Zagazig Journal of Food and Dairy Research 2099-2114

Zagazig J. Agric. Res., Vol. 43 No. (6A) 2016

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

EFFECT OF DRYING METHODS ON CHEMICAL COMPOSITION OF MORINGA LEAVES POWDER

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ABSTRACT

Moringa leaves contain large amount of several important nutrients which are essential to the human body. The present investigation efforts have been made to prepare powder from (*Moringa oleifera* L.) leaves by different drying methods, including shadow drying, and oven drying at different temperatures (50°C, 60°C and 70°C). Results indicated that shadow dried sample was better than oven dried samples due its high nutrients content. Moisture, protein, fat, fiber, ash and total carbohydrate contents of moringa powder were found in the range of 4.80 -6.77%, 21.52 to 22.90%, 7.94 -9.11%, 9.36-11.21%, 7.71-8.13% and 53.09- 60.12%, respectively. Sixteen amino acids were identified in moringa leaves powder. Lysin, leucine and phenylalanine were the most abundant essential amino acids in all studied samples. Moringa leaves powder contained 17 fatty acids. The highest saturated fatty acid was palmitic acid ($C_{16:0}$) of dried moringa leaves dried at 50^{o}C (10.77g/ 100g fat) while the major unsaturated fatty acid was α-Linolenic ($C_{18:3}$) of dried moringa leaves dried at 60^{o}C (52.46 g/100g fat). Vitamins A, E and C were present in different concentrations, where the highest values were found in fresh moringa leaves followed by leaves dried in shadow while those of lower values were found in oven dried sample. Results also illustrated that the moringa leaves powder is rich source of natural antioxidants. The highest content of the identificated sugars in moringa leaves powder (shadow drying) was stachyose (1009.75 mg/100g). Glucuronic acid was found in moderate concentration (876.59 mg/100g). Sucrose and raffinose were also detected (608.68 mg/100g, 607.89 mg/100g), respectively in moringa leaves powder. The study revealed that dried leaf powder of moringa can serve as an excellent source of nutrientional value and it was concluded that shadow drying method was the best method for drying moringa leaves.

Key words: *Moringa oleifera* leaves, shadow drying; oven drying, nutrients, chemical composition, antioxidants.

INTRODUCTION

Moringa (*Moringa oleifera* L.) is considered one of the most useful trees, in the world. As almost every part of the moringa tree can be used for food, medication and industrial purposes (Khalafalla *et al*., 2010). In many tropical and subtropical countries, various parts of moringa (leaves, fruits, immature pods, and flowers) are incorporated in the traditional food for humans (Siddhuraju and Becker, 2003; Anhwange *et al*., 2004). Moringa commonly known as drumstick, horse radish, shobhanjana, murungai, soanjna, shajna, sainjna is often known as "mother's best friend". Due to its high content of bioactive compounds, moringa leaves have been used in wide applications of food products. (Siddhuraju and Becker, 2003; Anwar *et al*., 2005; Fahey, 2005; Price, 2007; Singh and Prasad, 2013). Moringa leaves have been reported to be a rich source of β-carotene, protein, vitamin C, calcium and potassium and act as a good source of natural antioxidants, thus prolonging the shelf-life of fat containing foods

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due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotinoids (Siddhuraju and Becker, 2003; Anwar *et al*., 2005; Anwar *et al.,* 2007 ; Price, 2007). Total antioxidant activity of moringa pods was 133.78% and in moringa leaves was 168.34% (El-Masry *et al.*, 2013)

Moringa leaves are rich source of flavonols such as kaempferol and 3'-OMe quercetin. A flavone, acacetin and a glycoflavone 4-OMe Vitexin were also identified. Phenolic acids identified in moringa leaves included melilotic acid, p-coumaric acid, and vanillic acid (Nambiar and Daniel, 2005).

Daily intake of 25 grams of moringa leaves powder was found to provide child with 42% protein, 125% calcium, 61% potassium, 41% magnesium, 71% iron, 272% vitamin A and 22% vitamin C of the recommended allowances (Folkard and Sutherland, 1996).

