **(Udomkun *et al*., 2020**). Many researches designed and evaluated the usage of solar greenhouse dryers on different plants. **Sadodin and Kashani (2011)** found that drying copra by solar greenhouse dryer led to reduce the dampness from 52.2% to 8% in 55 h under full load conditions**.** Whereas, **Arun *et al*. (2014)** designed and developed a natural solar greenhouse dryer for drying and studying characteristics of tomatoes and compared it with the direct sun method. The outcomes showed that the drying by solar dryer needed 29 h only for decreasing the tomatoes moisture content from 90% to 9% (w.b.) while the drying by direct sun needed 74 h. In addition, the dried samples quality produced from solar greenhouse is higher than that from direct sun drying. **Morad *et al.* (2017**) installed three identical solar greenhouse dryers for drying peppermint leaves under load levels (2, 4 and 6 kg/m^2). Obtained data revealed that drying plant under load level of 4 kg/m^2 tends to increase the drying rate by 24.8%.

Many drying methods such as oven and microwave drying are also used to preserve medicinal herbs. **Taha *et al.* (2015)** evaluated the influence of drying by oven at (40, 50, 60 and 70 ^{o}C) and microwave 180, 360, 540, 720 and 900 W) with three levels of load (0.5, 1.25 and 5 kg/m^2) on the essential oil content from mint leaves. They found that the highest essential oil content was obtained at temperature 50 ^{o}C with rate 1.25 kg/m^2. Also, **Saeidi *et al.* (2016)** found that the highest essential oil contents (0.94 and 0.93%) for spearmint was achieved by oven drying at 40^{o}C, followed by the shade drying, respectively. Microwave drying consider an alternative drying method to enhance the quality of dried products, since it selectively heats the product and reduces drying time as, **Demirhan and Özebk, (2010)** studied the influence of drying by microwave on basil leaves moisture content, drying time and drying rate. They noticed incrementing the microwave output power from 180 to 900 W and the sample mass from 25-100 g, the drying time reduced from 28 to 6.5 min and reduced from 16 to 44 min, respectively. Moreover**, (Ahmed, 2018)** studied the effect of microwave drying technique on sage leaves under three different power density levels of (6.7, 10 and 20 W/g). Data showed that the lowest energy consumption and highest drying efficiency for drying sage leaves were 4.96 MJ/kg H2O and 45.52% at using power density of 6.7 W/g.

The incorporation of medicinal and aromatic plants of *Lamiaceae* family to bread products has become important that, these plants containing phytochemical compounds that positively affect the properties of bread, improve its health benefits and increase shelf life. Addition of dried oregano and thyme leaves, resulted in increasing contents of antioxidant compounds and bioactive in the bread though the baking procedure negatively affected the level of these compounds (**Skendi *et al*., 2019**).

Due to importance of sage in many fields, the present study aimed to:

(1) Studying the effect of different drying methods on essential oil content, essential oil composition and chemical compositions in the sage leaves. (2) Determining the suitable drying method for sage leaves. (3) Estimating the addition of dried sage leaves to wheat flour to prepare flatbread at different concentrations.

MATERIALS AND METHODS

The present experiments were carried out during the summer season of 2022 at the EL-Quassassin, Horticulture Research Station, Ismailia Governorate, Egypt (30°33' N Latitude, 31° 56' E Longitude) in order to select the optimum drying conditions for sage leaves by natural and artificial methods that save its product quality and benefits with the least drying time and to improve good bread properties.

Materials

Sage plant

The seedlings of sage (*Salvia officinalis* L.) were planted in the Experimental Farm of EL-Quassassin, Horticulture Research Station in April 2022. The plants of sage were harvested in July 2022 and the fresh leaves were separated and used in this work.

Some sage plant physical properties, which effect on the behavior of drying process, were determined as shown in **Table (1)**.

Table (1). Sage plant physical properties.

Physical properties	Average value
Average height of plant (cm)	63.6
Average area of leaf (cm^{2})	7.52
Leaves thickness (mm)	1.16
Fresh mass of 100 leaf (g)	30.2
Fresh leaves bulk density (kg/m^3)	55.16
Leaves Moisture content (%)	77.82

Solar greenhouse dryer

Three identical solar tunnel dryers as shown in **Fig.1** were used with overall dimensions of 100 cm length, 50 cm width and 40 cm height. The dryer frame was constructed from plastic pipe and wood. A clear plastic film covered the frame 200 µm thick. The sage leaves were spread in a layer 4-6 cm thickness according to the different load levels on a black wire net. The net was installed at the batch inside bottom of a greenhouse. This black wire net is used as a solar absorber for increasing the collection efficiency of solar radiation. Electric air fan was used (active solar dryer) made in China with dimensions of 9 cm length, 3 cm width, 9 cm height and 3.6 W with 2400 rpm as shown in **Fig. 1**. The fan was controlled by a digital thermostat to operate when temperature exceeds a set degree. The air velocity was 0.5 m/sec. In the opposite side of the greenhouse, a 10x5 cm air inlet and a 20x10 cm door were installed for collecting and loading samples of sage leaves.

Microwave oven

Sage leaves were spread on the turntable glass plate with diameter 18 cm of a digital microwave oven (Smart, Model: SM-2320MS smart, 230 V, 50 MHz, input 1300 with output power 800 W, 26-liter capacity).

Electric oven

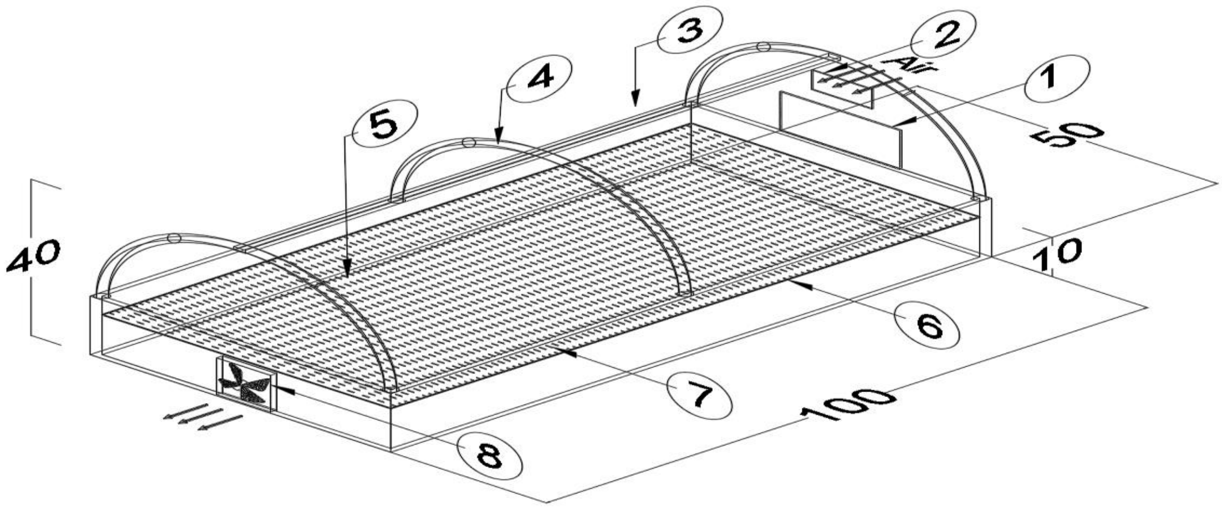
An electric oven was used to dry sage samples (Fisher Scientific, model Isotemp 737f, 60 MHz) The oven drying chamber dimensions are 50 cm length, 40 cm width and 50 cm height, made in Canada.

Traditional sun drying

Sage leaves were dried under direct sun conditions in wooden trays with dimensions of 30 x 20 cm.

Shade Drying

Sage leaves were dried in shade chamber under ambient air temperature in wooden trays with dimension 30x20 cm. The trays were protected from direct sunrays during the process of drying.



No.	Part name	No.	Part name	No.	Part name	No.	Part name
1	Front door	3	Plastic cover	5	Black floor net	7	Air chamber
2	Window	4	Pipe frame	6	Wall	8	Electric air fan

Figure 1. Schematic views of the solar greenhouse dryer

Methods

The experiments were conducted in two groups as follows:

1. Drying experiments

The experiments of sage leaves drying were studied under the following variables:

1.1. Natural drying methods:

a. Three different natural drying as follow drying in shade, traditional sun drying and solar greenhouse dryer.

b. Three different sage leaves loads (2, 4 and 6 kg/m^2).

1.2. Artificial drying methods (depend on heat from electric devices):

Initial tests showed that the use of load 4 kg/m^2 led to obtain high drying rate. So, the 4 kg/m^2 load was selected for experiments of artificial methods) as follow:

a- Microwave under three different powers levels of 400, 640 and 800 Watt or power density of 4, 6.4 and 8 W/g, respectively.

b- Electric oven under three different temperature levels of 45, 50 and 55 °C.

2. Application experiments

Three concentrations of dried sage leaves (1, 1.5 and 2%) were added to wheat flour during prepare flatbread.

Measurements

Evaluation of the drying treatments was taken into consideration under the following measurements and indicators:

Solar radiation

It was measured by pyranometer (model H-201 with an accuracy of 0.001 W/m^2). The solar radiation was recorded from 8 am to 6 pm as shown in Table 2.

Temperature and humidity

The temperature and humidity were measured by thermo-hygrometer model HC-250. The temperature ranges from -50 up to +70 °C, resolution 0.1 °C and humidity range from 20 to 90% with 1% resolution.

Moisture contents determination

The average moisture content of fresh samples was determined by drying samples in an oven at 105 ºC up to 24 h **(AOAC., 2002)**. The moisture contents of samples were calculated on wet basis (w.b., %) by the following equation:

$$M_C,\ \% = \frac{(m_w - m_d)}{(m_w)} \times 100$$

Where: M_C is moisture content; m_w is wet sage mass (kg); m_d *is* dry sage mass (kg).

Drying rate

The drying rate is the ratio of the difference between the dry basis moisture content the sample before and after drying to the time ($g_{water}/g_{dry\ matter}$) and can be calculated according to the following formula (**Falade and Abbo, 2007**):

$$\text{Drying rate, } g_w/g_d \text{ min} = \frac{(M_t - M_{t+\Delta t})}{(\Delta t)}$$

Where: M_t is moisture content ($g_{water}/g_{dry\ matter}$) at time (t); $M_{t+\Delta t}$ is moisture content ($g_{water}/g_{dry\ matter}$) at time ($t+\Delta t$)

The Drying Efficiency

The drying efficiency (η_D) is defined as the ratio between the required energy to remove the moisture from the plants and to available energy.

Solar greenhouse dryer drying efficiency

Solar radiation is the energy falling on the area of the drying chamber only.

$$\eta_D,\ \% = \frac{Wr * Lv}{I * A} \times 100$$

Where: Wr is water removal rate (kg/s); Lv is latent heat of vaporization, $2256.7*10^3$ (J/kg); I is solar intensity on horizontal surface (W/m^2); A is surface area of dying chamber (m^2).

Electric oven drying efficiency

$$\eta_D,\ \% = Wr \times \frac{LHV}{P} \times 100$$

Where: Wr is water removal rate (kg/s); LHV is Latent heat of vaporization, $2256.7*10^3$ (J/Kg); P is Power consumed (W).

