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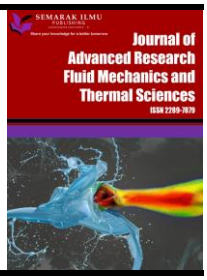

Drying Behavior of Moringa Oleifera Leaves using Tray Dryer

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ABSTRACT

Moringa oleifera leaves have been dried in a tray drier to investigate the drying behaviors of Moringa oleifera leaves at three different temperatures for their moisture content, color, iron and protein content, as well as total phenolic content. Three levels of temperatures were chosen varying from 50, 60 and 70 °C in this study. Drying time reduced significantly with the rise in temperature. The final moisture content of dried leaves at 50, 60 and 70 °C was 4.89, 4.79, and 4.59 % and reached equilibrium moisture content at 4, 2, and 1.5 hours. For the water activity, all the dried leaves give a low amount of water activity from 0.0912 to 0.1838 at 70 - 50 °C where the higher the temperature the lower the water activity. This indicates that the lower the temperature, the slower the drying time required to decrease moisture content to below 5 % and a smaller amount of water activity. This ability to preserve its taste and nourishment. For the color changes, the value for greenness (-a) has no significant difference but notable differences were detected between the color parameters of fresh and dried leaves for whiteness L value and yellowness b. This shows that drying under a tray dryer has the same color as the fresh *M. oleifera* leaves. There was no notable difference in the value for protein but a significant difference ($P<0.05$) in the value for iron contents of the fresh and dried leaves. The total phenolic content (TPC) obtained from this study was 46.97 - 55.78 mg GAE/g FW for drying at 50 to 70 °C. Results from this study discover a great option for large-scale drying using method.

1. Introduction

Moringa oleifera Lam. is among Moringa species which is the most frequently cited use for therapeutic and nutrition purposes in most countries due to the plant containing an appropriate number of amino acids along with high quantities of essentials nutrients such as carbohydrates, protein, vitamins, calcium, and minerals as well as its ability to withstand in drought resistance. In addition, the plant is known to be a multipurpose tree as all parts of the plant starting from the roots,

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seed, woods, pods, oil, fruits, flower, and leaves have their own benefits and it is also used widely for dealing in malnutrition as it gives cheaper nutrition and contains natural antioxidant properties [1]. Taking 3 oz full of *M. oleifera* leaf powder able to give enough iron and calcium required for pregnant and breastfeeding women [2]. In addition, according to Trigo *et al.,* [3], *M. oleifera* leaf powder is among the greatest natural sources of iron and calcium, as well as a multivitamin supplement with high levels of amino acids and other minerals.

Drying is a vital procedure in removing moisture content from the products by maintaining the aroma of raw herbs, nutritional characteristics, and appearance, as maximum as possible while preserving and extending its storage quality in the quality of flavour and free from microorganisms [4,29]. The first step in the food production is the drying method, especially when considering herbs as the initial step in every food processing industry. Different drying approaches may affect a notable difference in the composition of physicochemical in a dried sample [5]. Plenty of techniques applied by the prior researchers for drying *M. oleifera* leaves such as shade drying, oven drying, sunlight, microwave drying, freeze-drying and tray dryer [6-10].

The tray dryer is a closed insulated compartment in which trays are placed on top of one another in which hot air is supplied by a fan or natural flow [11]. These methods had gained popularity with scholars as a drying process for food, medicine, herbs, chemicals, dye, and material, especially on the large scale, as the dryer is a simple and cost-effective design [12]. Besides, it is also able to establish a great condition of the final sample and is capable to reduce the drying time without affecting the condition of the sample as food sample, since the food is spread out on trays to a proper volume and thickness, it may be dried uniformly as an airflow dispersion across the trays [11].

The prior research on the drying of *M. oleifera* leaves using a tray dryer was completed by Aznury *et al.,* [10] and investigated the drying effect on different temperatures and drying efficiency without taking to account the changes behaviours after drying. The aims of this research were to:

i. determine the influence of tray dryer at several temperatures (50, 60 and 70 °C) on the moisture and water activity of *M. oleifera* leaves;
ii. to analyze the differences in the color, iron, and protein contents of the sample after drying; and
iii. examine total phenolic content for *M. oleifera* leaves by utilizing microwave-assisted extraction (MAE) technique.

2. Materials and Methods

2.1 Materials

Moringa Oleifera Lam. leaves were obtained from Hadham Enterprise, Johor, Malaysia same as the previous study by Samad *et al.,* [9].