Fresh moringa leaves were found to contain high amount of amino acids, especially essential amino acids such as, methionine, valine, phenylalanine, leucine, lysine and tryptophan, accounting for 2.12, 6.47, 6.38, 10.12, 6.73 and 2.17 g / 100 g protein, respectively (El-Masry *et al.*, 2013).

Moringa leaves have been used to combat malnutrition, especially among infants and nursing mothers and hasten uterine contraction during child birth in pregnant women. It's antihypertensive, diuretic, antispasmodic, antiulcer, and anticancer and cholesterol lowering activities have been reported (Caceres *et al*., 1992; Dangi *et al*., 2002).

Leaves of moringa are traditionally used as purgatives and in the treatment of headaches, hemorrhoids, fevers, inflammation of noise and throat, bronchitis, eye and ear infections, and to combat vitamin C deficiency (Mukunzi *et al*., 2011). Drying of plant leaves increases its shelf life. For drying fruits and vegetables different methods are used such as direct sun drying, shadow, cabinet drying, oven drying, and freeze drying (Satwase *et al.*, 2013) .

Liman *et al.* (2014) examined the effect of three different drying techniques (sun drying, oven drying at 150^{o}C for 4 hr., and drying with electrical moisture analyzer stabilized at 70^{o}C for 1 day) on the mineral composition (Ca, K, Mg, Na, and P) of moringa leaves . They could not obtain definite conclusion as which method is the best to be used. Nutrient, had been retained in moringa seeds in cabinet-tray drying method (in terms of protein and fat) compared to oven drying, sun drying and shadow drying (Aremu and Akintola, 2014).

Olabode *et al.* (2015) examined the effect of drying temperature 60, 70 and 80^{o}C on the nutrients of moringa leaves. Moisture, protein, fat and crude fiber contents of moringa leaves were decreased while ash and tannin contents increased as temperature increased. Temperature of drying had varing effects on the components of leaves.

Satwase *et al.* (2013) studied the effect of sun drying, shadow drying, cabinet drying, and oven drying at 60^{o}C. Cabinet dried samples were the best samples. It had highest nutrient retention followed by shadow, sun drying and oven dried samples. Cabinet tray drying method was observed as suitable dehydration process of drumstick leaves.

The aim of the present study was to examine the effect of two drying techniques, namely, shadow drying at ambient temperature as well as oven drying at (50, 60 and 70^{o}C) on chemical composition of moringa leaves.

MATERIALS AND METHODS

Materials

Moringa leaves were obtained from of El-Shikh Zwide Research Station in North Sinai, Desert Research Centre, Ministry of Agriculture at two successive seasons 2014 and 2015.

Methods

Preparation of Samples

Fresh leaves were collected from moringa tree were cleaned by removing stems and other unwanted parts. The leaves were washed with warm water 30^{o}C±4 to remove dirt particles. The excess water was allowed to drain out from leaves then moringa leaves were put on a piece of cotton cloth to absorb up the remaining of the tap water at room temperature.

Drying Techniques

The fresh leaves were dried in shadow and hot air using electric oven as follow:

Shadow Drying

The leaves were spread on filter papers and kept at room temperature for seven days. The leaves turned over once per day. Care was taken to observe that there was no fungal growth on the leaves (Satwase *et al.*, 2013).

Oven Drying

Moringa leaves were spread on drying trays (38 × 27cm) and dried in a laboratory drying oven (Heraeus instruments - Germany) equipped with a ventilating fan. Drying was carried out at three different temperatures (50, 60 and 70°C for 48 hr.) as reported by Satwase *et al.* (2013)

Grinding Leaves

The dried moringa leaves were ground in a mill (company IKA-Germany) containing sieves with narrow holes to get powder ≤ 0.5 mm. The moringa leaves powder were collected and stored in black plastic pags at room temperature.

Chemical Analyses

Moisture, protein, fat, ash and crude fiber contents were determined according to AOAC (2005). Total carbohydrate content was calculated by difference as follows: 100 – (% moisture + fat + protein+ ash).

