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ORIGINAL ARTICLE

The Effect of Microwave, Oven, and Natural Drying Methods on Characteristics of Savory (*Satureja hortensis* L)

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ABSTRACT
Regarding the significance of Savory (Satureja hortensis L) in pharmaceutical industry and as a dried additive in food industry, the present research aims to investigate the effect of various drying methods (microwave, oven and natural drying methods) on characteristics of Savory. The present research compares the various effects of these drying treatments on Savory characteristics (Satureja hortensis L) dried at regular intervals in terms of color analysis, essential oil content, weight loss percentage and apperance quality of samples. The findings of research indicate that there is a direct relationship between the highest color changes anddrying time. It can be concluded that the color changes in Savory is a function of time and drying temperature. The faster the rate of drying process with respect to temperature, the less color changes.There is a significant difference between microwave drying treatment and other drying treatments in terms of Savory appearance quality and color changes. Howere, there is no significant distinction among these methods with respect to other parameters.
Keywords: *Drying, Savory, Microwave*

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INTODUCTION

Food safety has always been a main concern for food consumers and industry, Specifically, the number of reported cases on food-related infections and their negative social and economic consequences are increasing. Therefore, threre is a continuous effort to produce more safe food and develop natural antimicrobial agents. Also, it is necessary to use new methods for reducing or destroying pathogens transferred from food [19].

Savory which is a plant from mint family with the scientific name *"Satureja hortensis L"* is widely widespread in tropical regions. Savory has 15 species in Iran with 9 species exclusive to tjis country. Regarding the significance of Savory in Iran and the effort to increase its consumptionin food industry, on the one hand, and its export potential to other parts of the world specially to the Persian Gulf Countries, on the other hand, Savory has been used in flavorings of brew drinks, chicken, sauces, and vegetables. Moreover, the essential oil of Savory is used alone for industrial purposes or in combination with other essential oils [5].

The most important medicinal properties of Savory are as follows: analgesic, antiarthritis, antibacterial, anticancer, antidiuretic, antiherpes simplex, anti inflamatory, anthelmintics, antioxidant, antiseptic, antifungal,antispasmodic, diaphoretic, digestive stimulant, diuretic, purgative, sedative, stomach tonic and stimulant, fragnant and carminative. Savory foliage and flowers are also used as stimulants.

Moreover, the Savory's tea, essential oil and extract are used as sedative, analgesic and antispasmodic (muscular cramp) [19]. Savory stimulates blood circulation and its ointment is used for curing rheumatism and arthritis. Savory is also applied in conventional medicine for treatment of renal and neurotic disorders [4].

Drying is one of the typical processes of food industry in which a great amount of water is excluded from food through evaporation and sublimation. As a result, a reduction in the water activity occurs. Some of the main reasons for drying food include preventing from microbial and enzyme activities, lowering the rate of harmful chemical actions and reactions such as non- enzymatic browning and auto-oxidation, reducing size and weight for facilitating the packaging and transportation, storing and preserving food in fruitful seasons to be used in scarce seasons [5]. Drying is considerd as one of the oldest method for preserving food [21]. Sun drying which dates back to many years ago is used as a useful method in most countries even in developed countries due to its simplicity and inexpensiveness. However, this method has its own drawbacks including the likelihood of contamination being directly exposed to environmental factors, insects, birds and rodents damages, and the lengthy process of drying which has a negative economic effect. These shortcomings have imposed some restrictions on its application [1].

Therefore, a set of more recent drying treatments such as oven drying, microwave drying, freeze drying, drying in the sun and drying in the shade have been introduced. Due to these drawbacks, microwave drying treatment was developed to prevent from a reduction in product quality and to arrive at an efficient heat transfer process (8). Nevertheless, these methods have their own restrictions, too. For example, drying in the sun treatment is not feasible in some regions due to the short period of solar radiation or drying with freezing method has the drawback of electricity consumption and cost. However, it is a fast, hygienic method with industrial uses (2).

The drying treatment equations can be divided into three types including experimental, quasi-experimental, and theoretical. In quasi-experimental equations, the resistance against mass transfer at the product level will be ignored. In other words, the product level reaches a balance with its surrounding moisture without consuming a long time. One of the most well-known drying quasi-experimental equations is Louis and peach equations [5].

