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Effect of Refractance-Window Drying Method on Quality Characteristics of Balady Menthol

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ABSTRACT

This work was carried out to study the drying effect on balady menthol plant using the novel Refractance-Window drying methods (RW) at (40, 50 and 60°C), as compared with the natural sun drying method. The obtained results showed that the best drying method for drying menthol tested is by using RW at 60°C for 8 min. followed by RW at 50°C for 10 min. and RW at 40°C for 12 min. respectively as compared by sun drying method at 37-39°C for 12 hrs. The data obtained indicated also that menthol samples dried with RW at different temperatures / periods used were found to have the beat colour when compared with sun drying method. However, no significant differences were found in pH values of different dried menthol produced by different drying methods used. Also, it could notice that menthol dried by RW at 50°C for 10 min. has the same volatile compounds as that of dried by sun drying method. The most high level of volatile compounds were found to be Carvone, namely as 66.347% in sun dried menthol and 67.787% in RW menthol dried at 50°C for 10 min. Regarding microbiological evaluation, it was found that menthol samples dried by RW at 60°C for 8 min. were free from total bacterial count as well as free from mold and yeast. Meanwhile, the microbiological quality was found to decrease gradually as using RW at 50°C followed by RW 40°C and at least sun drying.

Keywords*:* Refractance-Window drying method, natural sun drying, Balady Menthol.

INTRODUCTION

The name of the genus "Menta" comes from the name of Greek nymph "Menthe", which loved Pluto belonging to the Labiatae family is a large family of chiefly annual or perennial, herbaceous and 30–100 cm length. (Doymaz 2006). The chemical composition and antioxidant activities of Menthe (*longifolia L. and viridis*) essential oils were pulegone (54.41%) as a major component followed with isomenthone (12.02%), 1,8-cineole (7.41%), borneol (6.85%), and piperitenone oxide (3.19%). Mentha was riched in carvone (50.47%), 1,8-cineole (9.14%), and limonene (4.87%). Balla, *et al.,* (2017).

Drying has one of the most efficient ways to preserved foods. It is reduces products water activity, which is inhibit microbial growth and decreased derivative reactions, resulting in higher stability. Besides, drying results in substantial volume reduction, this facilitates transport and storage (Okos *et al.,* 1992). The main aim of drying products is to allow longer periods storage, minimize packaging requirement and reduce shipping weight (Maskan, 2001).

Sun drying has the traditional method of drying in developing countries and it has denotes the spreading of foodstuff in the sun on a suitable surface such as mat, roof, or drying floors Visavale (2012). Sun drying has the evaporation of water from products by sun assisted by movement of surrounding air. To be successful, it was demands a rainless season of bright sunshine and temperatures above 98° F coinciding with the period of product maturity. The main problems of sun drying are dust, rain and cloudy weather (Mong *et al.,* 2011).

Refractance-Window drying method was a recent non-thermal method for drying products including heat sensitive purees and slices of fruits and vegetables. With numerous advantages, this direct drying technology was found several applications in the algae, nutraceutical, pharmaceutical, cosmetic and pigment handling industries (Ortiz-Jerez *et al.,* 2015). The major components of a typical Refractance-window drying system essentially, evenly applied food materials over a thin infrared transparent material or polyethylene film (such as Mylar film) resting over the surface of water get heated (Baeghbali *et al.,* 2010). The film material can be either is moving or stationary. In a moving film configuration, the food was usually moved concurrently with the hot water, with belt velocities between 0.6 and 3 m/min (Kudra and Mujumdar, 2009). Thermal energy carried with the circulating water transmits sensible heat through the film to the food material spread as a thin layer over the film by conduction and radiation. This approach was characteristic to the Refractance-window technique. Water in the food was quickly evaporated owing to rapid transfer of heat energy, resulting in a state of thermal equilibrium. Additionally, radiation effects were also evident, depending on the material characters (Raghavi *et al.,* 2018). RW drying method is inexpensive and simple in operation when compared to freeze drying. Quality and color of Refractance-window products dried on Mylar sheet were comparable to freeze dried products. Short drying time is essential in countries where energy cost is very high. RW drying were energy efficient and have a good capacity for microbial reduction (Nindo *et al.,* 2006 and Abony *et al.,* 2002).