Determination of Amino acids

Amino acids were separated on INGOS amino acid analyzer (Model: AAA400).

Preparation of Hydrolyzed Amino Acids

Preparation of hydrolyzed amino acids was according to the method of Csomos and Simon-Sarkadi (2002), as follow:

1. The dried and defatted grinding sample (0.2g) was hydrolyzed with 10 ml HCL (6N) in sealed tube, heated at 105^{o}C for 12 hr.
2. The resulting solution was diluted to 25 ml with de-ionized water.
3. After filtration, five ml of hydrolysate was evaporated in water bath until to be free from HCL.
4. The residue was dissolved in diluting citrate buffer (pH 2.2).

Preparation of Diluting of Buffer 0.2M Na, pH 2.2

The samples and standards were diluted with 0.2 ml citrate buffer pH 2.2 to proper concentration.

Determination of Fatty Acids

Fatty acids were determined according to the method described by the international Organization for Standardization (ISO 5508, 1990 and ISO, 5509, 2000).

Fatty acid methyl esters were prepared from total lipid by using rapid method according to the method of IUPAC (2000). Fatty acid methyl esters were formed by trans-esterification with methanolic potassium hydroxide as an intermediate stage before saponification take place.

Separation and Identification of Fatty Acids Methyl Esters by Gas Liquid Chromatography (GLC)

Fatty acid methyl esters of leaves oil were quantified by gas-liquid chromatography (HP 6890 GC capillary) equipped with a flame ionization detector (FID) using a 60 m x 0.32 mm x 0.25 um DB-23 capillary column. The injector and detector temperatures were set at 230°C and 250°C, respectively. Hydrogen gas (flow rate 40 ml/min.) was used as carrier gas and temperature programming was as followes: from 150 to 170°C at 10°C/min and from 170°C to 192°C at 5°C/min, holding five min and from 192°C to 220°C during 10 min . Individual methyl esters were identified by comparison to known standards.

Determination of Minerals

Acid digestion method was used to digest all the organic matter of dry moringa leaves powder with sulphuric acid for 24 hr., then digest at 125°C. After complete digestion the samples were cooled, diluted with distilled water up to final volume of 50 ml.

Minerals were done Inactively Coupled Argon Plasma, ICAP 6500 Duo, Thermo Scientific, England, 1000 mg/l multi-element

certified standard solution; Merk, Germany was used as stock solution for instrument standardization.

Determination of Vitamins

Determination of Vitamin C was determined according to the method of AOAC (2006).

Vitamin A and E were determined according to Noll (1996) and Pyka and Sliwiok (2001)

Determination of Total Phenolic Content

Total phenolic contents were determined by the Folin-Ciocalteu method (Siddhuraju and Becker, 2003). 0.5 ml of moringa extract powder in distilled water (1:10) was mixed with 2.5 ml of Folin–Ciocalteu reagent diluted in distilled water (1:10 *V/V*). The mixture was hand shaken and after 5 min of rest, 2 ml of sodium carbonate 4% (*V/V*) were added. Samples were incubated for 2 hr., in the dark and the absorbance was measured at 740 nm using UV/Vis spectrometry. The calibration curve was prepared by four data points ranging from 10 to 100 mg/l solutions of gallic acid in water.

Determination of Phenolic Compounds by HPLC

Phenolic compounds were determined by HPLC according to the method of Pascale *et al.* (1999) as follows: 5 g of moringa powder sample were mixed with methanol and centrifuged at 10000 rpm for 10 min and the supernatant was filtered through a 0.2 µm Millipore membrane filter then 10 µl was collected in a vial for injection into HPLC Agilent (series 1100) equipped with auto samplling injector, solvent degasser, UV detector set at 280 nm and quaternary HP pump (series 1100). The column temperature was maintained at 35°C. Gradient separation was carried out with methanol and acetonitrile as a mobile phase at flow rate of 1 ml/min. phenolic acid standard from sigma Co. were dissolved in a mobile phase and injected into HPLC. Retention time and peak area were used to calculate phenolic compounds concentration by the data analysis of Hewllet Packared software.