Color is regarded as one of the most significant parameters of quality in industry and agriculture since it is closely related to factors such as food freshness, ripeness, desirability and immunity. Food color changing synthetics is a complicated phenomenon and there is no reliable method for estimating color changes that can be used in engineering calculations [7]. Color is considered as the most significant attributes of physical appearance for appreciating food quality traits. Customers tend to associate color with the taste, immunity, longevity and nutritional properties of food. Since there is a high correlation between color and physical, chemical and sensory evaluation of food quality, customers' satisfaction in influenced by color [22]. Color is one of the most significant quality attributes of dried fruits which changes during the chemical and biochemical reactions of drying and long preservation processes [10]. Color changes can be used to define the appropriate thermal process conditions for maximizing product quality. Color changes are measured using three reflection indexes in the colorimetric system and can be used for estimating quality changes [7].

Ozcan and Arsalan [12] studied the effect of various drying methods on the color of rosemary foliage. They realized that the foliage color have been preserved much more in oven drying method compared with sun drying method . Antonio Volga Galoz *et al.* (2009) studied the effect of drying in the shade on the physical and chemical properties of phenolic compounds and red pepper color. They found out that red pepper, as a very good source of antioxidants and vitamin C loses its phenolic compounds and vitamin C after being dried. However, it indicates more antioxidant property at higher drying temperatures than lower temperatures [16].

Recently, there has been much research carried out by various researchers on drying medicinal plants such as mint species, tea, echinacea, parsley, chamomile, saffron, etc. Topuza *et al.* [2009] studied the effect of various drying treatments (freeze-drying, drying in the shade and oven drying) on the red pepper color. They found out that freeze drying is the best drying method for preserving color since the pigments are preserved through heating and oxidation [25]. Besides, in 2010, the effect of various drying methods on several plants (rosemary, oregano, marjoram, basil) was studied. The results illustrated that drying in the shade is an ideal method for all the analyzed species since it brings about the least nutritional damages [18]. The Savory essential oil is used in the canned food and soft drinks industries. Savory has antimicrobial property and prevents from growing some funguses [5]. Due to the significance of Savory in Iran and an effort to increase its consumption in food industry and its export potential to other parts of the world, the present research aims to investigate the effects of various drying teratments on charaeteristices of Savory to decide on the best drying method.

MATERIALS AND METHODS
Materials
Savory plant was purchased from Khorasgan region in Isfahan City. A laboratory digital scale manufactured by Sertorius company with an accuracy of 3 decimal digits was used to weight the fresh Savory, dried Savory, and withdrawal of the Savory moisture during the drying process.
Primary Materials Preparation
The Savory sample was purchased from Khorasgan region in Isfahan City. After removing mud and waste materials from the sample, it was distributed in 5 kg packages. A portion of this was put away as control sample. Each sample was analyzed discretely and other samples were kept at a temperature of -18°C. In addition, there were two replications for each step.
Oven Drying Treatment
The laboratory drier (manufactured by Memert Company in Germany) was used to exclude moisture from fresh Savory to reach 1.3 % moisture content. In this method, the thin layers of Savory foliage were placed on the oven trays. After drying the Savory, various analyses were carried out in terms of moisture content, modeling, and color.
Oven Drying Treatments at 70° C and 100° C Temperatures
In this treatment type, the thin layers of Savory foliage are placed on the oven trays at a temperature of 70° C for 9 hours. In the oven drying method at 100° C, thin layers of Savory foliage were placed on the oven trays at a temperature of 100° C for 9 hours for being dried. After drying the Savory foliage, various experiments were carried out.
Microwave Drying Treatment
A household oven (Delonghi MW605) with a maximum output current of 850 Watt and operating frequency of 2450 MHz with the dimensions 320×200 was used. In this method, the fresh Savory foliage were placed into Petri dish. Then, they were placed in a microwave for 6 minutes to be dried (5).
Natural Drying Treatments
In this method, the Savory foliage were placed on the seedling trays for 8 hours from sunrise to sunset under the direct radiation to be dried. It is worthy to note that the relative moisture at this time was 10 % and the air temperature was 35° C, respectively. After the samples were dried, the necessary experiments were carried out. In the drying Savory in the shade, the Savory foliage were placed on an aluminum foil and were dried at the room temperature of 27° C and partial moisture of 38° C for 48 hours(5).
Moisture Percentage
2-5 grams of Savory foliage were weighted carefully and placed on a clean aluminum container which had been weighted previously. The aluminum container was placed in an oven at a temperature of 110° C to reach a fixed weight. Then, the container was taken out of the oven and placed in a desiccator for cooling. After that, the dried sample container was weighted using calculations. The moisture percentage was calculated using the difference between the initial t and final weights (27):

$$\text{(1) Moisture Percentage} = \frac{\text{Initial weight - Final weight}}{\text{Sample weight (gr)}}$$