Therefore, This work was carried out to threw the light on the effect of RW drying methods as a novel drying method at three different temperatures (40, 50 and 60°C), as compared with natural sun drying method regarding to quality characteristics as the falling rate period of moisture content (%), Physical properties (color, pH), mineral contents (%), volatile compounds and microbiological aspects for produced dried Balady Mint with less expensive drying methods, which are able to produce high quality products.

MATERIALS AND METHODS

Materials

Menthol plant samples

Plants of Menthol (*Menthaviridis L.,)* (Mint.) were collected from Agriculture Research Center (ARC) farms in Giza region. The samples were obtained at period from June to August 2017.

The Chemicals used

All chemicals and Mediums (plat count agar**,** Potato dextrose agar) of the analytical methods used in present study were purchased from El- Gamhouria Trading Chemicals and Drugs Company, Egypt.

Methods

Drying Methods

Sun drying processing (SD) method

Tested plant menthol herbs were prepared and distributed uniformly as a one layer on stainless steel trays of size (3×1.2 m) area and dried under direct sunlight at ambient temperatures between (37:39°C) until dried to approximate moisture content percentage (4-6%) for (12 hours) at June to August 2017 according to method (Ghanem, 1998)

Refractance Window (RW) drying method

Three different drying temperatures samples investigated (40, 50 and 60°C) were used for carrying out RW to drying Mint. plant samples investigated. Temperature control unit was used to adjust the temperature during the drying process while water temperature was measured using the thermometer. According to method (Abul-Fadl and Ghanem, 2011).

Analytical methods

Physical evaluation

Determination of color density

The color density of fresh and dried Mint samples was determined as absorbance of the diluted centrifuged extracts. The absorbance was measured at 440 nm for menthol, using Perkin Elmer Lambda UV/VIS Spectrophotometer according to (Ranganna 1977).

Determination of pH value:

The pH value of fresh and dried Mint plant herb samples in this study was carried out by a Jenway 3505 pH meter (UK) with a combined electrode at 25^0c as described in A.O.A.C. (2005).

Chemical evaluation

Moisture determination

The moisture content of different Mint. samples were determined by drying Mint. samples to constant weight in an electronic oven at 105 ± 1°C according the methods of A.O.A.C. (2005).

Volatile essential oil determination

Extraction and identification of volatile essential oil were carried out at Medicinal and Aromatic Plants Research Department Laboratory, Horticulture Research Institute, Agriculture Research Center as follows.

a- Extraction of Volatile essential oil:

The air-dried Mint. of each sample was hydro distilled in a Clevenger-type apparatus for 3 h, to determine the volatile oil percentage (Volume/Weight). The obtained oils were dehydrated by filtration through anhydrous sodium sulfate and kept in a refrigerator in dark bottles for GC analysis (Arraiza, *et al.,* 2012).

b- Gas chromatography spectrometry analysis (GC):

Identification of volatile essential oil components was estimated by Gas Chromatography Spectrometry according to Adams, (1995).

Microbiological Analysis

The microbiological analysis were carried out including the determination of total count bacterial and yeast and mold count according to the methods recommended by (Oxoid 1982, UK).

Statistical analysis

All data of dried Mint samples were analyzed using SPSS (version 16.0 software Inc. Chicago, USA) of completely randomized design as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of different drying methods on the falling rate period of moisture content (%) for dried Balady Mint.

The relation between moisture content and falling rate period to reach the required moisture content (drying curves) of dried Balady Mint by different drying methods as sun drying method and RW under temperature (40, 50 and 60ºC) are listed in Tables (1).