Determination of Antioxidants Activity

Antioxidants activity was determined by DPPH (2.2-diphenyl-1picryl hydrazyle) method according to Su and Silva (2006).

Determination of Saccharides

Sugars were determined by HPLC according to Zielinski *et al.* (2014) as follows: 1 g of sample was mixed with deionized water and centrifuged at 10000 rpm for 10 min and the supernatant was filtered through a 0.2 µm Millipore membrane filter then 1-3 µl was collected in a vial for injection into HPLC Agilent (series 1100) equipped with auto sampling injector, solvent degasser, IR-detector using Aminex. Carbohydrate HPX-87°C column (300mm × 7.8mm). The column temperature was maintained at 85°C. Gradient separation was carried out with deionized water and acetonitrile flow rate of 1 ml/min. Sugar standard from sigma Co. was dissolved in deionized water and injected into HPLC. Retention time and peak area were used to calculate sugar compounds concentration by the data analysis of Hewllet Pack software.

Statistical Analysis

Data were analyzed by the ststistical Computer Program, SAS (2003), using the General Linear Model (GLM) procedure. All the characteristics were performed in conformity by factorial analysis and one way analysis model. The significant differences among treatments means were separated by Duncan's Multiple Range-Test (Duncan, 1955).

RESULTS AND DISCUSSION

The chemical composition of moringa leaves either fresh or dried by different drying methods was determined and the obtained results are tabulated in Table 1.

From the data presented in Table 1 it could be noticed that the moisture content of the four dehydrated samples ranged between 4.80 to 6.77% where the maximum moisture content was recorded for shadow dried sample,which was (6.77%) while the minimum moisture content was recorded for the oven dried sample at 70°C which was (4.80%). These results are consistant with the findings of Satwase *et al.* (2013), who found that shadow drying of moringa leaves had the highest moisture content (6.2%) compared with sun drying, cabinet drying and oven drying at 60°C. This could be attributed to the reduction in moisture

Table 1. Proximate chemical composition of fresh and dried moringa leaves

Component (%)	Fresh leaves	Shadow drying	Oven drying at		
			50°C	60°C	70°C
Moisture	75.42^{a} ±0.36	6.77 ^{b} ±0.47	5.59^{c}±0.13	5.39^{c} ±0.19	4.80^{c} ±0.20
Protein	7.52^{c} ±0.35	22.90^{a} +0.25	22.13^{ab}±0.20	22.04^{ab} +0.20	21.52^{b}± 0.32
Fat	1.78^{c} ±0.14	9.11^{a} ±0.13	8.46^{b} ±0.29	8.04 ^{b} ± 0.19	7.94^{b} ±0.08
Ash	1.90^{b} ±0.14	8.13^{a}± 0.14	7.91^{a} ±0.14	7.83^{a} ±0.14	7.71^{a} ±0.14
Fiber	1.99^{d} ±0.12	11.21^{a} ±0.17	10.22^{b} ±0.19	9.75^{c} ±0.19	9.36^{c} ±0.32
Total carbohydrate	13.38^{e} ±0.44	53.09^{d} ±0.19	55.81^{c} ±0.19	56.70^{b} ±0.19	58.03^{a} ±0.31

$^{a, b}$ .... Means in the same row in each classification bearing different letters differ significantly (P≤0.05)

content during drying that result in corresponding increase in dry matter content due to concentration of soluble solids. This is expected to improve the shelf life of the leaves since the activity of spoilage agents such as microorganisms and autolysis will be greatly hampered at such low moisture content. However, there may be an increase in the incidence of non-enzymic browning according to Derossi *et al.* (2011).

On the other hand, protein content of the different dehydrated samples was ranged from 21.52 to 22.90% where the shadow dried sample had the maximum protein content. These results are in agreement with those reported by Offor *et al.* (2014), who found that protein content of dried moringa leaves was 24.2%. Madukwe *et al*. (2013) also found that protein content of dry moringa leaves powder was 26.28%.