Physical Appearance
After completing the drying process, the visual assessment was used to analyze the effect of various drying methods on the samples physical appearance. Four score levels from 1-4 were assigned to the samples. These scores represent the quality properties of the samples as follows: **score 4:** very good, no undesirable color changes; **score 3:** good, a little undesirable color changes; **score 2:** average, fairly influenced by the drying treatment and **score 1:** poor, undesirable color changes [6].
Weight Loss Percentage
The weight loss percentage was calculated after drying the samples under drying conditions for various methods for a given time. Then, the samples were weighted again to measure the weight loss percentage compared with the initial weight of samples. The weight loss percentage of samples was shown in table 26.
Colorimetry
A high resolution digital camera (Canon 50d model) was used to assess the color changes of fresh Savory foliage after being dried using various drying treatments. The Savory foliage was placed inside Petri dishes with a diameter of %5 cm. Then, the samples were photographed at a distance of 30 cm. It is to note that for assuring a constant light, a light box and two 18 Watt florescent light bulbs were used. Next, the taken pictures were used in the software Image Pro Plus, version 6 and the multipliers L, a, and b were determined. The multipliers L, a, and b indicate brightness intensity (white/black), red/green, and yellow/blue colors, respectively. The negative multipliers a and b represent that the green and blue

colors are dominant colors. The multipliers L*, a*, and b* were used for analyzing the colors. The multiplier L* varies within a range of 0-100 and indicates brightness percentage so that for a completely white level, L* equals 100 and a*, and b* will be zero (0). In contrast, L*, a*, and b* equal zero (0) for black color. Also, multipliers a*, and b* vary between +120 to -120. The multiplier a* varies between green and red colors so that a negative a* indicates green color and a positive a* indicates red color. The multiplier b* varies between blue and yellow colors. A negative b* indicates blue color and a positive b* indicates yellow color. The color was measured using the equations (2), (3) and (4)

(2) $SI=\sqrt{a^{*2} + b^{*2}}$

(3) $H=\arctan(b^*/a^*)$

(4) $\Delta E= ((L_o - L^*)^2 + (a_o - a^*)^2 + (b_0 - b^*)^2)$^ 0.5

***Note:** LAB treatment and standard LAB equations were used for fresh Savory

Colorimetric Analysis

Color is considered as a significant parameter of quality in industry and agriculture since it is closely related to other parameters such as freshness, ripeness, desirability and immunity. Synthetics of food color changes is a complicated process so that there is no reliable method for predicting color changes to be used in engineering calculations [2]. There have been numerous researches on the effect of thermal processes on food color changes. Moreover, various colorimetric systems have been used for describing color changes. Color changes can be used to define the appropriate thermal process conditions for maximizing product quality. Color changes are measured using three reflection indexes in the colorimetric system and can be used for estimating quality changes. Recently, the CIELAB color system has been used by several researches [7].

Essential Oil Extraction

100 gram dried Savory together with 1500 CC deionized water poured into Clevenger apparatus for 6 hours at a temperature of 90°C to extract essential oil content. After extracting the essential oil, the extracted essential oil samples were poured into Penicillin bottles and kept at the temperature of -18° C to be placed in GC Mass Spectrometer [24].

Essential Oil Detection

Gas Chromatography apparatus (GC) and Mass Spectrometer (MS) were used to detect the essential oil contents of the Savory. The specifications of theses apparatuses are shown in Table 1. Chromatography gas is a chemical and physical process in which the fixed phase is in a solid or liquid state placed into a metal or glass column. The moving phase typically consists of neutral (rare) gases [14].