From the obtained data in table (1), it can be seen that the moisture content of the Balady Mint significant decreased when the drying time was increased (from 86.1% to 4.9 in 12 hours). In the beginning of drying cycle, the rate of moisture evaporation loss is very high (0.8%) and decreased to (0.3%) by natural sun drying at temperatures between (37:39°C). as reported by other workers (Mkaddem *et al.,* 2009)

It can be conclude that the falling rate period by using natural sun drying method at temperatures between (37:39°C) to reach the appropriate moisture content percentage 4.9% in 12 hr for Balady Mint.

Table 1. Effect of Sun **drying method on the falling rate period of moisture content (%) for Balady Mint.**

Drying time (Hours)	Temperature Weather (°C)	Moisture evaporation (%)	Moisture (%)
0	37.0 ±1.08 ^{a}	-	86.1±1.10 ^{a}
3	38.7±1.10 ^{ab}	0.80±0.08 ^{a}	60±1.07 ^{b}
6	39.5±1.11 ^{b}	0.60±0.06 ^{b}	43±1.01 ^{c}
9	39.1±1.10 ^{b}	0.54±0.05 ^{b}	28±0.75 ^{d}
12	39.3±1.15 ^{b}	0.30±0.04 ^{c}	4.9±0.18 ^{e}

M± SE: Means± standard error for Microbiological Aspects; the means within the same column having different superscript are significantly varied (P ≤ 0.05).

Effect of RW drying method under temperature (40, 50 and 60°C) on the falling rate period of moisture content (%) for dried Balady Mint.

The relation between moisture content and falling rate period to reach the required moisture content (drying curves) of dried Balady Mint. by RW under temperature (40, 50 and 60ºC) were presented in Tables (2,3 and 4).

Table 2. Effect of RW drying method under (40°C) on the falling rate period of moisture content (%) of Balady Mint.

Drying time (Minutes)	Balady Mint Moisture evaporation (%)	Moisture (%)
0	-	86.1±1.10 [a]
3	0.8±0.09 [a]	84.1±0.70 [a]
6	0.7±0.08 [ab]	60.7±0.66 [b]
9	0.6±0.07 [b]	23.8±0.22 [c]
12	0.3±0.04 [c]	4.4±0.10 [d]

M± SE: Means± standard error for Moisture evaporation (%) and Moisture (%) the means within the same column having different superscript are significantly varied (P ≤ 0.05).

Table 3. Effect of RW drying method under (50°C) on the falling rate period of moisture content (%) of Balady Mint.

Drying time (Minutes)	Balady Mint Moisture evaporation (%)	Moisture (%)
0	-	86.1±1.11 [a]
2.5	0.8±0.09 [a]	82±1.10 [b]
5	0.6±0.08 [b]	53±0.54 [c]
7.5	0.4±0.07 [c]	26±0.22 [d]
10	0.2±0.001 [d]	4.3±0.09 [e]

M± SE: Means± standard error for Moisture evaporation (%) and Moisture (%) the means within the same column having different superscript are significantly varied (P ≤ 0.05).

From the above result from Table (2), it can be seen that significant decrease of moisture content by increasing the drying time from (86.1% to 4.4 in 12 Min.) and also, the rate of moisture evaporation loss was decreased by drying time increased (from 0.8 to 0.3 %) for Balady Mint dried by RW under 40ºC.

As shown in table (3), it could be showed that the moisture content significant decrease with the drying time increase (from 86.1% to 4.3 in 10 Min. Also, the rate of moisture evaporation loss significant decrease by drying time increase (from 0.8 to 0.2 %) for Balady Mint dried by RW under 50ºC.

The obtained results from Table (4), it could be observed that a significant decreased in moisture content by the drying time increased (from 86.1% to 3.5 in 8 Min). Also, the rate of moisture evaporation loss noticed a significant decreased by increasing the drying time from (0.8: 0.2%) for Balady Mint dried by RW under 60ºC.

Table 4. Effect of RW drying method under temperature (60°C) on the falling rate period of moisture content (%) of Balady Mint.

samples Drying Time (Min.)	Balady Mint Moisture evaporation (%)	Moisture (%)
0	-	86.1±1.11 [a]
2	0.8±0.10 [a]	80±1.01 [b]
4	0.6±0.10 [b]	58.2±0.14 [c]
6	0.4±0.10 [c]	28±0.10 [d]
8	0.2±0.10 [d]	3.5±0.09 [e]

M± SE: Means± standard error for Moisture evaporation (%) and Moisture (%) the means within the same column having different superscript are significantly varied (P ≤ 0.05).