2.2 Drying of Moringa Oleifera Leaves

The drying procedure steps were conducted by referring to previous study by Samad *et al.,* [9]. *M. oleifera* leaves were cleaned with water and then dusted with a towel to remove contaminants from the surface of the leaves and to measure its initial moisture content. The leaves had been dried using a tray-dying method that consist of ten trays (dimension is 41.5cm x 41.5 cm x 3.0 cm for each tray). To obtain *M. oleifera* leaves powder (MOLP), three different temperatures (50, 60, and 70 °C) were investigated. 30 g of fresh leaves sample was spread thoroughly on a square tray to be used for all drying methods with triplicates to report the dry weight until the moisture content (MC) reached less than 5% (Geankoplis, 1993) and then ground using an electric grinder (Waring Commercial

Blender 8011S Model HGB2WTS3, USA) and sieved using a stainless-steel sieve with a diameter of 355 m aperture. The MOLP was then placed in a closed container in a dry and dark cupboard for future usage.

2.3 Extraction of Moringa Oleifera Using MAE

The extraction procedure was performed via MAE using MAS-II Plus Microwave Synthesis/Extraction Reaction Workstation (SINEO Microwave Chemistry Technology Co. Ltd., China) referring to optimise result done by Sin *et al.,* [13] with slight modification. The 1.5 g powdered *M. oleifera* sample was mixed with 100 mL of 35 % ethanol and placed in a Schott bottle to be soaked and then poured into 4 neck flasks to be extracted in MAE at temperature (65 °C), sample-to-solvent ratio (0.015) and ethanol concentration (35%) for 5 min while the microwave power was fixed at 375 W.

After MAE extraction, the *M. oleifera* leaves extract (MOLE) was set at room temperature to let it cool and centrifuged at the conditions of 15 min, 5000 rpm and 5 °C. Later, the supernatant was dried to evaporate the remaining ethanol solvent by using a rotary evaporator at 60˚C in a water bath until all the solvent is evaporated and then dried using a freeze drier (Alpha 1-2-LDplus, Germany). The MOLE obtained were set aside at 5 °C. The MOLE was analysed for TPC.

2.4 Colour Analysis

Colour analysis was completed following the procedure from previous study by Ali *et al.,* [8] and been recorded using CIE Standard Illuminant C at CIE L* a* b* color space coordinates

ΔE*ab was defined as shown Eq. (1) to signify the amount of the color change between two objects (dried leaves and fresh leaves) as follows in Potisate and Phoungchandang [14]:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

where L* is the brightness of a color; a* is the greenness of a color when negative; b* is the yellowness of a color when positive.

2.5 Protein and Iron Analysis

The protein and iron content were analyse referring to previous study Samad *et al.,* [9] by the association of Official Analytical Chemists (AOAC) method.

2.6 Total Phenolic Content (TPC) Analysis

The total phenolic content (TPC) of MOLE was evaluated using a modified Folin-Ciocalteu (FC) method [15]. 600 µL of water and 10 µL of the sample (50mg in 50ml of 35% ethanol) or standard solution of gallic acid were mixed, to which 50 µL of undiluted FC reagent was then added. After 10 min, 150 µL of 2 g in 100 mL sodium carbonate solution (Na2CO3) was added and the volume was filled up to 1 mL with water. Incubate the solution for 2 h at room temperature of 28 ± 1˚C and read absorbance at 760 nm by using EPOCH Microplate Spectrophotometer (BioTek Instrument Inc., USA). The result was expressed as the equivalent of milligrams of gallic acid per gram of Fresh Weight (mg GAE/g FW).

The standard calibration curve was expressed in TPC concentration of the sample equivalent to a milligram of gallic acid per gram (mg GAE/g) with Gallic acid hydrate. Based on the sample concentration, leaves powder dry weight and extract volume were used for calculating TPC yield, according to Eq. (2) by referring to Siddiqui *et al.,* [16]:

$$\text{TPC Yield} = C_1 \times \frac{V_{\text{extract}}\,(\text{ml})}{m_{\text{plant extract}}(\text{g})} \quad (2)$$

Where C1 is concentration of gallic acid obtained from the calibration curve in mg/ml, V is the volume of extract in ml, and m is the mass of the plant extract (g).

2.7 Experimental Design

The drying procedure steps were conducted at three levels of temperatures varying from 50, 60 and 70 °C until the moisture content (MC) reached less than 5%. Then, ground using an electric grinder and sieved to obtain *M. oleifera* leaves powder (MOLP). The MOLP obtained was analysed further for moisture content, water activity, protein and iron content including color analysis.