Table 1. Gas Chromatography (GC) and Mass Spectrometer (MS) Specifications

Gas Chromatography model	**Agilent 7890 A**
Mass Spectrometer model	**Agilent 5975 C**
Column type	**HP-5 MS**
Column length	**30 m**
Column inner diameter	**0.25 µm**
Column initial temperature	**60° C**
Column final temperature	**240 ° C**
Containing gas type	**He. 1 ml /min**
Detector	**FID 290 ° C - MS 280° C**

After injecting the sample, it enters the moving phase and goes through the fixed phase. Then, the separator propagates as a result of being heated between gas and fixed phase (solid or liquid) which can be resolved or absorbed. Considering the necessary gas volume and time for excluding the body from the column, the essential oil contents will be detected by detectors (20). The spectra were detected and compared with the available indexes of reference books and articles using inhibiting indexes and mass spectra of standard combinations.

RESULTS

Moisture Percentage

The oven drying method was used for estimating the moisture content at a temperature of 110°C. The results of the research indicated that there was no significant distinction between various drying treatments in terms of final moisture percentage of samples. However, there was a considerable difference between the wet and dried samples for all these drying methods shown in the following figures.

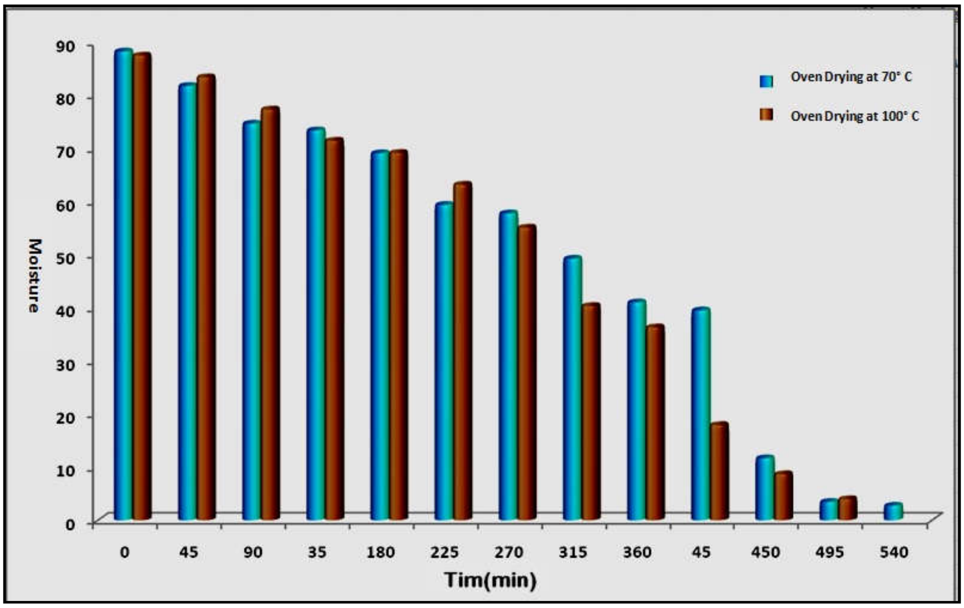

Figure 1. A comparison of moisture percentage variations per minute at 70° C and 100° C oven drying treatment

As it can be shown, there is no significant difference between oven drying treatments at the temperatures of 70°C and 100°C for a period of 300 minutes. However, after this time, there was an increase in the oven drying rate at 100°C. This indicates that there is a significant correlation between temperature and time in the drying process. After the completion of oven drying at 70°C, there was a 27% percent reduction in the moisture content of samples.