P =V * I * COS φ = 1.0208 KW.

Where: V is Voltage electrical, 220V; I is the intensity of electric current, 5.8A by clamp meter and COS φ = 0.8.

Microwave drying efficiency

$$\eta_D, \% = Wr \times \frac{LHV}{P} \times 100$$

Where: Wr is water removal rate (kg/s); LHV is Latent heat of vaporization, $2256.7*10^3$ (J/Kg); P is Power consumed, 1300 (W).

Essential oil percentage (v/w %)

Essential oil percentage was estimated from dried sage leaves according to **British Pharmacopoeia (1963)** by steam distillation for 2 h. using a Clevenger apparatus.

GC-MS analysis of essential oil constituents

Essential oil constituents of the selected samples of dried sage leaves were determined using Gas chromatography – mass spectrometry (GC – MS) analysis at National Research Center, Giza, Egypt. (Agilent 8890 GC System), coupled to a mass spectrometer (Agilent 5977B GC/MSD). The constituents of the essential oil were identified using computer matching and comparing the fragmentation patterns of their masses with those listed by **Adams (1989).**

Photosynthetic pigments Content

Chlorophyll a, chlorophyll b and carotenoids contents (mg/g d. wt.) were determined in dried leaves according to the method mentioned by **Saric *et al.* (1976)**.

Total phenolic content

Total phenolic content was analyzed in dried sage leaves spectrophotometrically by using the method described by **Amin *et al.* (2006)** as milligram gallic acid equivalent per gram of dry weight sample (mg GAE/100 g d. wt).

Total flavonoid content

Total flavonoid content was determined in the dried sage leaves according to **Zhuang *et al.* (1992)** as mg Quercetin/100 g d. wt.

Antioxidant activity

Antioxidant activity of dried sage leaves and flatbread samples were measured by DPPH assay. The antioxidant activity was evaluated by 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging method according to **Brand-Williams *et al.* (1995).**

Microbial load analysis

Microbial load for dried sage leaves was determined as total count of bacteria and fungi. Ten grams of each sample were added to conical flask contained on 90-ml of 0.85 % saline solution (0.85 g NaCl /100 ml distilled water) and placed on a mechanical shaker for 15 minutes. Pour plate method used to cultivate serially diluted portions of the samples up to 10^4. Two different types of agar culture media were used. Nutrient agar medium was used to estimate total bacterial count and the plates were incubated at 37 °C for 48 h. While, total fungal count was estimated on Potato Dextrose agar medium with incubation at 28°C for 5 days. For each sample, triplicate plating was carried out. The microbial counts (colony forming units, CFU/g) were transformed into logarithms (log) and means were determined.

Preparation of flatbread

Selected dried leaves of sage samples was milled and sieved then stored in polyethylene bags until used. Wheat flour, yeast, salt and sugar were purchased from local market for bread making.

Flatbread was prepared using 0 (control), 1, 1.5 and 2% of dried sage leaves / 100 g flour, dry yeast (2 g), salt (1g) and sugar (2g) according to the method mentioned by **Yaseen *et al*. (2007).**

Sensory evaluation

Sensory evaluation for flatbread was carried out by ten untrained panel members without care of age or sex. The judges were asked to give a score from 0 to 10 for taste, flavor, color, texture and overall acceptability (**Stone *et al*., 2020).**

Chemical analysis of dried sage leaves and prepared flatbread

Moisture content, crude protein, crude fiber, crude fat, and total ash were determined according to (**AOAC., 2012).** Total carbohydrate content was calculated according to the following formula:

Total carbohydrate content (%) = (100 - ash% +fat% +crude protein% +crude fiber %).

Determination of Hardness (N)

Hardness expressed in newton (N) of flatbread was carried out after 2 (zero time), 24 and 48 h of baking by using Brookfield CT3 instrument (Brookfield Engineering Laboratories, Inc., MA 02346-1031, USA) according to the method outlined in the **AACC. (2010)** which was modified for use with flatbread by using a small-scale holder TA-JPA fixture for punching through bread samples with maximum 12.7 mm diameter probe. Penetration was applied at two points of each bread part avoiding non-representative areas. The following test settings were used:

Target =10.0 mm, Trigger load = 5.00 N, Test speed = 2.50 mm/s, Return Speed = 2.50 mm/s and # of Cycles = 2. Hardness (average of two cycles), as described in the operating instruction manual. Staling rate (%) was determined after 24h and 48h of storage using the equation of **Sahin *et al.* (2020).**

$$\text{Staling rate (\%)} = \frac{Hs - H_b}{H_b} \times 100$$

Where: Hb= crumb hardness (N) after 2 h of baking, and Hs = crumb hardness (N) at a specific hours of storage.

Determination of Water activity (a_w)

Water activity was measured at (25±2°C) using a Decagon Aqualab meter series 3TE (pullman, WA, USA). All samples of flatbread at zero time, after 3 and 6 days were broken into small pieces immediately before water activity measurement (**Shahidi *et al*., 2008**).

Statistical analysis

The collected data were presented (means ± SD), subjected to analysis of variance (ANOVA) using the computer program (**Costate**) according to **Gomez and Gomez (1984).** Means were separated using Duncan at static test 5%.

RESULTS AND DISCUSSION

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

Solar radiation

Data in **Fig. 2** shows the measured solar radiation throughout the investigations period as function of daylight time from 10 to 12 July 2022. The average solar radiation inside and outside the solar greenhouse dryer was 730.21, 676.57 and 695.49 W/m2 for outside solar dryer and 596.55, 535.5 and 563.54 W/m2 for inside solar dryer during the first, second and third day. At second day the drying process started with 425.2 and 355.8 W/m2 at 8 a.m., and then, increased through the day to reach the maximum value of 953.4 and 802.4 W/m2 at 1 p.m., then dropped to be 265.24 and 165.32 W/m2 at 6 p.m., for outside and inside solar dryer, respectively. This variation in solar radiation during period of drying process affected the solar greenhouse dryer effectiveness in heating air. Also, relative humidity and temperature inside and outside the solar dryer.

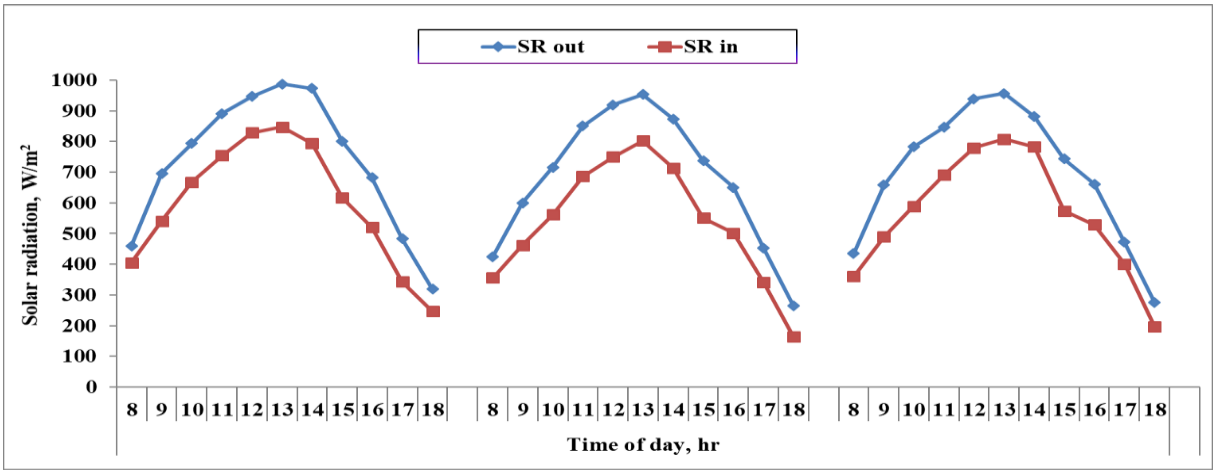


Figure 2. Average hourly solar radiation outside (SRout) and inside (SRin) the solar greenhouse dryer

Effect of different load levels on the temperature of drying air in solar greenhouse dryer

Fig. 3 displays the relation between different a sage leaves load levels in solar dryer with the variation of temperatures (internal temperatures of solar dryer added to ambient temperature). Hence, it appears that increasing the sage leaves load in the solar dryer, the temperature inside the dryer reduced. The dryer temperatures were 55.4, 54.1 and 51.8 °C at an average ambient temperature of 39.2 °C with and load levels of 2, 4 and 6 kg/m^2, respectively.

This is due to increment the evaporation from the sage leaves with increasing load level leading to reducing the bulk and dryer temperature of leaves. Drying sage leaves at load of 2 kg/m2 required one day for drying, while load of 4 or 6 kg/m2 required two days for complete drying. it was found That the measured temperature at 8 a.m. in second day, increased compared to the final measured temperature at 6 p.m. in the first drying process day This may be due to increment the storage of the thermal energy inside the solar dryer during the day and thus, the temperature will be increased inside the dryer. (**Condori *et al.*, 2001).**

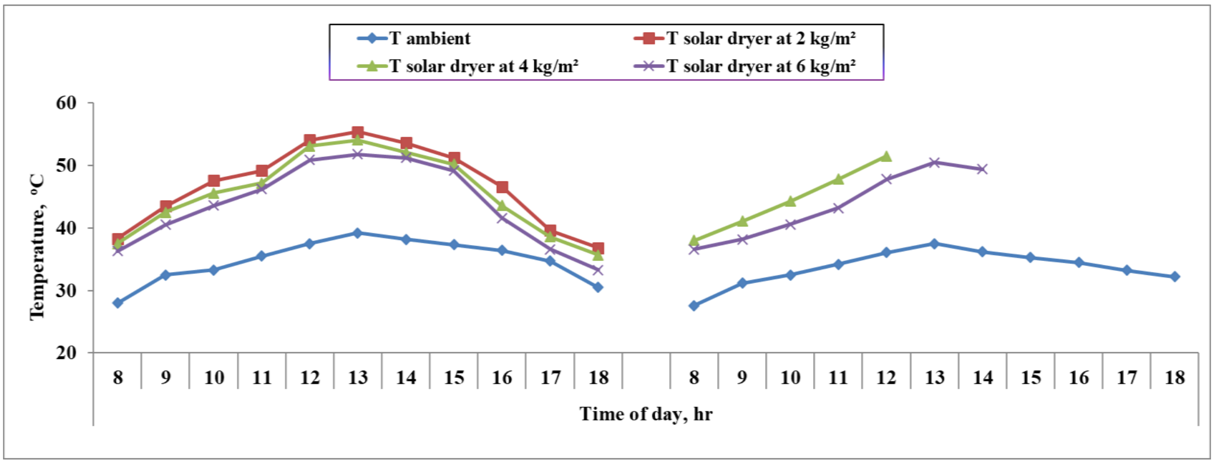


Figure 3. Effect of different load levels on the temperature of drying air in solar greenhouse dryer

Effect of different load levels on the relative humidity in solar greenhouse dryer

Fig. 4 illustrates the relative humidity as affected by different load levels at drying sage leaves. It was noted that the total average of relative humidity increased from 23.24, 27.57 to 29.46% by increasing the load levels from 2, 4 to 6 kg/m^2 during experiment period under total average of ambient relative humidity of 37.66%. In addition, the maximum relative humidity value was 37.56, 39.26 and 42.96% at an ambient relative humidity of 50.9% with load levels of 2, 4 and 6 kg/m^2, respectively. While, The minimum relative humidity value was14.2, 15.9 and 18.8% at an ambient relative humidity of 26.6% with loads levels of 2, 4 and 6 kg/m^2, respectively. The decrease in relative humidity is due to the increase in the temperature (**Condori *et al.*, 2001**).