The extraction procedure was performed via Microwave-assisted Extraction (MAE) at condition 1.5 g powdered *M. oleifera* sample was mixed with 100 mL of 35 % ethanol and placed in a Schott bottle to be soaked and then poured into 4 neck flasks to be extracted in MAE at temperature (65 °C), sample-to-solvent ratio (0.015) and ethanol concentration (35%) for 5 min while the microwave power was fixed at 375 W. After MAE extraction, the *M. oleifera* leaves extract (MOLE) was analysed for TPC.

2.8 Data Analysis

The results obtained were documented in average ± standard deviation (STDEV) for triplicates and statistically evaluated and performed utilizing Microsoft Excel. A difference of $P < 0.05$ level was counted as statistically significant. Besides, the t-test was calculated to determine the statistically significant of the result obtained.

3. Results and Discussion

3.1 Moisture Content & Water Activity

Table 1 tabulates the moisture content (MC), water activity (Aw) and drying time for MOLP at temperature limits for 50 – 70 °C. The initial moisture content for the fresh leaves was 80.34 %. Table 1 shows that the drying time increased when the temperature decreased. The greater the temperature, the quicker the drying time required to obtain the moisture content below 5 %. The final MC of dried leaves at 50, 60 and 70 °C were about 4.89, 4.79, and 4.59 % and achieved equilibrium moisture content at 4, 2, and 1.5 hours. For the water activity, all the dried leaves give a low amount of water activity from 0.0912 – 0.1838 at 70 - 50 °C where the higher the temperature the lower the water activity. Hence, it is free from microorganisms like mould, yeast, and bacteria.

Table 1
Moisture content and water activity after tray dryer method

T (°C)	Final MC (%)	Time (h)	Aw
50	4.89	4	0.1838
60	4.79	2	0.1208
70	4.59	1.5	0.0912

This indicates that the lesser the temperature, the slower the drying time required to obtain the MC to below than 5 %. By decreasing the MC capable to preserve their taste and nourishment along with the increase its shelf life [8,17]. This finding demonstrates that MC was significantly affected by temperature and drying time.

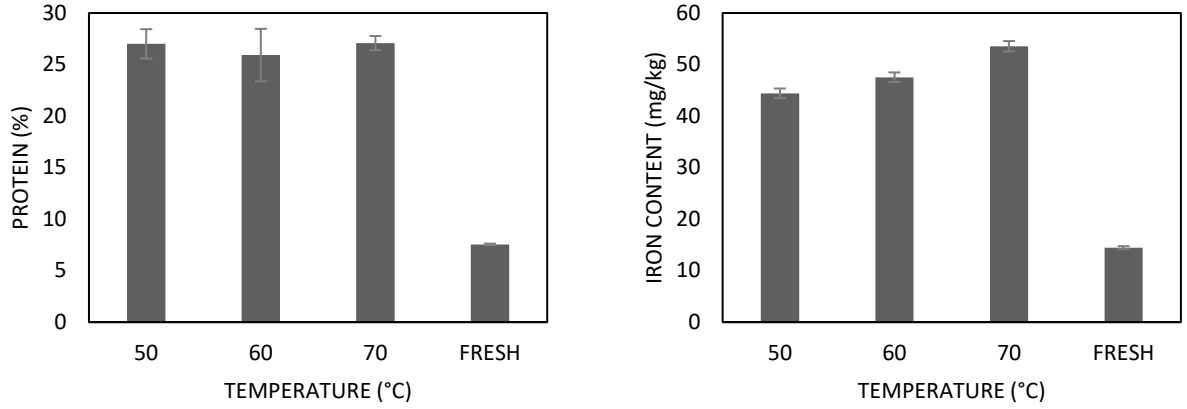
Comparable trend on the properties of drying has been stated by prior studies in using tray dryer for green herbs, for example, *M. oleifera* leaves, mint leaves, white mulberry leaves, curry leaves and green tea leaves [10,18,19,20,21]. Earlier research on the drying of *M. oleifera* leaves using conventional drying technique by Ali *et al.,* [7] showed around 8, 5.75 and 2 hours at 40, 50 and 60°C in an oven dryer which is more slower drying time contrasted to this research. This shows that a tray dryer technique gives a favourable option for drying many *M. oleifera* leaves at a considerably quicker drying time.