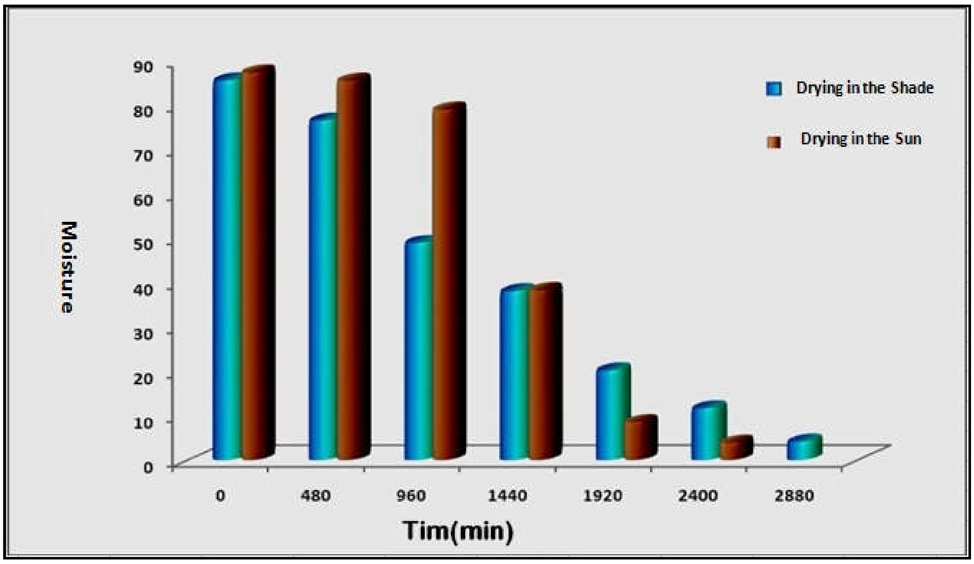

Figure 2. A comparison of moisture percentage variations per minute in natural drying treatments (sun drying and shade drying)

As it can be shown in figure 2 drying in the shade is a much more time-consuming treatment compared with other drying treatments. Nevertheless, the moisture content of samples was much less in drying in the sun than drying in the shade method.

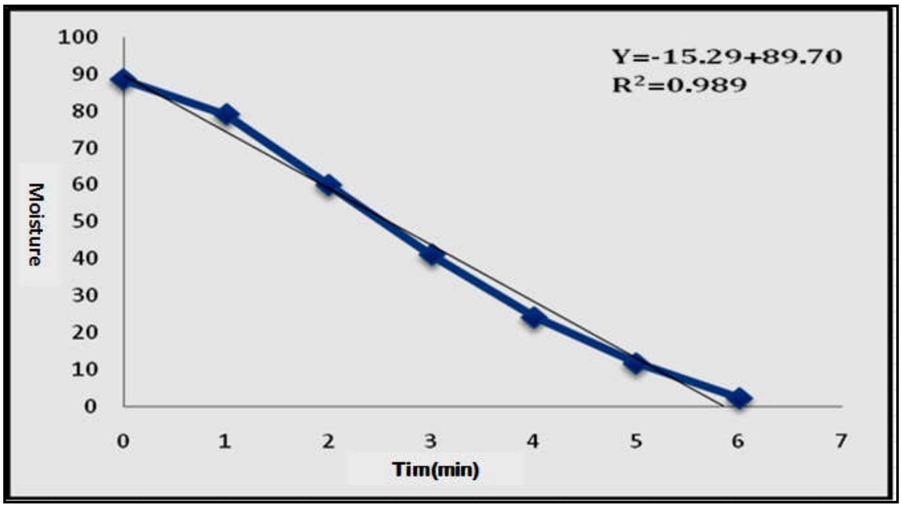

Figure 3. A comparison of moisture percentage variations per minute in microwave drying treatment

Due to short drying time, samples dried using microwave drying method indicated the least moisture content, i.e. 2.3% percent compared with other drying methods. This finding is in agreement with the results obtained by Ebadi et al. They found that there is considerable distinction between drying in the sun and drying in the shade treatments; and oven drying at 70° C and 100° C. However, they found no remarkable difference in microwave drying method with various powers (5).

Weight Loss Percentage

For measuring weight loss percentage of samples, the dried samples weight was compared with their initial weight. The results can be seen in table 2. As the results indicate there is a significant difference between microwave drying method and other drying methods in terms of weight loss percentage. In contrast, drying in the shade showed the least weight loss percentage.

Table 2. Weight loss percentage of samples in various drying methods

Drying Method	Microwave Drying	Oven Drying at 70° C	Drying in the Sun	Drying in the Shade	Oven at 100° C
Weight Loss Percentage	86.04	85.33	83.37	81.37	83.6

Physical Appearance

The physical appearance of samples was also influenced by the drying treatment type. The highest appearance quality score was given to the microwave drying method and the least appearance quality score to oven drying method. The results of appearance quality of samples in other drying methods are shown in Table 3.

Table 3. Appearance quality scores for various drying methods

Drying Method	Microwave Drying	Drying in the Shade	Drying in the Sun	Oven Drying at 70° C	Oven at 100° C
Appearance Quality Score	4	3	1	3	2

*** Score 4: very good Score 3: good Score 2: average Score 1: poor**

Colormetry

The color changes of samples were calculated using three reflection indexes in the colorimetric apparatus (2). As it can be seen in figure 4, the process of moisture withdrawal follows a quadratic equation. However, after passing 45 minutes of drying process, there is a slight change in dried Savory that can be ignored. Therefore, the highest percentage of dried Savory color changes can be attributed to the first 45 minutes in the oven drying method at 70° C or the withdrawal of initial moisture percentage.