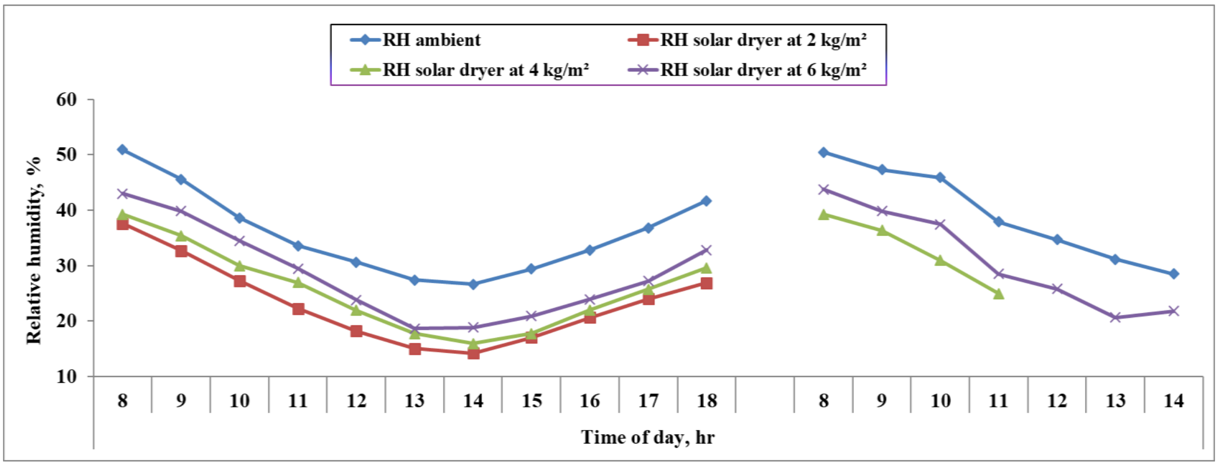


Figure 4. Effect of different load levels on the relative humidity in solar greenhouse dryer

Effect of different drying methods under different parameters on moisture content (w.b.).

Shade drying

Fig .5 shows the difference in moisture content under the shade drying method of different load levels 2, 4 and 6 kg/m^2 versus drying time. From the results, it was clear that reducing load levels led to reducing drying time of leaves. To reach the equilibrium moisture content for sage leaves from 77.82 to 8.91, from 77.82 to 8.55 and 77.82 to 8.64% w.b., the consumed drying time was 50, 60 and 65 hours for loads 2, 4 and 6 kg/m^2, respectively. It was observed that drying in shade consumed more time than all drying methods under the same condition.

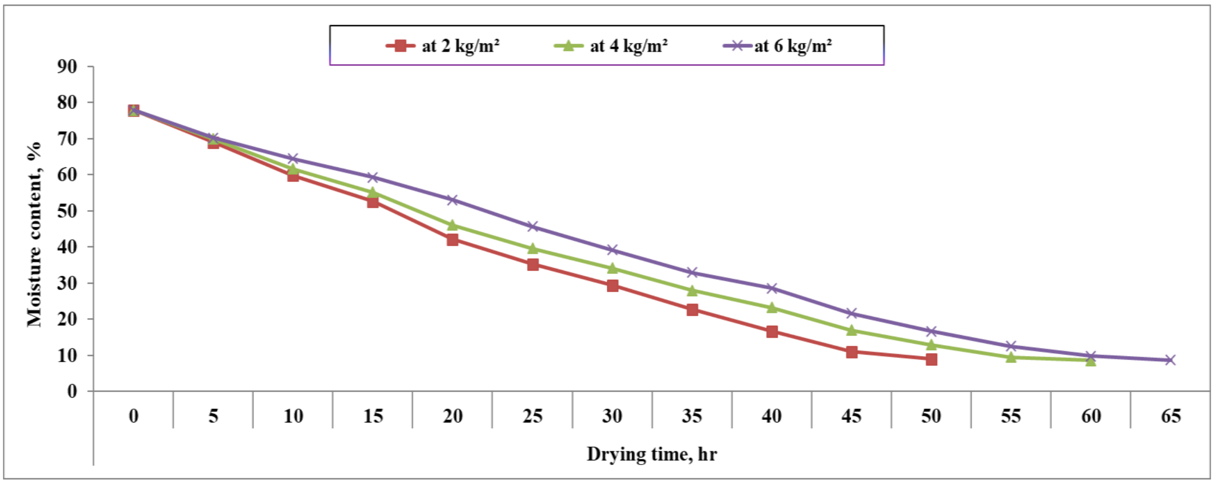


Figure 5. Effect of shade drying method on moisture content (w.b.) at different load levels

Traditional sun drying

Fig. 6 displays the relation between different load levels with moisture content and drying time at traditional sun drying method. Hence, it appears that the required drying time increased by increasing sage leaves load. From the results, it can be seen that load levels of 2, 4 and 6 kg/m^2 for traditional sun method for drying sage samples from the initial to the final moisture content of 8.09, 8.03 and 8.04%

w.b. only took 18, 21 and 26 hours. It was observed that drying sage leaves by traditional sun method took more drying time than solar greenhouse dryer under the same condition.

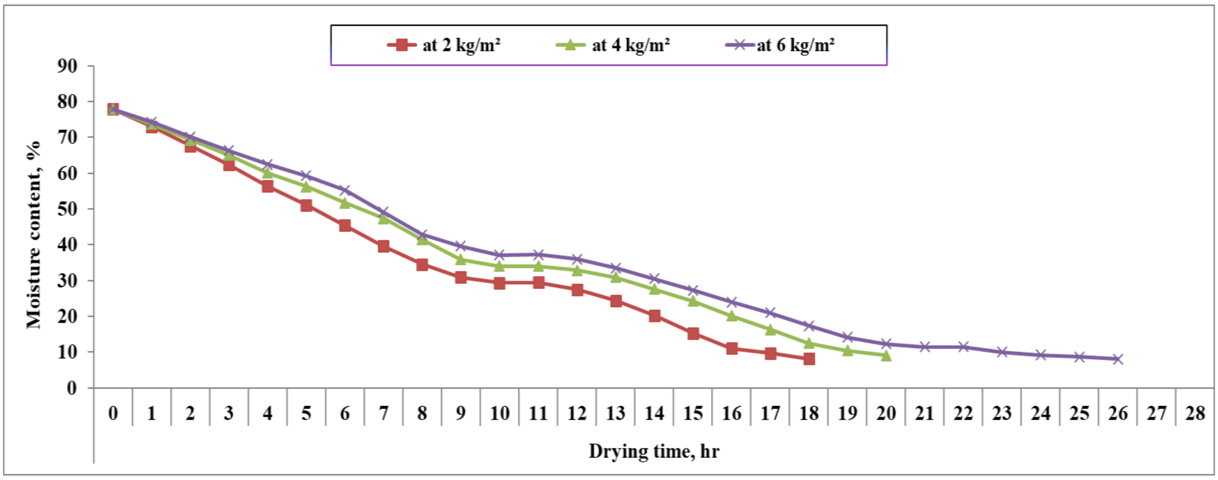


Figure 6. Effect of traditional sun drying method on moisture content (w.b.) at different load levels

Solar greenhouse drying

Fig. 7 displays the relation between moisture content and drying time at three levels of loading of 2, 4 and 6 kg/m^2 for drying by the solar greenhouse dryer. To achieve the suitable moisture content of 8.3, 8.19 and 8.09 % w.b. for sage leaves using solar drying from the moisture content of fresh leaves 77.82% w.b., it required 9, 13 and 15 hours, at load levels of 2, 4 and 6 kg/m^2, respectively. The results clearly showed that the required drying time increased by increasing sage leaves load. In addition, using solar greenhouse dryer for drying sage leaves led to reduce in drying time by 50, 38.1 and 42.31% compared with traditional sun method. This may be due to the greenhouse effect associated with transparent plastic films.

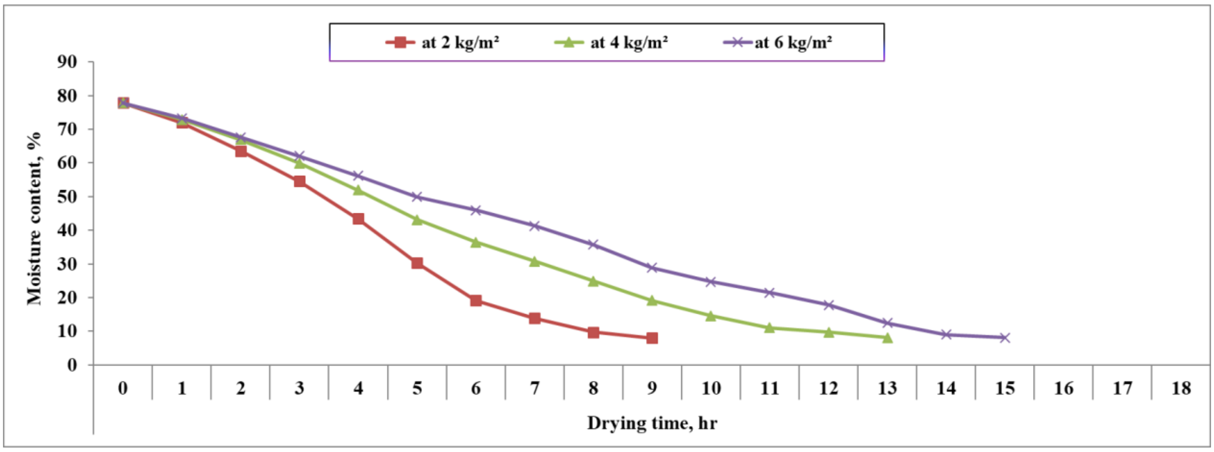


Figure 7. Effect of solar greenhouse drying method on moisture content (w.b.) at different load levels

Electric oven drying

The effect of electric oven drying method at different temperature levels on moisture content of sage leaves are illustrated in **Fig. 8.** The moisture content of sage leaves was reduced with increased drying time under the various drying of temperatures. The effect of electric oven drying method on moisture content of sage leaves at different temperature levels are illustrated in **Fig. 8.** The moisture content of sage leaves reduced with increment drying time under various drying temperatures. The equilibrium in moisture content of sage leaves was achieved using electric oven temperature levels (45, 50 and 55 °C) with loading level 4 kg/m^2. The results showed that, for reducing the moisture content to 8.53, 8.34 and

8.15% w.b. required drying time of 13, 10 and 8 hours at temperature levels 45, 50 and 55 °C, respectively, with load 4 kg/m^2.