It could be conclude that the best drying method used for drying Mint was found to be RW drying method using temperature (60ºC) because it was recorded significant decrease of falling rate period of moisture content (3.5%) in 8 min, followed by RW using temperature (50ºC) which recorded moisture content (4.3% in 10 min). As compared with the sun drying method with moisture content of (4.9% in 720 min), followed by RW using temperature (40ºC) which recorded moisture content of (4.4% in 12 min)

Effect of different drying methods on some physical properties of produced dried Balady Mint.

The processing of dried food products involved several processing variables that determine the final quality of the dried products. Removal of moisture causes physical and chemical changes that influence both the quality attributes (e.g. color, pH) and the level of acceptance of the product by consumers (Methakhup, 2003).

The color density and pH value of produced dried Balady Mint by RW under temperature (40, 50 and 60ºC and sun drying (control) were listed in Table (5).

From the above result from Table (5), it can be seen that the color density of dried Balady Mint (Optical Density of solution measured spectrophotometrically at 440 nm) by using natural sun drying was noticed significant increased for color density (1.291) as compared with the dried Balady Mint samples by using the RW drying methods under temperature 40, 50 and 60ºC (0.910, 0.836 and 1.104, respectively). The present results were agreement with the data obtained by (Rocha, and Melo, 2011).

Table 5. Effect of different drying methods on Physical properties of produced dried Balady Mint.

Characters	Different drying methods used for balady Mint. Natural sun drying	RW 40°C	RW 50°C	RW 60°C
Color	1.291±0.09 [a]	0.910±0.06 [c]	0.836±0.05 [d]	1.104±0.07 [b]
pH	6.64±0.11 [a]	6.61±0.10 [a]	6.60±0.10 [a]	6.62±0.11 [a]

M± SE: Means± standard error for Physical properties; the means within the same row having different superscript are significantly varied (P ≤ 0.05).

The higher color change in open sun drying was mainly due to the direct exposure to solar radiation for a longer period that induced non-enzymatic browning or Millard reaction.

The desirable green color of Balady Mint, due to the presence of chlorophyll pigments. The differences in the color of dried Balady Mint could be due to subsequent degradation of green chlorophyll to olive green pheophytin, and the prolonged exposure to heat induced increased impermeability of hydrogen ions across the cell membranes during drying, leading to oxidation of (Rocha, and Melo, 2011).

From the same results from Table (6), it can be seen that the pH values of dried Balady Mint were showed no significant difference between different drying methods. The present results were agreement with the data obtained by (Rocha, and Melo, 2011).

From the previously discussion, it could be concluded that when compared the RW drying methods under temperature 40, 50 and 60ºC by natural sun drying methods resulted to reduce in the color change in all produced dried Balady Mint by RW under (40, 50 and 60ºC) .

Effect of different drying methods on volatile compounds of produced dried Mint.

Balady Mint in the present work was found to be enriched by some volatile compounds such as (*α-pinene, Myrcene, Limonene, 1,8 cineole, β-ocimene, α-terpineol, Dihydeocarvcol , Trans-carveol, Carvone, Dihydeocarvcol* *acetate, β-caryophyllene and Caryophyllene oxide*), that known to be have healthy effect for their bioavailability in human body. These volatile compounds act as antioxidants, anticarcinogenic and also considered as chemo preventive for inhibition of pathogenic bacteria. (Hameed, *el al.,* (2015) and Balla, *et al.,* (2017).

The effect of natural sun drying and RW drying using of temperature 50 and 60ºC on volatile compounds of produced dried Balady Mint, were estimated and presented in Table (6).

Table 6. Effect of different drying methods used on volatile compounds of produced dried Mint.