3.2 Protein and Iron Content

From Figure 1(a) illustrated 7.55 % of fresh MOLP in the protein content was and a bit higher as compared to the amount was reported by Trigo *et al.,* [3] which was 6.7 %. After the drying process, lots of moisture was reduced to less than 5%, and the amount of protein increased to 27.01, 25.92 and 27.08 % at 50, 60 and 70 °C. There was no notable difference ($P>0.05$) in the protein content of the dried MOLP at different temperatures. This shows that even at high or low temperatures, the amount of protein content would be almost similar. However, in this study found that, at low temperatures (50 °C) it takes four times longer than compared to dry at 70 °C. But protein is very sensitive to high temperatures as denaturation of protein cells might influence it at high temperatures. This can be supported by a study from Razzak *et al.,* [22] where the protein content decreased from 24.67 to 19.89 % at 60 – 80 °C using an oven dryer.

The protein content in this study was acceptable with the finding by Ali *et al.,* [8] where the amount of protein obtained was 29.8, 28.8 and 28.6 % at 40, 50 and 60 °C respectively using oven drying method while a study by Samad *et al.,* [9] obtained from 28.15 – 28.75 % at 300 - 1000 W using microwave drying method. The difference in protein content may be because of the diverse locality and moment of harvested [6]. This amount of protein content indicated a great advantage in therapeutic and nutrition purposes because of a good amount of nutrient preservation.

According to Figure 1(b) the amount of fresh MOLP was 14.46 mg/kg similar to previous study by Samad *et al.,* [9] and after the drying the amount of iron improved to 44.41, 47.54 and 53.54 mg/kg at 50, 60 and 70 °C due to moisture change. There is a substantial difference ($P < 0.05$) between 60 and 70 °C. A higher amount of iron for fresh leaves was reported by a previous study by Ali *et al.,* [8] at 18.5 mg/kg and the result for oven drying at 40, 50 and 60 °C were 207.7, 216.6 and 209.6 mg/kg. The differences could be regarding of locality of the plantation of *M. oleifera* and the time been harvested [6].



(a) (b)

Fig. 1. Content for tray drying of MOLP at 50, 60 and 70 °C (a) Protein, (b) Iron

The improved amount of protein and iron after drying were caused by the variation in nutrient concentration of internal composition within the *M. oleifera leaves* as the moisture was decreased to less than 5% [23]. This implies that finding the best drying method for *M. oleifera* leaves which have a great amount of iron and protein content after drying is necessary as it can improve the nutrition amount as well as can maintain its advantageous qualities [24].

3.3 Color Measurement

Appearance of a dried leaves is an important marker in terms of quality part to get a customer approval for the end-product. The tabulate data in Table 2 shows the color analysis of fresh and dried MOLP for three temperatures (50, 60 and 70 °C). The original values of L*, a* and b* for fresh *M. oleifera* leaves was 41.25, -3.95 and 3.33. The brightness values L* decreased a little as the drying temperature rise from 50 to 70 °C. There was a notable difference to the changes in L* and b* values as the drying temperature increases. This small difference in L* may resulted in the leaves appearance to turn into dark green. Similar effect has been stated by Rudra *et al.,* [25] where the L* value declined after drying at all drying temperatures during oven drying. Chlorophyll degradation is one of the causes that the changes in brightness value of dark green in *M. oleifera* leaves occur [7].

Table 2
Effect of different tray dryer temperature on the color of *M. oleifera* leaves; L* is the brightness of a color; a* is the greenness of a color when negative; b* is the yellowness of a color when positive

Drying Condition	FRESH	50 (°C)	60 (°C)	70 (°C)
L*	49.93 ± 1.32[a]	47.80 ± 1.69[b]	45.44 ± 1.22[a]	46.44 ± 1.44[b]
a*	-3.95 ± 0.25[a]	-2.78 ± 0.08[b]	-2.38 ± 0.31[b]	-2.016 ± 0.60[b]
b*	3.33 ± 0.18[a]	2.77 ± 0.28[b]	1.82 ± 0.20[b]	1.92 ± 0.10[a]
ΔE*ab		2.4933	4.9876	4.2317

In this study, all the drying process stop at MC less than 5% hence, study by Chen *et al.,* [30] support that at lower moisture the color of the sample is similar to fresh sample by referring to the amount of $\Delta E*$. However, from this study it found that the ΔE*ab obtained at 60 °C has the highest color change matched to the fresh leaves while 50 °C has the smallest which was a 2.49 color difference. This shows that the changes in color values were minimum in lower temperature as the

drying received lower heat thermal. Furthermore, study by Ali *et al.,* [8] confirm this by stating that low ΔE*ab levels are preferable in dry food items when compared to the fresh leaves.