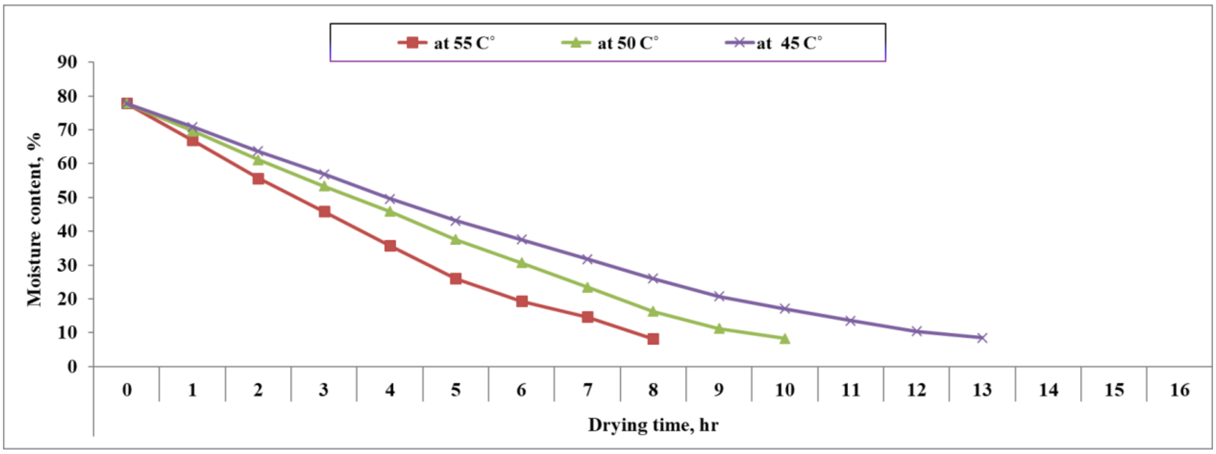


Figure 8. Effect of electric oven drying method on moisture content(w.b.)at different temperatures

Microwave oven drying

Fig. 9 illustrates the microwave drying curves of drying time versus moisture content and the power levels (400, 640 and 800 W at load level of 4 kg/m^2) or power density (4, 6.4 and 8 W/g). This figure shows the equilibrium moisture content of 8.35, 8.54 and 8.72% w.b. for sage leaves using microwave drying required drying time of 14, 10 and 8 min at power density of 4, 6.4 and 8 W/g, respectively. It is apparent that moisture content is reduced continuously with increasing drying time. It is apparent that leaves moisture content is reduced with increasing drying time, continuously. The drying process for sage leaves occurs in the range of the falling period. This displays that diffusion is the physical mechanism of dominant governing moisture movement in the leaves samples, other authors found the same results during drying some plant (**Akpinar *et al.*, 2003**).

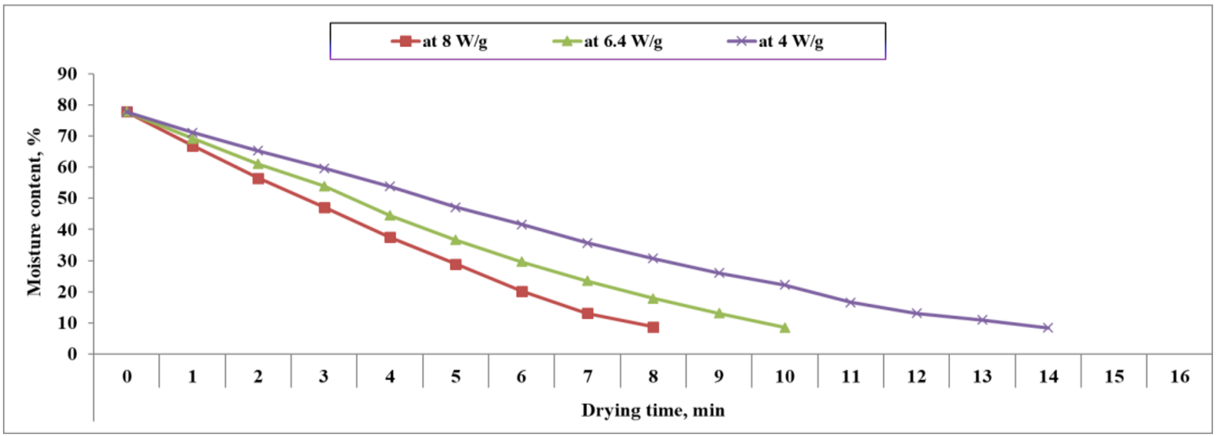


Figure 9. Effect of microwave oven drying method on moisture content (w.b.) at different power density

Effect of different drying methods under different parameters on drying rate

Figs. 10 to**14** show the influence of different drying methods under different parameters on sage drying rate (**$g_w/g_{d.}$ min)**. The drying rate was decreased by increased drying time, continuously. It is obviously noted that, all the drying operations were occurred in falling period and in drying period, there was not any constant-rate, this data is a compatible with **(Akpinar *et al.*, 2003)**. Data show that, the drying rate is a strong function of load levels, drying methods and consumed time. Drying rate is high at the first hours of operation for all temperatures and reduces with time. This is a result of reduced internal moisture content resistance at the drying operation beginning; therefore, when energy is affected, the moisture content can evaporate, easily by move it to surface, this result is in agreement with (**Emmanuel and Fakayode 2011**). In addition, the drying operation needs more energy for breaking the molecular bond of moisture whereas constant energy was supplied; so, it needs longer time, therefore sage drying rate reduced. While, loads levels affected on the drying rate. Decreasing load led to decreasing drying period, which caused increasing the drying rate in the first hours the reducing the rate continuously (**Fatouh *et al.*, 2006**).

Concerning the influence of different load levels on drying rate at different drying methods (**Figs. 10, 11 and 12**) the curves show the decreased of drying rate by increasing the sage loads at different drying methods (shade, traditional sun, and solar greenhouse) under the same conditions. The average drying rate was 0.00114, 0.00095 and 0.00088 g_w/g_d. min. for shade drying, 0.0034, 0.0029 and 0.0024 g_w/g_d. min. for traditional sun drying, and 0.0064, 0.0048 and 0.0038 g_w/g_d. min. for solar greenhouse drying under loads of 2, 4 and 6 kg/m^2, in that order. It appears that, the greenhouse solar dryer gets higher drying rate than shade and direct sun methods.

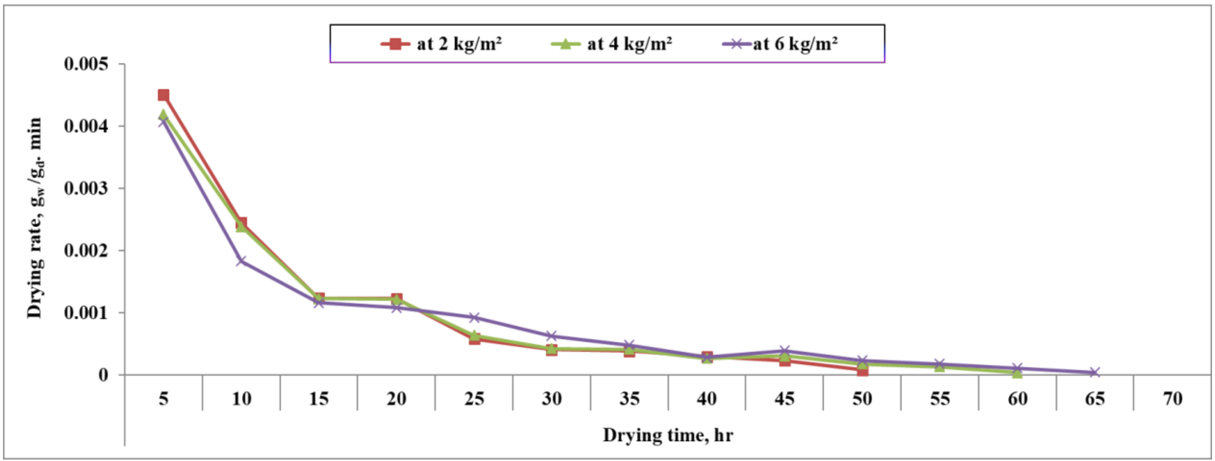


Figure 10. Effect of shade drying method on drying rate (gw/gd. min) at different load level

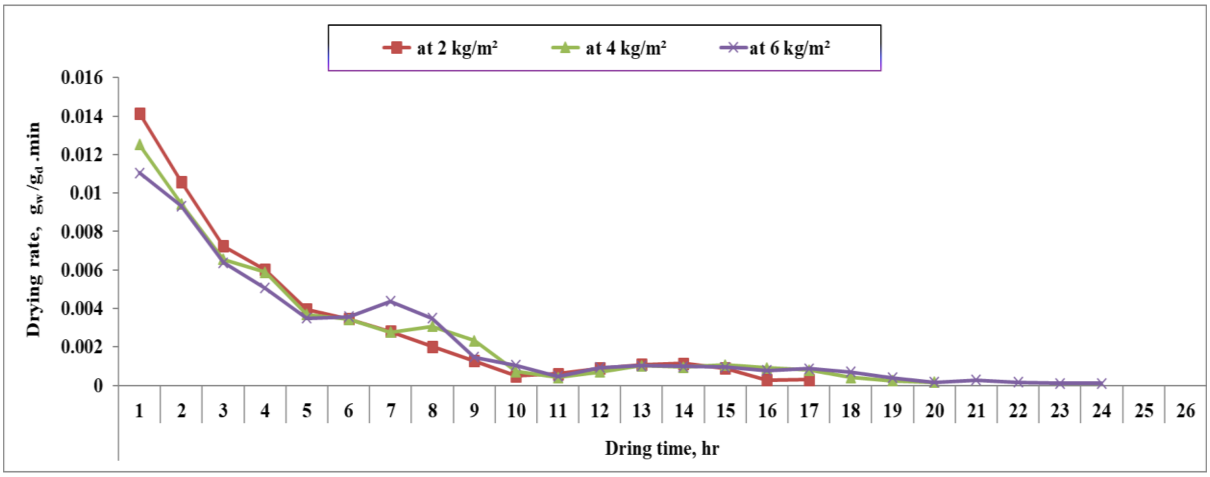


Figure 11. Effect of traditional sun drying method on drying rate (gw/gd. min) at different load levels

Relating to the influence of different temperature levels on the drying rate at oven drying method under load 4 kg/m^2, (**Fig. 13**), the results show that, the sage drying rate increased by increasing temperature levels. The average drying rate was 0.0044, 0.0057 and 0.0071g_w/g_d. min. at temperature levels 45, 50 and 55 °C, respectively, under load of 4 kg/m^2.