Volatile compounds	Volatile compounds (%) of dried Mint by different drying methods		
	Sun drying	RW under	
		50° C	60° C
α-pinene	0.727	0.695	8.734
Myrcene	1.186	7.63	5.384
Limonene	7.367	5.532	15.808
1,8 cineole	4.962	1.928	----
β-ocimene	1.581	1.617	----
α-terpineol	0.673	0.952	10.974
Dihydeocarvcol	3.837	3.911	----
Trans-carveol	2.413	2.342	----
Carvone	66.347	67.787	59.1
Dihydeocarvcol acetate	1.317	1.35	----
β-caryophyllene	0.549	0.532	----
Caryophyllene oxide	1.45	1.402	----

From data given in Table (6), it is clear that the Mint dried by sun drying and RW drying method under 50° C was found to contain the same 12 volatile compounds (α-pinene, Myrcene, Limonene, 1,8 cineole, β-ocimene, α-terpineol, Dihydeocarvcol , Trans-carveol, Carvone, Dihydeocarvcol acetate, β-caryophyllene and Caryophyllene oxide) the dried Mint RW drying methods showed more improved in five compounds of these volatile compounds (Myrcene (7.63%), β-ocimene (1.617%), α-terpineol (0.952%), Dihydeocarvcol (3.911%) and Carvone (67.787%), opposite of these that found in dried Mint. By sun drying method (Myrcene (1.186%), β-ocimene (1.581%), α-terpineol (0.673%), Dihydeocarvcol (3.837%) and Carvone (66.347%). However, the dried Mint by sun drying and RW method have approximately the same content of another five volatile compounds such as (α-pinene (0.695%), Trans-carveol (2.34%), Dihydeocarvcol acetate (1.35%), β-caryophyllene (0.532%) and Caryophyllene oxide (1.402%) opposite (α-pinene (0.727%), Trans-carveol (2.413%), Dihydeocarvcol acetate (1.317%), β-caryophyllene (0.549%) and Caryophyllene oxide (1.45%) . The present results were agreement with the data obtained by [Hameed, *el al.,* (2015) and Balla, *et al.,* (2017)].

In general, it could be observed that these results may be attributed to different drying conditions used (depending on the product type and conditions used as, drying time, drying temperature, dryer structure, short drying time, low level of oxygen). Hameed, *el al.,* (2015) and Balla, *et al.,* (2017).

Effect of different drying methods used on microbiological aspects of fresh and dried Balady Mint.

In view of safety evaluation of any processed foods, either after preparation or after storing, to be ready for human consumption, the microbiological quality is mainly undertaken. In present work, the microbiological values in forms of total bacterial count and Molds & yeasts were estimated in Balady Mint dried by Refractance-window (RW) under temperature (40, 50 and 60°C) and they compared with sun drying (control).

Directly after drying of Balady Mint by different methods, the obtained data were statistically analyzed and recorded in Table (7).

It could be primarily observed from Table (7) that the Balady Mint samples dried with different methods showed that the samples dried with RW under temperature of 60°C no TBC and M&Y were detected.

However the Mint samples dried with RW under temperature 50°C were found to be free from TBC while it have 3.0 log cfu/g for M&Y. On the other hand, the samples dried with RW under temperature 40°C were recorded 3.0 log cfu/g for both TBC and M&Y as compared with samples dried by sun drying (3.0 and 3.48 log cfu/g for TBC and M&Y respectively).

Table 7. Effect of different drying methods on microbiological aspects (log cfu /g) * of Fresh and dried Balady Mint.

Microbiological aspects	Different drying methods used for balady Mint.				
	Fresh	Sun drying	RW		
			40°C	50°C	60°C
Total bacterial count	3.18±0.22[a]	3.0±0.13[b]	3.0±0.13[b]	ND	ND
Molds and yeasts count	3.70±0.23[a]	3.48±0.24[a]	3.0±0.14[a]	3.0±0.14[a]	ND

cfu/g* = Colony forming unit /gram   ND: no detected.**

M± SE: Means± standard error for Microbiological Aspects; the means within the same row having different superscript are significantly varied (P ≤ 0.05).