The present data illustrated that fat content ranged between 7.94 - 9.11%, shadow dried samples had the highest fat content (9.11%) while the oven dried samples at 70°C had the lowest fat content (7.94%). Madukwe *et al.* (2013) found that the fat content of dry moringa leaves powder was 9.21%.

Ash content of different dehydrated samples was in the range of 7.71 to 8.13%. Ash content of shadow dried samples was the highest compared to the other dried samples. These results agree with those reported by Bussani *et al*. (2011) who found that ash value of dry moringa leaves powder was 7.64%.

Concerning to the fiber content, results tabulated in Table 1 shows that shadow dried samples contained the highest fiber content (11.21%), followed by oven dried samples at 50°C which was (10.22%). Bussani *et al*. (2011) found that fiber content of dry moringa leaves powder was 11.40% and El Sohaimy *et al.* (2015), found that fiber content of dry moringa leaves powder was 11.23%.

Carbohydrate content ranged between 53.09 to 58.03% in dried samples (Table 1), it could be observed that, the highest carbohydrate content was recorded for oven dehydrated moringa leaves at 70°C. These results are in agreement with those reported by Madukwe *et al*. (2013) they found that, Carbohydrate content of dry moringa leaves powder was 49.35% and Kayi (2013) who found that, carbohydrate content of dry moringa leaves powder was 63.11%, similarly Offor *et al.* (2014) found that carbohydrate content of dried moringa leaves from Ebonyi State, Nigeria was 50.4% and, El Sohaimy *et al.* (2015) found that carbohydrate content of dry moringa leaves powder was 56.33%.

Data in Table 2 indicated that the leaves of moringa subjected to different dehydration methods contained 16 amino acids (8 essential amino acids and 8 non-essential amino acids). Lysin, leucine and phenylalanine were the most abundant essential amino acids in all studied samples, where their contents ranged between 36.07 to 41.65, 5.73 to 6.74 and 4.94 to 5.50% g/100g protein, respectively.

Table 2: Amino acids composition of fresh and dried moringa leaves (g/100g protein)

Amino acid		Fresh	Shadow drying	Oven drying			Egg amino acids reference
				50°C	60°C	70°C	
			Essential				
1	**Phenylanaline**	5.02	5.44	4.94	5.50	5.40	5.70
2	**Threonine**	1.92	1.99	2.00	2.20	1.88	5.10
3	**Methionine**	0.32	0.37	0.79	0.56	0.56	3.40
4	**Leucine**	5.73	6.36	6.17	6.74	6.46	8.80
5	**Isoleucine**	2.39	2.76	2.51	2.87	2.89	6.30
6	**Lysine**	41.65	37.23	40.61	36.32	36.07	7.00
7	**Valine**	4.10	4.62	4.25	4.83	5.78	6.80
8	**Histidine**	3.35	3.70	3.36	3.78	3.88	-
	Total	64.48	62.47	64.63	62.80	62.92	43.1
			Non-essential				
9	**Aspartic**	8.37	8.02	6.57	6.81	7.27	
10	**Serine**	2.34	2.46	2.18	2.37	2.34	
11	**Glutamic**	10.41	10.91	10.10	11.16	11.07	
12	**Proline**	0.05	0.10	0.07	0.10	0.10	
13	**Glycine**	6.59	7.07	7.73	7.62	7.40	
14	**Tyrosine**	1.46	1.63	2.14	1.70	1.45	
15	**Cystine**	-	-	-	-	-	
16	**Alanine**	6.29	7.33	6.58	7.45	7.46	
	Total	35.51	37.52	35.37	37.21	37.08	

These findings are in accordance with those reported by El-Masry *et al.* (2013), who found that the major essential amino acids of moringa leaves were leucine, phenylalanine and lysine.