Regarding the effect of power density (radiation power at 4 kg/m2) on drying rate at microwave oven drying method, (**Fig. 14**), results show that the sage drying rate increasing by increasing power density and decrease by decrease in moisture content. Where, during the higher power, heat transfer within the sage sample was faster because more heat was produced inside the sample generating a large

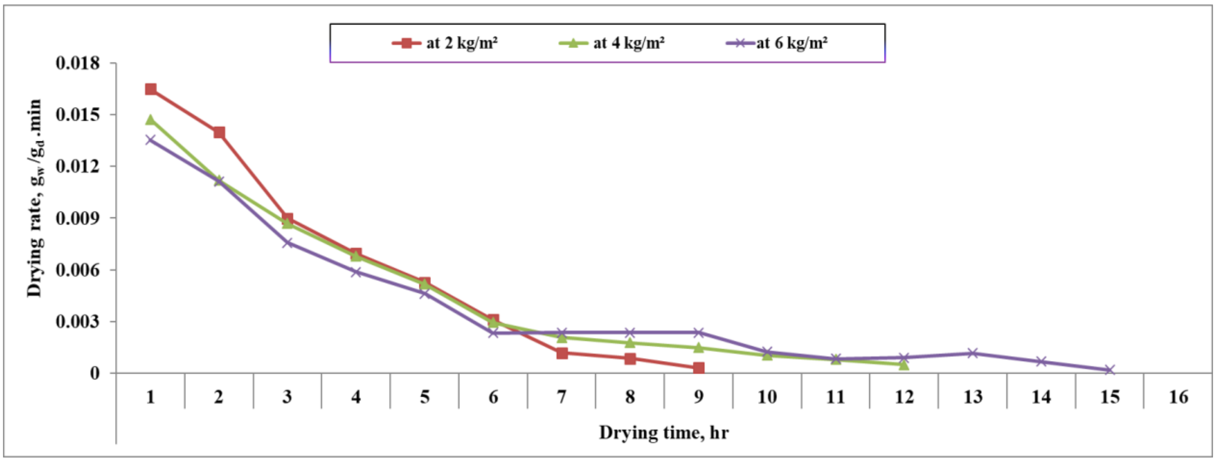


Figure 12. Effect of solar greenhouse drying method on drying rate (gw/gd. min) at different load levels

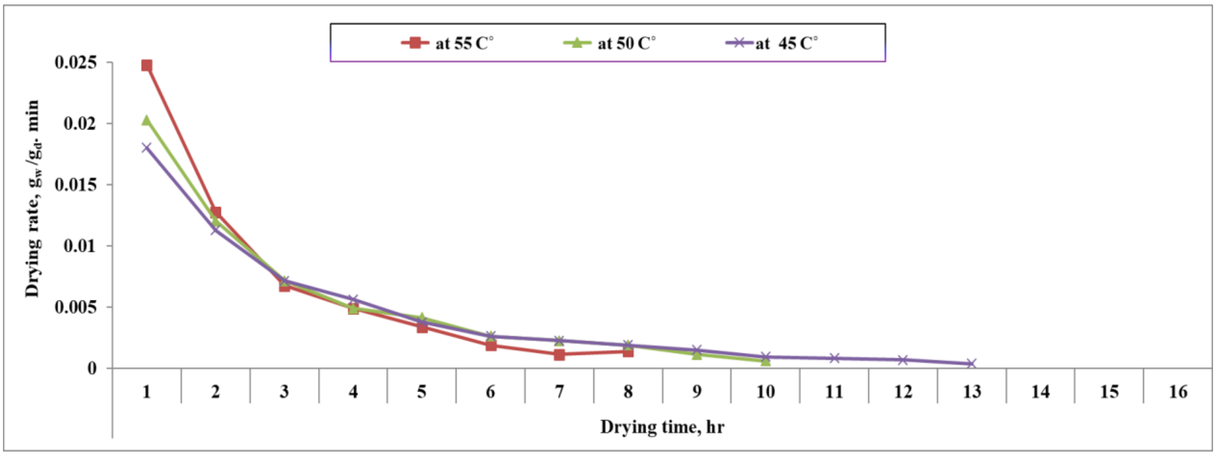


Figure 13. Effect of electric oven drying method on drying rate (gw/gd. min) at different temperature levels

vapor pressure inequality between the surface and the center of sample due to the microwave volumetric heating. At the drying process beginning, it was noted that the drying was higher, while the sample moisture was higher. The average drying rate was 0.244, 0.341 and 0.426 g_w/g_d. min. at power density of 4, 6.4 and 8 W/g (400, 640 and 800 Wat load of 4 kg/m^2), respectively.

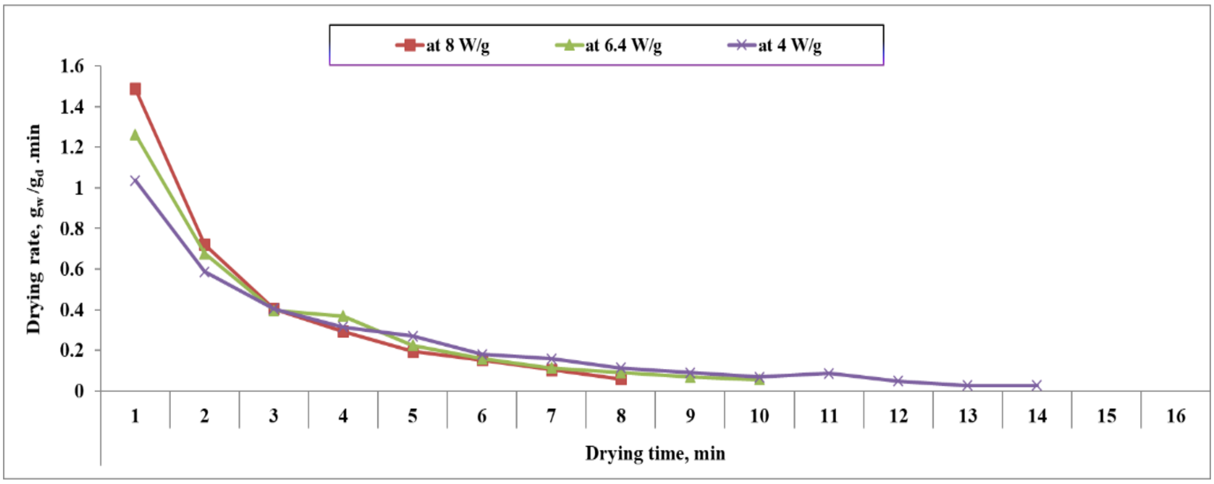


Figure 14. Effect of microwave oven drying method on drying rate (gw/gd. min) at different power density levels

Effect of different drying methods under different parameters on drying efficiency

Fig. 15 shows the relation between the drying efficiency and natural drying methods (shade, traditional sun, and solar greenhouse) and different loads levels of 2, 4 and 6 kg/m^2. Results clarify that the drying efficiency of natural methods was affected by the mass of sage with non-significant difference between load 4 and 6 kg/m^2. Where, the drying efficiency increased by increased load level, and the highest daily drying efficiency was obtained at solar greenhouse dryer. The drying efficiency values were 19.14, 31.32 and 34.45% for solar greenhouse dryer; and 8.19, 14.64 and 17.4% for traditional sun drying, while for shade drying were 3.45, 5.74 and 7.94 % at levels of loading 2, 4 and 6 kg/m^2, respectively.

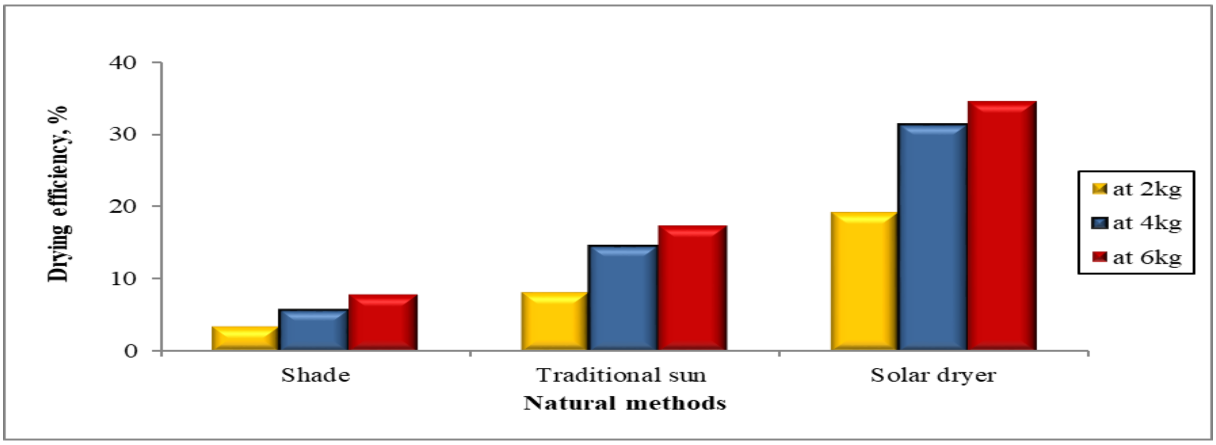


Figure 15. Effect of natural drying methods on drying efficiency at different load levels

Concerning the effect of different temperature levels and power density (radiation power at 4 kg/m^2) on the drying efficency for artificial methods (electric oven and microwave oven, respectively) at load 4 kg/m^2 (**Fig. 16**), it was observed that, the drying efficiency of microwave was higher than drying by electric oven. In addition, Data show that the power density affected the microwave drying efficiency with non-significant difference between load 6.4 and 8 W/g. Where, the drying efficiency decreased by decreased power density. The highest daily drying efficiency for oven was obtained by increasing temperature level with non-significant difference between temperature 55 and 50 ^{o}C. The values of drying efficiency were 31.25, 45.16 and 47.55% for microwave at power density 4, 6.4 and 8 W/g (400, 640 and 800Wat load of 4 kg/m^2), respectively; while for electric oven drying were 14.31, 18.76 and 20.1% at temperature levels 45, 50 and 55 ^{o}C, respectively; under load of 4 kg/m^2.

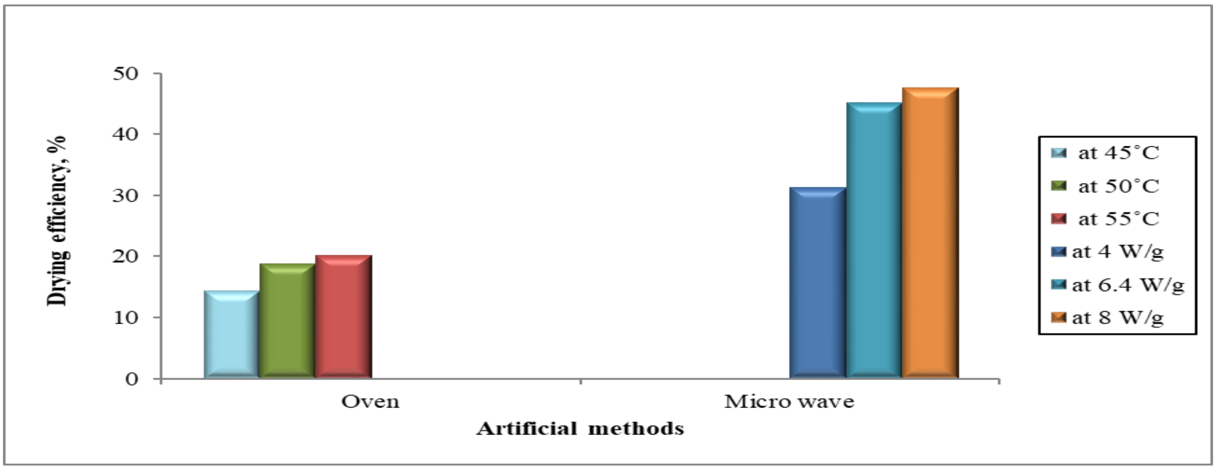


Figure 16. Effect of artificial drying methods on drying efficiency at different parameters under load of 4 kg/m^2

Effect of different load levels in natural drying methods on essential oil content (%) of sage leaves

Data in **Table (2)** indicates the effect of different drying methods at load levels 2, 4 and 6 kg/m^2 on the essential oil content. It was found that the highest essential oil content (3 and 2.95%; 2.87 and 2.83%; 3.09 and 3.07%), respectively, for shade, traditional sun, and solar greenhouse drying methods was found at load level 2 and 4 kg/m^2 with no significant difference among themselves. While, drying at load level 6 kg/m^2 lead to decrease the essential oil content. Increasing load level lead to increasing drying time, which resulted in decreasing the essential oil content. Our results agreed with **Taha *et al.* (2015)** on mint and **Dalia *et al.* (2015)** on peppermint**.**

Table (2). Effect of different load levels in natural drying methods on essential oil content (%) of sage leaves

Drying method / Load level (kg/m^2)	Shade	Traditional sun	Solar greenhouse dryer
2	3.00 a±0.087	2.87 a±0.044	3.09 a±0.030
4	2.95 a±0.056	2.83 a±0.079	3.07 a±0.026
6	2.77 b±0.062	2.62 b±0.026	2.92 b±0.012

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.