From this research, there are slight variations in the color as darkening occurred, although the color nearly to the initial fresh *M. oleifera* leaves as there is just a little reduction in the value of color parameter by using tray drying technique. This shows that the tray drying technique at 50 °C able to sustain a perfect and acceptable green color as the original leaves.

3.4 Total Phenolic Content

The study by Rahim *et al.,* [26] stated that antioxidants that originated from plants have been known as free radical scavengers. Moreover, researchers found that some medicinal plants consist of multiple classes of natural antioxidants, such as phenolic acids, flavonoids, and tannins, which have more strong antioxidant activity than dietary plants [27].

MOLE contain abundant phenolic compounds such as quercetin and kaempferol which belongs to the flavonoid group [14]. This is due to the free radical scavenging capability being enabled by the hydroxyl groups; therefore, the TPC could be used as a basis for rapid screening of antioxidant activity. The TPC of the MOLE was measured based on the standard calibration curve of y = 0.3406x - 0.003, R^2 = 0.9948. From Figure 2, the range of TPC obtained from this study was from 51.87 – 54.81 mg GAE/g FW for drying at 50 - 70 ºC. There is no significant difference in temperatures for drying MOLE using a tray dryer. The amount of TPC obtained in this study is lower with the study reported by Abd Hashib *et al.,* [31] for drying pineapple using spray dried was 58 mg GAE/100g fruits compared with fresh pineapple.

The decreased value for TPC was due to the thermal processing of different temperature as the bounding between phytochemical were released from the matrix. Hence, it causes a synergistic effect with other phytochemicals, for instance, phenolics and flavonoids might also affect. Besides, study shows that MOLE have a strong source of cytokinin which can distinguish signals and gives a lot of phenolics and other plant secondary metabolites [28]. However, the previous studies by Potisate and Phoungchandang [14] were found to be lower which the study from 5 varieties at the range of 7 – 33 mg GAE/g FW. The differences could be regarding of locality of the plantation of *M. oleifera* and the time been harvested [6]. Hence, it can conclude that MOLE are rich in total phenolic contents and can act as natural antioxidants.

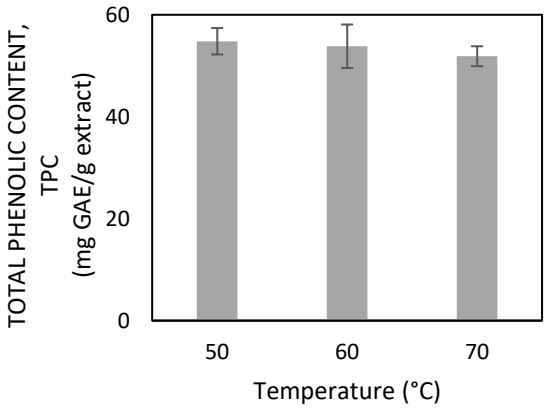


Fig. 2. The total phenolic content for tray drying of MOLE at 50, 60 and 70 °C

4. Conclusions

Drying using tray dryer method was studied at three different temperatures varying from 50, 60 and 70 °C. The drying time decreased significantly with the increase in drying temperature. The final MC of dried MOLP at 50, 60 and 70 °C were 4.89, 4.79, and 4.59 % and reached equilibrium MC at 4, 2, and 1.5 hours. The water activity obtained was from 0.0912 – 0.1838 at 70 - 50 °C. This result indicates that, the lower the temperature, the slower the drying time required to decrease moisture content to below 5 % and a lower amount of water activity. By lowering the moisture content enable to preserve their taste and nourishment. For the color changes, the value for greenness (-a) has no significant difference but significance differences were detected between the color parameters of fresh and dried leaves for brightness (L) value and yellowness (b). This shows that drying using a tray dryer has the same color as the fresh *M. oleifera* leaves. The protein contents for MOLP obtained were 27.01, 25.92 and 27.08 % while the iron contents were 44.41, 47.54 and 53.54 mg/kg at 50, 60 and 70 °C respectively. The TPC of MOLE obtained from this study was 46.97 - 55.78 mg GAE/g FW for drying at 50 - 70 °C. Results from this study discover a great option for large-scale drying using method tray dryer on *M. oleifera* leaves as a fast-drying technique.

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