Glutamic, aspartic acid and alanine were the major non-essential amino acids, of all studied samples ranging between 10.10 to 11.16, 6.57 to 8.37% and 6.29 to 7.46 g/100g protein, respectively. Cystine was not detected in all studied samples of moringa leaves. Bussani *et al.* (2011) found that moringa leaves had a very low content of cystine (0.01 %).

Results in Table 2 illustrate obviously that all studied samples of moringa leaves had low contents of essential amino acid compared to egg protein, with one exception related to lysine, which was higher than that of egg by 5 folds approximately.

The variations in the amino acid composition could be influenced by protein quality and the origin of the plant (cultivated or wild). Usually cultivated plants are fertilized which could influence the quality of proteins (Sanchez-Machado *et al.*, 2009).

The Fatty acids composition of moringa leaves either fresh or dried by different drying methods are shown in Table 3.

Seventeen fatty acids were identified in dried moringa leaves. Data presented in Table 3 demonstrated that $C_{8:0}$ and $C_{10:0}$ were not detected in all studied samples. The major saturated fatty acid in all studied samples of moringa leaves was palmitic acid ($C_{16:0}$), which ranged between 4.95 and10.77%. The lowest concentration was found in oven dried moringa leaves at 70°C. Sample dried in shadow and dried sample in oven at 50°C had highest concentration of palmitic acid which were 9.89% and10.77%, respectively. The major unsaturated fatty acid was α-Linolenic $C_{18:3n3}$ being 31.11% for sample dried in oven at 50°C and 52.46% for sample dried in oven at 60°C. Total saturated fatty acids content ranged between 8.69% for oven sample dried at 70°C and 24.53% for sample dried in shadow at ambient temprature. On the other hand, the total unsaturated fatty acids content ranged between 49.77% for oven dried sample at 50°C and 66.70% for oven dried samples at 60°C. There are very important two ratios; the first is saturated /unsaturated ratio which related to oil stability, while the second is oleic/linoleic which related to palatability.

From the previous results, it could be concluded that the higher of drying temperature, the lowers of the oil stability. The highest palatability was recorded for the fresh sample while the lowest palatability was recorded for the oven dried sample at 70°C.

Fatty acids profiles obtained in the present study come in partial agreement with results obtained by Compaoré *et al.* (2011). Sanchez-Machado *et al.* (2009) reported that α-linolenic acid had a higher value of 56.87% of interest was α-linolenic, which is an n-3 fatty acid that belongs to the group of the essential fatty acids.

Findings differ in the present study from that of Sanchez-Machado *et al.* (2009) who found 14 fatty acids, which could be attributed to the age of the leaves, soil type and climatic conditions.

The minerals content of different samples of moringa leaves either in the fresh or with dried are shown in Table 4.

Calcium, potassium, magnesium, and iron are the major minerals detected in all studied samples. The highest value of calcium and iron were in shadow drying sample and drying at 70°C being 2208 and 2036 mg/100g, respectively. The highest contents of potassium and magnesium were found when dried in oven treatment at 70°C, being 1000 and 398.2 mg/ 100g; respectively; Selenium was not detected in all studied samples. These results are in agreement with those reported by El-Masry *et al.* (2013) and Yameogo *et al*. (2011), they found that the major elements in dried *moringa oleifera* leaves were calcium, potassium and magnesium.

Cadmium, cobalt, chromium, molybdenum, lead and vanadium were detected in minor concentrations. These results are in agreement with data reported by Severino *et al.* (2009), who stated that cadmium, arsenic, chromium and lead were lower or not detected in some samples of moringa leaves collected from different areas .

Differences observed between the obtained results and those reported in literature can be attributed to geographical, soil composition, cultivation climate, ripening stage varity of moringa and harvesting time of leaves and the extraction method used (Compaoré *et al*., 2011).

Vitamins Content of Fresh ad Dried Moringa Leaves

Vitamins play an important role in improving human health promoting. Vitamin A is a natural antioxidant capable of inhibiting free radicals formation and is important for improving the immune system. Vitamin E is useful for enhancing the immune system function and skin repair. Vitamin C is very important for cardiovascular health and reducing free radicals in the cells (Thurber and Fahey, 2009).