No detection of the total microbial counts of balady Mint. samples tested dried with RW under temperature 60°C which may be attributed for two main reasons; the first, our products obtained have low final moisture content about (3.5%) as shown in Tables (1 till 4) and thus this creating a low water activity in such samples which led to a media not valid for microbial growth and subsequently caused a stopping of microorganisms growth or the death of some organisms. The second reason indicated that the largest inhibition was achieved by essential oils found in Balady Mint. [Hameed, *el al.,* (2015) and Balla, *et al.,* (2017)].

Finally, it could be concluded that the Refractance-window (RW) drying method could effectively retard the microbial growth (total bacterial and Mold & yeast counts) followed by RW under temperature 50°C and RW under temperature 40°C methods, while the Mint. samples dried by sun drying showed a highest total bacterial and Mold & yeast counts.

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تأثير طريقة التجفيف بالنافذة الإنعكاسية على خصائص الجودة للنعناع البلدي

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تم تنفيذ هذا العمل لدراسة تأثير التجفيف على نبات النعناع البلدي باستخدام طريقة التجفيف بالنافذة الانعكاسية (RW) عند درجة حرارة (٤٠ ، ٥٠ و ٦٠ درجة مئوية) مقارنة بطريقة التجفيف الشمسي الطبيعي. أظهرت النتائج التي تم الحصول عليها أن أفضل طريقة لتجفيف النعناع البلدي كانت طريقة التجفيف بالنافذة الانعكاسية (RW) عند ٦٠ درجة مئوية لمدة ٨ دقائق, تليها التجفيف بالنافذة الانعكاسية (RW) عند ٥٠ درجة مئوية لمدة ١٠ دقائق، ثم التجفيف بالنافذة الانعكاسية (RW) عند ٤٠ درجة مئوية لمدة ١٢ دقيقة على التوالي بالمقارنة مع طريقة التجفيف الشمسي عند (٣٧- ٣٩ درجة مئوية) لمدة ١٢ ساعة. أشارت البيانات التي تم الحصول عليها أيضًا إلى أن عينات النعناع البلدي المجففة بالنافذة الانعكاسية (RW) في درجات حرارة مختلفة وعلى فترات مختلفة وجد أنها ذات لون أفضل عند مقارنتها مع العينات المجففة بطريقة التجفيف الشمسي. ومع ذلك ، لم يتم العثور على فروق ذات دلالة إحصائية في قيم الرقم الهيدروجيني لعينات النعناع البلدي المجففة التي تم تجفيفها بطرق التجفيف المختلفة المستخدمة. يمكن أن تلاحظ أيضًا أن النعناع البلدي الذي تم تجفيفة بالنافذة الإنعكاسية (RW) عند ٥٠ درجة مئوية لمدة ١٠ دقائق يحتوي على نفس المركبات الطيارة مثل المركبات الموجودة في العينات المجففة بواسطة طريقة التجفيف الشمسي. أعلى مستوى من المركبات الطيارة كان متمثلا في مركب ال Carvone بنسبة ٦٦,٣٤٧ ٪ في النعناع المجفف بالتجفيف الشمسي وبنسبة ٦٧,٧٨٧ ٪ في النعناع البلدي المجفف بالنافذة الإنعكاسية (RW) عند ٥٠ درجة مئوية لمدة ١٠ دقائق. فيما يتعلق بالتقييم الميكروبيولوجي ، وجد أن عينات النعناع البلدي المجففة بواسطة طريقة التجفيف بالنافذة الانعكاسية (RW) عند ٦٠ درجة مئوية لمدة ٨ دقائق كانت خالية من العد الكلي البكتيري وكذلك خالية من العفن والخمائر. وفي الوقت نفسه الجودة الميكروبيولوجية تنخفض تدريجيا باستخدام طريقة التجفيف بالنافذة الانعكاسية (RW) عند ٥٠ درجة مئوية تليها طريقة التجفيف بالنافذة الانعكاسية (RW) عند ٤٠ درجة مئوية ثم طريقة التجفيف الشمسي.