Effect of different drying methods on essential oil content (%), chlorophyll a+b content (mg/g d. wt.) and carotenoids content (mg/g d. wt.) of sage leaves at load level 4 kg/m^2.

Effect of different drying methods on essential oil content, chlorophyll a+b, and carotenoids contents at load level of 4 kg/m^2 was described in **Table (3).** The highest essential oil content (3.07 %) was found in dried sage leaves by solar greenhouse dryer followed by dried sage leaves by the oven at 45 and 50 °C with non-significant difference between them. While the lowest essential oil content found in dried leaves by microwave at 800W. These results are in line with **Sellami *et al*. (2012**) on sage. In concerning the contents of chlorophyll a+b and carotenoids, the highest contents were achieved by using microwave drying method followed by solar greenhouse dryer and in shade drying methods. Our results agreement with those observed by **Mirmostafaee *et al.* (2014**) on peppermint, **Taha *et al*. (2015)** on mint and **Yilmaz *et al*. (2021)** on thyme.

Table (3). Effect of different drying methods on essential oil content (%), chlorophyll a+b content (mg/g dry wt.) and carotenoids content (mg/g dry wt.) of sage leaves at load level 4 kg/m^2

Character / Drying method	Essential oil (%)	Chlorophyll a+b content (mg/g d. wt.)	Carotenoids content (mg/g dry wt.)
Shade	2.95b ±0.056	0.740e±0.003	0.350d±0.003
Traditional sun	2.83c ±0.079	0.744e±0.006	0.301f±0.008
Solar greenhouse dryer	3.07 a±0.026	0.798d±0.006	0.317e±0.006
Oven at 45°C	3.05a±0.050	0.696 f±0.006	0.272 g±0.006
Oven at 50°C	3.03ab±0.070	0.715ef±0.017	0.286 g±0.009
Oven at 55°C	2.71d±0.017	0.614g±0.002	0.236 h±0.009
Microwave at 400 W	0.80 e±0.070	1.126c±0.007	0.379c±0.008
Microwave at 640 W	0.68f ±0.050	1.520a±0.035	0.690a±0.008
Microwave at 800 W	0.50g ±0.017	1.314b±0.027	0.621b±0.012

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.

Effect of different drying methods on total phenolic content (mg GAE/100 g d. wt.), total flavonoid content (mg Quercetin/100 g d. wt.) and antioxidant activity (%) of sage leaves at load level 4 kg/m^2.

Data in **Table (4)** describes the effect of different drying methods on total phenolic content, total flavonoid content and antioxidant activity of sage leaves at load level of 4 kg/m^2**.** It was noted that, the highest total phenolic contents (1.907 mg GAE/100 g d.wt.) was found in dried sage leaves by microwave followed by dried leaves using solar greenhouse dryer with non-significant difference among themselves. While, the highest total flavonoid content (0.190 mg Quercetin/100 g d. wt.) was achieved in dried leaves by solar greenhouse dryer. These results are parallel with **Saifullah *et al*. (2021)** on lemon-scented tea tree leaves and **Yilmaz *et al*. (2021)** on thyme. According to **Inchuen *et al.* (2010),** that the highest of total phenolic content in microwave-dried sage leaves may be due to the intense heat generated from the microwave creates a high vapor pressure and temperature in the leaves tissue, resulting in the disruption of leaves cell wall polymers thus causing extraction of more phenolic compounds. The antioxidant activity is affected by the content of total phenolic and flavonoids. The impact of different drying techniques on antioxidant activity is revealed in **Table (4).** Results showed that dried leaves by solar greenhouse and microwave had the highest level of antioxidant activity (88.98 and 88.93%,), respectively. Our results are in harmony with **Hihat *et al*. (2017)** on coriander leaves. Moreover, the observed increment in antioxidant activity under conditions of high temperature or power density may be due to the generation and accumulation of Maillard-derived melanoidins, which have varying degree of antioxidant activity, enhancing the antioxidant properties (**Miranda *et al*., 2009).**

Table (4). Effect of different drying methods on the total phenolic content (mg GAE/100 g d. wt.), total flavonoid content (mg Quercetin/100 g d. wt.) and antioxidant activity (%) of sage leaves at load level 4 kg/m^2.

Character / Drying method	Total phenolic content (mg GAE/100 g d.wt.)	Total flavonoid content (mg Quercetin/100 g d.wt)	Antioxidant activity (%)
Shade	1.154d ±0.007	0.063e±0.005	86.79b ±0.187
Traditional sun	1.626 c±0.005	0.100c±0.005	87.61 b±1.207
Solar greenhouse dryer	1.878 a±0.098	0.190a±0.006	88.98a ±0.035
Oven at 45°C	1.761 b±0.026	0.100 cd±0.009	85.45c ±0.040
Oven at 50°C	1.768 b±0.023	0.096 d±0.009	87.00 b±1.010
Oven at 55°C	1.788 b±0.011	0.110c± 0.010	87.48 b±0.501
Microwave at 400 W	1.763b ±0.007	0.109cd±0.009	87.03b ±1.001
Microwave at 640 W	1.907 a±0.007	0.134b±0.006	88.93a±0.030
Microwave at 800 W	1.802b ±0.046	0.113c±0.007	87.23 b±0.488

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.

Effect of drying methods on essential oil constituents

Studying the effect of drying methods on the essential oil composition of sage leaves is very important; where it is considered an important matter in determining the quality of the oil. Essential oils extracted from dried leaves at shade, traditional sun, solar greenhouse, oven at 50**°C** and microwave at 640 W drying methods at load 4 kg/m^2 of sage leaves were subjected to GC-MS analysis. The influence of various drying methods on essential oil compositions was presented in **Table (5)** and **Fig. 17.** A remarkable variation appears in the percentage of essential oil components obtained by different drying methods. In total, twenty-nine components were identified in certain drying methods while they were absent during others. It was found that the main components of the essential oil of dried sage leaves are 1.8 cineole (30.73-43.97%), (+)- camphor (14.45-17.58%), *β*-caryophyllene (1.73- 8.34%), α-terpinyl acetate (2.88-6.76%), camphene (4.08- 7.25%), β-pinene (4.44 -7.16%), α- thujone and *β*-thujone (thujones overall 2.13-3.49%). It was noted the highest percentage of 1,8 cineole (43.97%) which consider the main component, found in essential oil of dried leaves by solar greenhouse dryer while the lowest content (30.73%) was found in essential oil of dried leaves by using microwave. The second main component was (+)-camphor, which showed the highest percentage (17.58%) in dried leaves in shade. Whereas, However, the highest percentage of β-caryophyllene (8.34%) and (-)-bornyl acetate (6.76%) was appeared in essential oil of dried leaves by microwave. Some compounds appear due to drying by microwave method as *β*-phellandrene, sabinene hydrate, cis-*β*-terpineol, isocamphopinone, aromandendrene, spathulenol and caryophylene oxide and absent in essential oils of other drying methods, may be due to the effect of high temperature which lead to probably as a consequence of oxidation reactions, hydrolysis of glycosylated forms, or some release of substances (**Xing *et al*., 2017)** . Similar results were obtained by **Sellami *et al.* (2012*)*** and **Sadowska *et al*. (2017)** on sage**.** The variation in the compounds due to the effect of different drying methods gives the possibility to choose the suitable drying method for specific sage purpose. To preserve the optimal antiseptic, antimicrobial and anti-inflammatory properties of sage, for which 1,8 cineole according to **Delamare (2007),** are responsible, solar greenhouse and oven at 50 **°C** should be applied. On the other hand, the optimal methods for recovery of *β*-Caryophyllene, α-humulene, d-viridflorol, according to **Ghorbani and Esmaeilizadeh (2017)** responsible for antioxidative and anticancer activities, microwave drying method should be used.

Table (5). Chemical composition of the essential oils extracted from dried leaves of sage using different drying methods at load level 4kg/m^2

No	Drying method / Component	RT	Shade	Traditional sun	Solar greenhouse	Oven at 50	Microwave at 640W
1	**α-Thujene**	6.17	--	0.4	--	--	0.44
2	**α-Pinene**	6.37	5.06	5.8	5.25	5.02	3.52
3	**Camphene**	6.71	6.41	7.25	5.47	5.89	4.08
4	**β-Phellandrene**	7.31	--	--	--	--	0.32
5	**β-Pinene**	7.40	6.99	7.16	7.04	6.31	4.44
6	**β-Myrcene**	7.72	2.02	2.07	2.12	1.48	0.78
7	**α-Terpinene**	8.42	--	0.42	..	--	0.52
8	**D-Limonene**	8.75	2.63	2.74	2.75	1.81	1.09
9	**1,8-cineole**	8.84	40.79	41.05	43.97	42.5	30.73
10	**γ-Terpinene**	9.56	0.66	0.75	0.7	0.67	0.94
11	**Sabinene hydrate**	9.82	--	--	--	--	0.4
12	**cis-β-Terpineol**	10.69	--	--	--	--	0.38
13	**Thujone**	10.89	2.27	2.06	2.24	1.52	1.41
14	***β*-Thujone**	11.19	1.22	1.22	1.09	0.94	0.72
15	**(+)-Camphor**	12.00	17.58	16.8	14.45	16.92	15.57
16	**trans-3-Pinanone**	12.45	0.78	0.73	0.66	0.71	0.71
17	**Camphol**	12.60	2.82	2.23	2.56	2.5	3.56
18	**Isocamphopinone**	12.84	--	--	--	--	0.37
19	**Terpinen-4-ol**	12.91	0.98	0.82	0.87	0.73	1.12
20	**α-Terpineol**	13.28	2.34	1.9	2.57	2.69	3.24
21	**Myrtenol**	13.44	0.64	--	--	0.63	1.01
22	**(-)-Bornyl acetate**	15.88	1.68	1.72	1.31	1.87	2.64
23	**α-Terpinyl acetate**	17.55	3.39	2.88	4.13	3.13	6.76
24	***β*-Caryophyllene**	19.44	1.73	1.99	2.27	3.09	8.34
25	**Aromandendrene**	19.92	--	--	--	--	0.38
26	**α-Humulene**	20.29	--	--	0.54	0.74	2.18
27	**Spathulenol**	23.31	--	--	--	--	0.49
28	**Caryophylene oxide**	23.44	--	--	--	--	1.08
29	**d-Viridiflorol**	23.65	--	--	--	0.85	2.77
Total Identified Components No.			18	19	18	20	29
Sum %			100	100	100	100	100