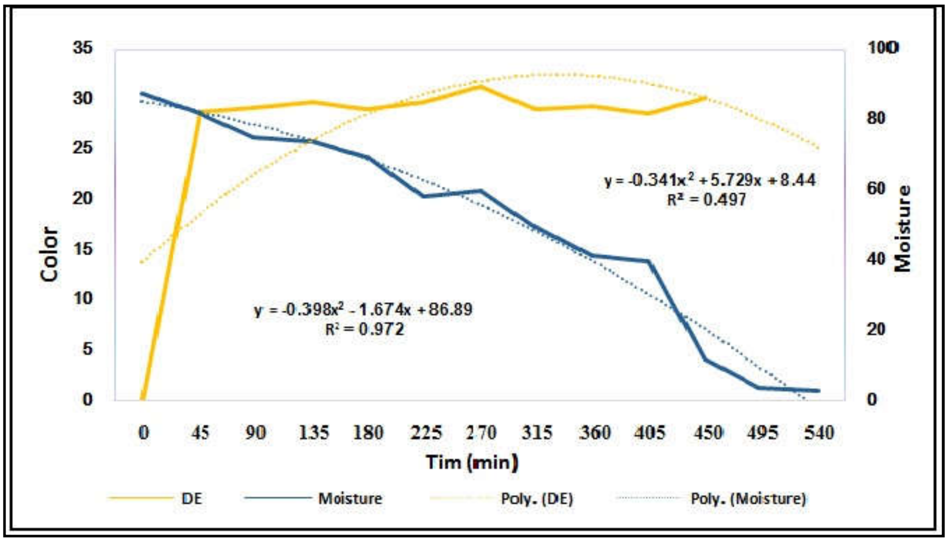

Figure 4. Color analysis of samples produced during oven drying treatment at 70 ° C

The very weak R^2 indicates a low correlation between samples longevity in oven drying treatment at 70° C and color changes. Similarly, in the oven dying method at 100° C, as it was shown in figures 4 and 5, the highest color changes occur at the first minutes of drying process. In fact, the 4 percent withdrawal of initial moisture results in the highest color changes in the samples. After this, the extreme moisture withdrawal even 83% to 4 % does not have any significant influence on color changes.

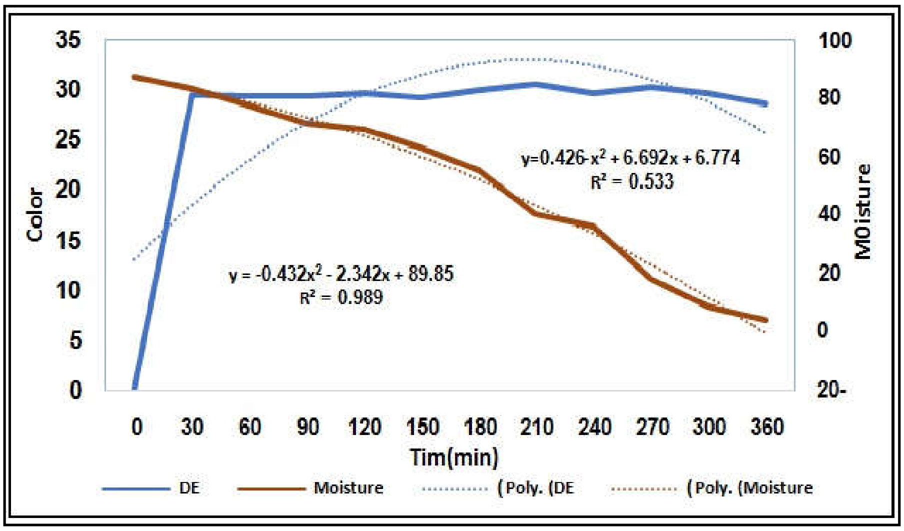

Figure 5. Color analysis of samples produced during oven drying treatment at 100° C

However, color changes influences the brightness and Lab parameters. Also, there is a slight change to these parameters which is given by Δ E. The weak R^2 also indicates that there is a small correlation between the samples longevity in oven drying method at 100° C and color changes.

In microwave drying treatment similar to the former drying methods, the big color changes take place during the initial withdrawal of moisture from samples. However, in microwave drying method, the highest color changes can be attributed to the first minute of drying with a withdrawal of initial 8 percent of moisture. As it can be seen in figure 6, microwave drying method causes the least color changes compared with other drying methods.