The content of vitamins A, E and C of moringa leaves either in the fresh or in the dried by different drying techniques were determined and the obtained results are demonstrated in Figs. 1, 2 and 3.

The content of vitamin A was 15.71 mg/ 100 g in moringa leaves dried at 70°C, compared with the fresh moringa leaves which was 33.07mg/100g (Fig. 1).

Table 3. Fatty acid composition of fresh and dried moringa leaves (g/100g fat)

Fatty acid		Fresh	Shadow drying	Oven drying at		
				50°C	**60**°C	**70**°C
Lauric	$C_{12:0}$	0.40	0.36	0.38	N.D	N.D
Myritic	$C_{14:0}$	0.59	1.31	1.17	0.52	0.47
Tetradecenoic	$C_{14:1}$	N.D	0.99	0.46	0.17	N.D
Pentadecanoic	$C_{15:0}$	0.07	0.13	0.19	0.13	N.D
Pentadecanoic (cis-10)	$C_{15:1}$	0.28	0.09	0.26	0.76	1.09
Palmitic	$C_{16:0}$	8.02	9.89	10.77	7.52	4.95
Palmitoleic	$C_{16:1}$	1.67	4.31	3.21	0.29	0.24
Margaric	$C_{17:0}$	0.24	0.31	0.39	0.33	0.36
Heptadecnoic(cis-10)	$C_{17:1}$	0.04	0.05	0.09	0.12	N.D
Stearic	$C_{18:0}$	1.94	1.40	1.57	1.63	1.47
Oleic	$C_{18:1}$	4.19	2.97	3.07	2.73	2.37
Linoleic	$C_{18:2}$	6.59	9.05	9.27	6.45	7.77
g-Linolenic	$C_{18:3n6}$	1.31	1.79	1.19	1.73	1.53
α-Linolenic	$C_{18:3n3}$	40.22	32.01	31.11	52.46	42.61
Arachidic	$C_{20:0}$	5.37	10.02	4.39	0.63	0.18
gondoic	$C_{20:1}$	1.44	1.00	1.11	1.69	0.73
Behenic	$C_{22:0}$	1.45	1.47	1.44	1.10	1.26
Total unknown		26.14	22.82	29.89	21.70	34.96
Total saturated fatty acids		17.68	24.53	19.92	11.86	8.69
Total unsaturated fatty acids		55.74	52.26	49.77	66.70	56.34
Totalsaturated/total unsaturated		0.31	0.46	0.40	0.17	0.15
Oleic / lenoleic		0.63	0.32	0.33	0.42	0.30

N.D = Not detected

Table 4. Mineral content in fresh and dried moringa leaves (mg /100g)

Mineral	Fresh	Shadow drying	Oven drying		
			50°C	60°C	70°C
Major mineral					
Calcium	1805	19698	220	1974	2036
Magnesium	328.8	378	352.2	368.2	398.2
Potassium	720	840	820	860	1000
Trace mineral					
Aluminum	27.8	44,38	33.78	38.04	33.6
Boron	9.858	10.204	9.552	13.668	13.716
Cadmium	0.01	0.01	0.01	0.01	0.01
Cobalt	0.03	0.03	0.044	0.032	0.032
Chromium	0.2	0.2	0.2	0.2	0.2
Copper	0.632	0.72	0.764	0.844	0.892
Iron	41.14	60.32	48.24	47.72	48.28
Manganese	6.448	7.656	6.44	7.338	8.022
Molybdenum	0.02	0.02	0.02	0.02	0.02
Nickel	0.188	0.17	0.19	0.138	0.164
Lead	0.086	0.11	0.188	1.2	0.82
Vanadium	0.22	0.362	0.132	0.1	0.12
Selenium	N.D	ND	N.D	N.D.	N.D
Zinc	2.524	2.864	2.576	2.614	3.05