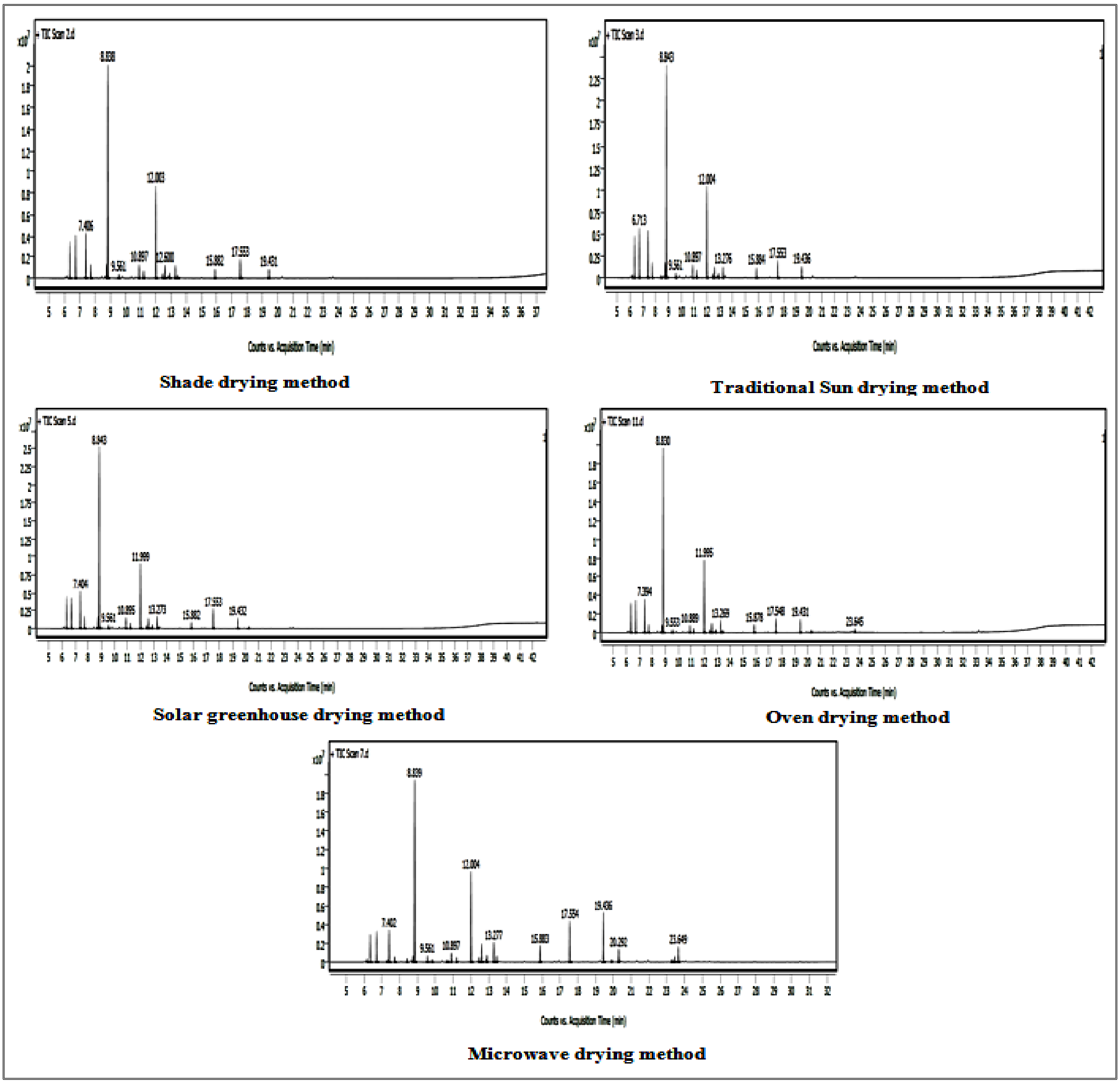


Figure. 17. Chemical composition of the essential oils extracted dried leaves of sage using different drying methods at load level 4 kg/m^2

Effect of different drying methods on total bacterial count and total fungal count in sage leaves at load level 4 kg/m^2

Table (6) illustrates the influence of drying methods on total bacterial and fungal counts in sage leaves at load level 4 kg/m^2. It was found that, the highest total bacterial count (4.80 log (CFU/g)) was found in drying sage leaves in shade. Whereas, using the microwave lead to the lowest microbial load followed by solar greenhouse drying method. Furthermore, all drying method lead to inhibit fungal growth except drying in shade has total fungal count reach to (2.78 log (CFU/g)). Our results agree with **Dababneh (2013)** and **Dalia *et al.* (2015)** on peppermint.

Three samples of dried sage leaves by solar greenhouse dryer, oven at 50 ^{o} C microwave at 640 W at load level 4 kg/m^2 were incorporated at different concentrations 0, 1, 1.5 and 2% of wheat flour (w/w) during flatbread preparation to investigate their effect on improving its chemical properties and antioxidant activity.

Table (6). Effect of different drying methods on total bacterial count and total fungal count in sage leaves at load level 4 kg/m^2.

Character / Drying method	Total bacterial count Log (CFU/g)	Total fungal count Log (CFU/g)
Shade	4.80 a ±00	2.78±0.025
Traditional sun	2.70b ±0.07	ND
Solar greenhouse dryer	2.32e ± 0.07	ND
Oven at 45°C	2.53 c±0.01	ND
Oven at 50°C	2.5 cd±0.00	ND
Oven at 55°C	2.48d ±0.02	ND
Microwave at 400 W	2.47d±0.01	ND
Microwave at 640 W	1.97f±0.02	ND
Microwave at 800 W	1.95f±0.01	ND

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.
***ND** means not detected.

Chemical composition of dried sage leaves.

Data in **Table (7)** reveals that, the highest content of ash (9.13%), fiber (30.54%) and protein (4.41%) was observed in dried leaves with solar greenhouse dryer. There was non-significant difference in ash content among dried leaves with solar greenhouse dryer and oven drying method. Whereas the highest content of carbohydrates observed in dried leaves with microwave at 640W. Also, it was noted that there was non-significant difference in moisture and fat contents among there samples. The variation in the composition may be attributed to effect of the drying method.

Table (7). Chemical composition of dried sage leaves at different drying methods

Composition / Drying method	Moisture (%)	Ash (%)	Fat (%)	Fiber (%)	Protein (%)	Carbohydrates (%)
Solar greenhouse dryer	8.10a± 0.110	9.13a± 0.031	8.52a± 0.030	30.54a± 0.031	4.41a± 0.080	47.40c± 0.092
Oven at 50 º C	8.35a± 0.090	9.09ab± 0.021	8.57a± 0.055	25.32b± 0.025	3.34b± 0.090	53.68b± 0.059
Microwave at 640W	8.54a± 0.110	9.03b± 0.049	8.50a± 0.034	23.83b± 0.030	2.29c± 0.060	56.35a± 0.063

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.

Chemical composition of flatbread samples

Chemical composition of flatbread samples containing selected dried sage leaves was illustrated in **Table (8).** The results show that, generally addition of dried sage leaves at different concentrations improve the chemical compositions compared to the control except carbohydrate content, which the highest content (84.88%) found in the control.

The highest contents of ash, fat and fiber observed in flatbread with addition 2% of both dried sage leaves with solar greenhouse dryer and 2% of dried leaves with the oven. Furthermore, the highest contents of fiber and protein were found in samples with addition 2 % and 1.5% of dried leaves with solar energy followed by samples with addition 2% of dried leaves with the oven, with non-significant difference among themselves. These results go parallel with those obtained by **Hussein *et al*. (2014)** and **Lotfy *et al*. (2018).**

Table (8). Chemical composition of flatbread samples (% dry weight)

Sample of flatbread with		Moisture (%)	Ash (%)	Fat (%)	Fiber (%)	Protein (%)	Carbohydrates (%)
Control	**0**	6.35a± 0.070	1.57e± 0.034	1.46f± 0.023	11.36e± 0.112	0.72e± 0.027	84.88 a± 0.023
Dried leaves with solar greenhouse dryer	**1%**	6.20ab± 0.080	1.62cde ±0.050	1.70e± 0.045	11.94b± 0.120	0.80cd± 0.055	83.96cd± 0.145
	1.5%	6.00c± 0.080	1.66bc± 0.015	2.09c± 0.025	12.19a± 0.074	0.90a± 0.036	83.16e± 0.180
	2%	5.95c± 0.120	1.73a± 0.033	2.50a± 0.036	12.24a± 0.063	0.93a± 0.040	82.59g± 0.181
Dried leaves with the oven at 50 º C	**1%**	6.10bc± 0.120	1.61cde ±0.017	1.74e± 0.036	11.48de ±0.070	0.79cd± 0.022	84.38b± 0.192
	1.5%	6.00c± 0.090	1.65bcd ±0.031	2.24b± 0.021	11.52d± 0.056	0.83bc± 0.010	83.77cd± 0.096
	2%	5.95c± 0.090	1.71ab± 0.043	2.53a± 0.029	12.03a± 0.084	0.87ab± 0.052	82.87f± 0.015
Dried leaves with the microwave at 640 W	**1%**	6.24ab± 0.120	1.60de± 0.038	1.50f± 0.020	11.41de ±0.070	0.77de± 0.029	84.72b± 0.010
	1.5%	6.20ab± 0.090	1.62cde ±0.049	2.02d± 0.044	11.41de ±0.147	0.81cd± 0.039	84.14b± 0.189
	2%	6.00c± 0.110	1.65bcd ±0.034	2.19b± 0.034	11.74c± 0.075	0.82bcd ±0.021	83.6 d± 0.056

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.

Sensory evaluation

Flatbread is popular bakery products bought and consumed by people in many countries. Addition of natural substances may result in change in taste, flavor, colour, texture and overall acceptability. All these changes are important for the acceptance the product by the consumer. Data in (**Table 9)** summarizes the results of sensory analysis of tested flatbread. Taste, flavor, colour, texture and overall acceptability were affected by addition different concentrations of dried sage leaves to samples of flatbread compared to the control sample. It can be observed that the highest value of taste, flavor, colour and texture of flatbread was (8.79, 8.93,9.00, 8.93 respectively) for control sample followed by samples supplemented with 1 and 1.5 % of dried sage leaves by solar greenhouse dryer and dried sage leaves by the microwave with non- significant difference among themselves in most sensory score. In addition, the highest overall acceptability (8.93) was observed in control sample followed by sample supplemented with 1.5% of dried sage leaves by solar greenhouse dryer (**Table 9).** Our results agreed with **Lotfy *et al.* (2018**) who found the desirable acceptable sensory by adding some aromatic plants to bread.