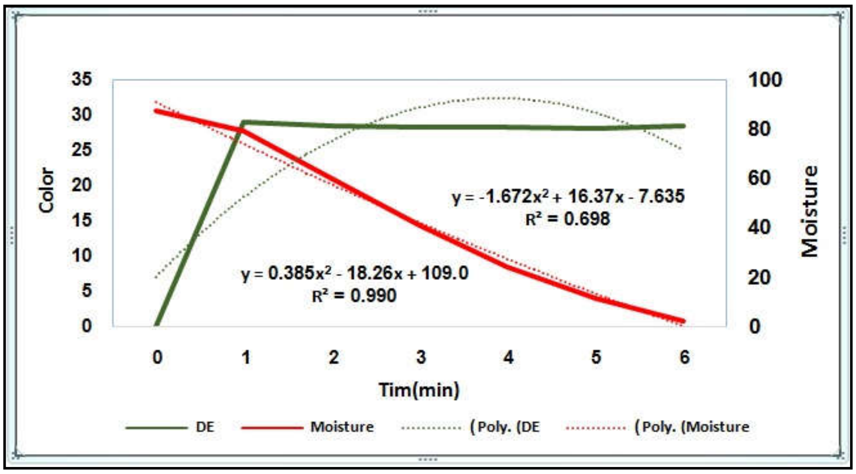

Figure 6. Color analysis of samples produced during microwave drying treatment

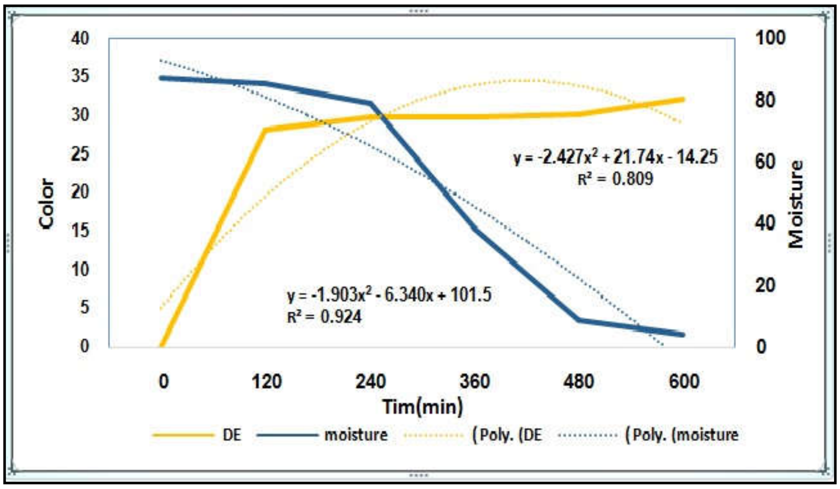

Figure 7. Color analysis of samples produced in the sun drying treatment

Drying in the sun and drying in the shade methods indicate similar color changes. Again, the highest color changes occur due to withdrawal of the initial moisture between 10-12 percent. After this, the color changes slow down.

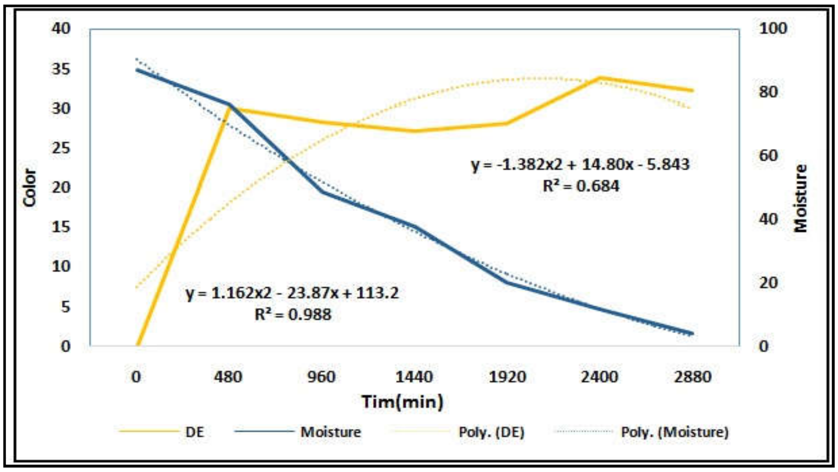

Figure 8. Color analysis of samples produced in the shade drying treatment

As we can see in figures 7 and 8, the color changes follow a quadratic equation. The strong R^2 indicates that there is a direct correlation between samples longevity in drying in the sun and in the shade methods.