Antioxidant activity

Data in **Fig. 18** shows the effect of addition dried sage leaves on the antioxidant of flatbread. It could be noticed that the addition of different dried sage leaves concentration to flatbread samples increased significantly their antioxidant activity compared with the control (5.45%). The highest antioxidant activity values (25.54 and 24.87%) was found in samples of flatbread prepared with concentrations of 2 and 1.5% from dried sage leaves with solar greenhouse dryer with non- significant difference among themselves. followed by concentration at 1.5 % with non-significant difference among themselves. In addition, the other samples with concentration of 2 and 1.5% have the same effect. These results may be due to the higher antioxidant activity of dried sage leaves as mentioned above results and discussion. Our results were on line with **Vasileva *et al*. (2018)** and **Skendi *et al.* (2019).**

Table (9). Sensory evaluation of flatbread

Sample of flatbread with		Taste	Flavor	Colour	Texture	Overall acceptability
Control	**0**	8.79a±0.350	8.93a±0.220	9.00a±0.290	8.93a±0.220	8.93a±0.130
Dried leaves with solar greenhouse dryer	**1%**	8.79a±0.350	8.93a±0.220	8.79ab±0.130	8.79abc±0.170	8.60abc±0.240
	1.5%	8.64ab±0.130	8.71ab±0.280	8.93ab±0.170	8.78abc±0.160	8.79ab±0.220
	2%	8.64ab±0.150	8.71ab±0.160	8.43c±0.170	8.43c±0.270	8.07de±0.280
Dried leaves with the oven at 50 º C	**1%**	7.87bc±0.320	8.00c±0.250	8.79ab±0.150	8.79abc±0.220	8.57abc±0.240
	1.5%	8.57ab±0.140	8.43bc±0.340	8.71ab±0.250	8.71abc±0.230	8.43bcd±0.365
	2%	8.36bc±0.260	8.43bc±0.190	8.57bc±0.090	8.57abc±0.290	7.71e±0.230
Dried leaves with the microwave at 640 W	**1%**	7.57bc±0.320	8.29bc±0.240	8.78ab±0.140	8.86ab±0.142	8.64abc±0.320
	1.5%	8.71ab±0.070	8.57ab±0.270	8.79ab±0.150	8.79abc±0.254	8.57abc±0.320
	2%	8.29bc±0.350	8.64ab±0.350	8.57bc±0.290	8.50bc±0.13	8.29cd±0.230

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.

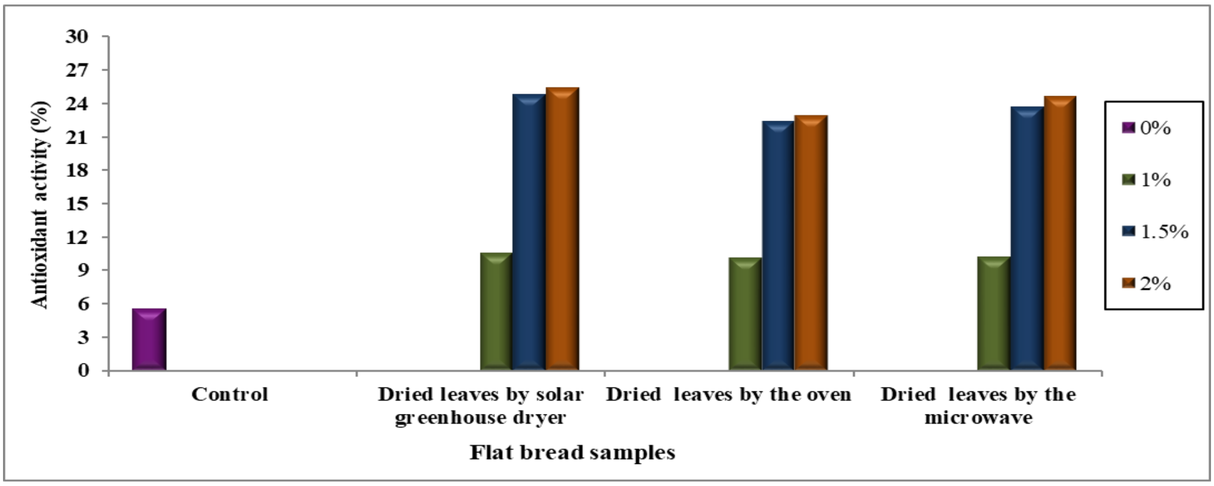


Figure. 18. Antioxidant activity (%) of flatbread prepared with dried sage leaves

Hardness (N) and staling rate (%) of flatbread after storage time

The hardness (N) of the samples was estimated at zero time and after storage periods of (24 and 48 h.) are reported in **(Table 10)**. Addition of different dried leaves concentrations and storage time have a statistically significant effect on the hardness. From the results, it was observed that the hardness decreased by increasing the dried leaves concentration. It could be noticed that the highest hardness (32.18 and 39.44) after 24 and 48 h, respectively was observed in the control samples. While the lowest hardness (22.46 and 24.03) after 24 and 48 h, respectively was found in samples of flatbread supplemented with 2% of dried sage leaves with solar greenhouse dryer. Flatbread with herbal at medium and high level preserves their freshness for the longest time. These results matched with **Dhillon *et al*. (2013)** who found that, the hardness decreased with addition of oregano herb to bread.

Bread staling is a complicated process that occur during storage of bread and originated from a group of physical and chemical changes in the bread which results in crumb hardness, taste and other characteristic (**Al-Mahsaneh *et al*., 2018)**. Staling rate was estimated for each sample after storage periods (24h - 48h) as shown in **(Table 11)**. It was found by increasing the concentration of dried sage leaves, the staling rate decreased. The results showed that the control sample had the highest staling rate

(52.13 and 86.48%) after 24 and 48 h, respectively, compared with the other samples. On the other hand, the lowest staling rate was observed in flatbread sample supplemented with 2 and 1.5% of dried leaves with solar greenhouse dryer and with the oven with non- significant difference **(Table 11).** This could be attributed to the high dietary fiber content of the dried sage leaves with solar greenhouse dryer and the oven. Fibers improve the nutritional value and some properties of the bread (**Gómez *et al.*, 2003**). These results matched with those obtained by **Mehder (2013).**

Table (10). Hardness (N) of flatbread at zero time, 24 h and 48 h

Sample of flatbread with		Hardness (N)		
		At zero time	After 24 h	After 48 h
Control	0	21.15ab±0.484	32.18a ±0.990	39.44a ± 1.216
Dried leaves with solar greenhouse dryer	1%	21.17ab ± 1.047	31.66a ± 1.235	33.69b ± 0.585
	1.5%	20.00 cd ±1.355	25.74d ± 0.175	27.80cd± 1.700
	2%	17.31d ± 1.305	22.46e ± 1.190	24.03e ± 0.81
Dried leaves with the oven at 50 º C	1%	21.35a± 0.870	31.82a± 0.910	35.52b ± 1.445
	1.5%	20.71ab±0.358	26.78c ± 1.040	28.94cd± 1.264
	2%	21.30a ± 1.085	27.26bc±2.075	29.76c ± 0.885
Dried leaves with the microwave at 640 W	1%	19.67 abc ±1.070	28.79b± 0.285	29.96c ± 1.065
	1.5%	19.50 bc ±0.100	28.09bc±0.810	29.90c ±0.950
	2%	18.40cd ± 0.315	24.01de ± 0.360	26.36de± 0.590

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level

Table (11). Staling rate (%) of flatbread at 24 h and48 h

Sample of flatbread with		Staling rate (%)	
		After 24h	After 48h
Control	0	52.13a±1.631	86.48a±1.491
Dried leaves with solar greenhouse dryer	1%	49.52b±1.145	59.11c±1.837
	1.5%	28.68de±0.700	39.00f±0.459
	2%	29.73de±0.327	38.79f±0.090
Dried leaves with the oven at 50 º C	1%	49.04b±1.698	66.35b±1.065
	1.5%	29.33de±1.529	39.77f±1.962
	2%	27.93e±1.007	39.66f±0.896
Dried leaves with the microwave at 640 W	1%	46.39c±1.439	52.31d±0.128
	1.5%	44.30c±0.878	53.33d±0.030
	2%	30.49d±1.298	43.26e±1.002

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.

Water activity of flatbread after storage time

Data present in **Table (12)** show the changes in water activity (a_w) during storage. The addition of dried sage to flatbread has a statistically significant effect on water activity. The control sample has the highest water activity (0.921 and 0.932) after storage 3 and 6 days, respectively. Whereas, the lowest water activity was in sample supplemented with 1.5 and 2% of dried sage leaves by solar greenhouse dryer and the microwave after storage period at 3 days and 6 days. Their water activities are in the range of 0.918 to 0.932. The lowest water activity, which is different from the other test samples and ranges from 0.914 to 0.906 after 3 days and from 0.893 and 0.898 after 6 days. Generally, the water activity of flatbread decrease with the addition of dried sage leaves, which may lead to decrement the development of microorganisms and increment shelf life.

Table (12). Water activity of flatbread at zero time, after 3 days and after 6 days

Sample of flatbread with		Water activity (a_w)		
		At zero time	After 3 days	After 6 days
Control	**0**	0.918ab±0.005	0.921a±0.006	0.932a±0.005
Dried leaves with solar greenhouse dryer	**1%**	0.917abc±0.005	0.917a±0.005	0.912b±0.005
	1.5%	0.915abc±0.007	0.914ab±0.006	0.898c±0.006
	2%	0.916abc±0.009	0.906b±0.004	0.892c±0.004
Dried leaves with oven at 50 º C	**1%**	0.921a±0.002	0.920a±0.006	0.917b±0.004
	1.5%	0.919a±0.003	0.918a±0.003	0.917b±0.002
	2%	0.919a±0.004	0.917a±0.005	0.915b±0.009
Dried leaves with microwave at 640 W	**1%**	0.919a±0.007	0.915ab±0.008	0.912b±0.004
	1.5%	0.918ab±0.006	0.913ab±0.007	0.896c±0.005
	2%	0.918ab±0.005	0.915ab±0.008	0.893c±0.004

Values are means of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level.

CONCLUSION

The drying experiment was evaluated by multiple of drying characteristics (moisture content, drying rate and drying efficiency) and chemical analyses under different drying methods to illustrate the effect of drying parameters on the quality of sage (*Salvia officinalis* L.) leaves, and its utilization as natural additive to improve the properties of flatbread to the production of healthier foods. The issue of choosing appropriate drying method and its parameters is a complex task. Therefore, it would be difficult to selected optimal one method, thus, therefore, we recommend that:

-At drying by natural methods: Using solar greenhouse dryer at load level of 4 kg/ m^2.

-At drying by artificial methods: (i) To obtain the optimum essential oil content, the electric oven is used at a temperature level of 50°C under a loading level of 4 kg/m^2. (ii) To obtain the highest, total phenolic content, total flavonoid content, antioxidant activity and lowest microbial load, microwave oven is used at power of 640 W under load level of 4 kg/ m^2 (power density of 6.4 W/g).

-In concerned to add dried sage leaves by the different drying methods on flatbread, depending on the overall acceptability and the other results, the optimal condition is the addition of 1.5 % of dried sage leaves by solar greenhouse dryer.

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