Essential Oil Extraction

100 gram dried Savory together with 1500CC deionized water poured into Clevenger apparatus for 6 hours at a temperature of 90° C to extract essential oil content. This extraction method was used for all the drying methods. The extracted essential oil from each drying method was reported discretely in percentages.

Table 3. Extracted essential oil from dried samples using various drying methods (Percentage)	
Fresh	**0.15%**
Dried in the sun	**1.0142%**
Dried in the shade	**1.828%**
Dried using oven at 70° C	**0.642%**
Dried using oven at 100° C	**0.714%**
Dried using microwave at 100° C	**0.785%**

Sefidkon et al. also reported that the highest essential oil was extracted using drying in the shade with a percentage of 1.6 % (4). Rahmati *et al*. comparing the means of various drying methods indicated that the highest essential oil (3%) was extracted using drying in the shade and oven drying at 50° C methods and the least essential oil (0/9%) was extracted using drying in the sun method [24]. The results of these researches are in line with the present research. The present research illustrated that the highest essential oil (1.81%) was extracted using drying in the shade method and the least essential oil was extracted using oven drying at 70°C shown in the table 4.

Essential Oil Detection

Gas Chromatography apparatus (GC) and Mass Spectrometer (MS) were used to detect the essential oil contents of the Savory. Chromatography gas is a chemical and physical process. The researches carried out by various researchers such as Sefid kon *et al*. indicate that the highest detected essential oil was Carvacrol (48.1 %) in oven drying at 45° C and the lowest detected essential oil was Gamaterpin (4.39%) in drying in the sun. Carvacrol is one of the major components of Savory essential oil with an antimicrobial property which is cultivated in most parts of the world [4]. The other components of Savory essential oil have an important function in the Savory essential oil quality due to the antibacterial property of Carvacrol [13]. Skon *et al.* found that the oven drying at 40° C results in evaporation and changing the major compounds (Menthone, Sineol 1. 8 Pulegone) of spearmint essential oil [23]. As it can be seen in figure 5, the active ingredients of Savory essential oil are Carvacrol, Gamaterpin and Pisimon, respectively.

Table 4. Active ingredients of Savory essential oil are Carvacrol, Gamaterpin and Pisimon

Savory	Psimon	Gamaterpin	Carvacrol
Fresh	4.57 ± 7.16 a	16.76 ± 4.02 c	61.88 ± 5.37 b
Oven drying at 50° C	3.9 ± 0.81 b	19.97 ± 3.12 b	63.18 ± 4.71 b
Oven drying at 100° C	3.8 ± 0.72 b	5.98 ± 0.13 d	76.04 ± 2.03 a
Microwave drying	3.42 ± 0.22 b	14.92 ± 2.89 c	59.71 ± 1.87 c
Drying in the sun	3.93 ± 0.03 b	24.34 ± 1.83 a	58.94 ± 1.42 c
Drying in the shade	3.6 ± 0.31 b	29.42 ± 2.22 a	52.8 ± 1.91 d

CONCLUSION

Savory is well-known as an aromatic and medicinal plant, so that the foliage, flower and stalk of this plant are used as tea, or additive in many foods. The present research aimed to improve Savory's various properties. The results of research indicated that, due to short drying time, samples dried using microwave drying method had the least moisture content, i.e. 2.3% percent and the best appearance quality compared with other drying methods. Also, the color analysis demonstrated the highest saturation ratio of green color for control sample. After drying the treatments, there was a decline in the saturation ratio. On the other hand, samples dried using drying in the sun or in the shad methods indicated the highest saturation ratio. This implies that the more the rate of drying is, the less saturation ratio will be. The results of their study demonstrated that freeze drying treatment results in slight color changes. An analysis of essential oil content indicated that the highest essential oil (1.82%) was extracted using drying in the shade method and the lowest essential oil was extracted using oven drying treatment at 70°C. Finally, the analysis of extracted essential oils using Gas Chromatography apparatus (GC) and

Mass Spectrometer (MS) illustrated that the active ingredients of Savory essential oil are Carvacrol, Gamaterpin and Psimon, respectively.

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