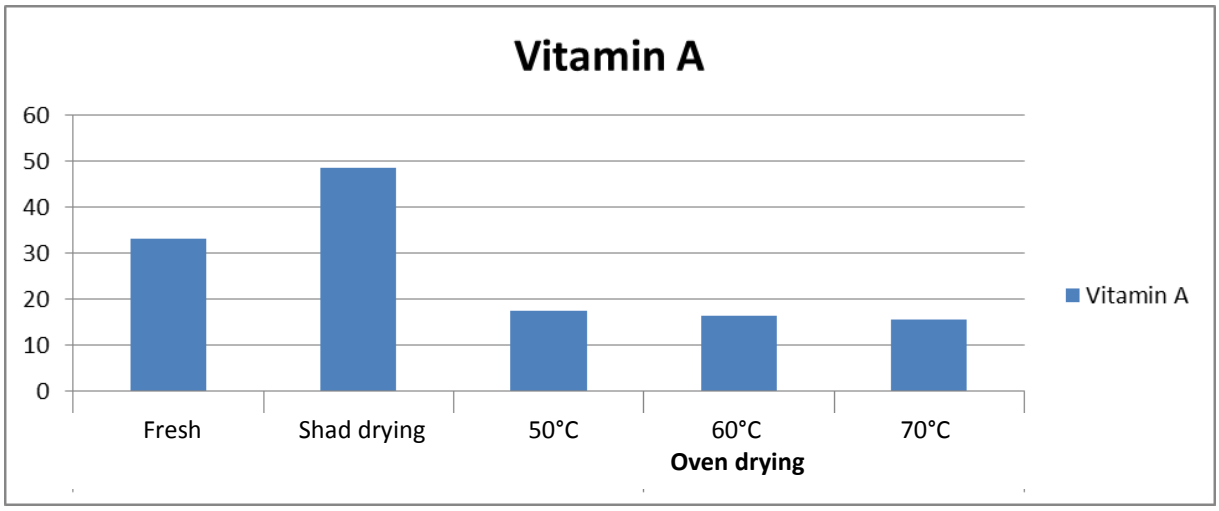

Fig. 1. Vitamin A content of fresh, shadow and oven dried moringa leaves

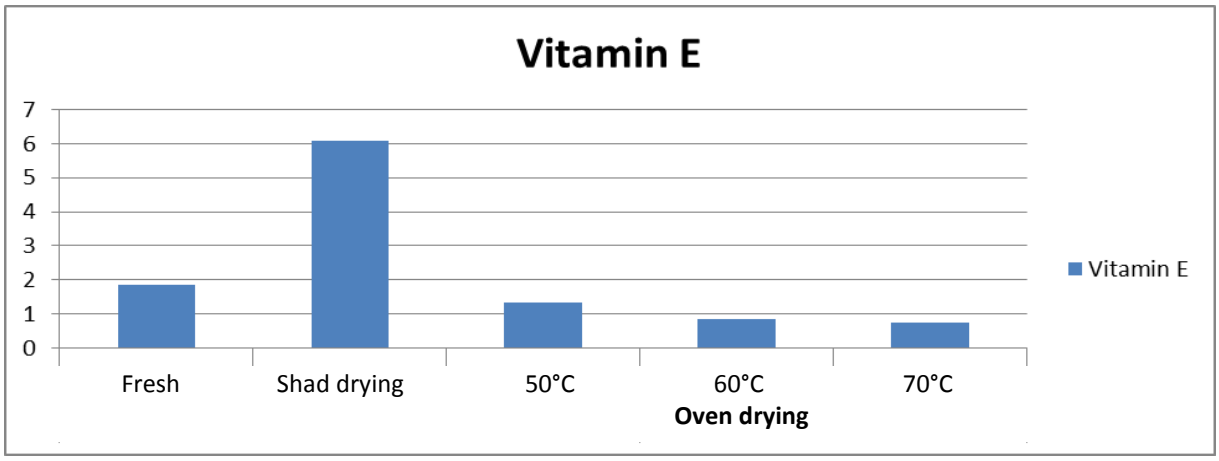

Fig. 2. Vitamin E content of fresh, shadow and oven dried moringa leaves

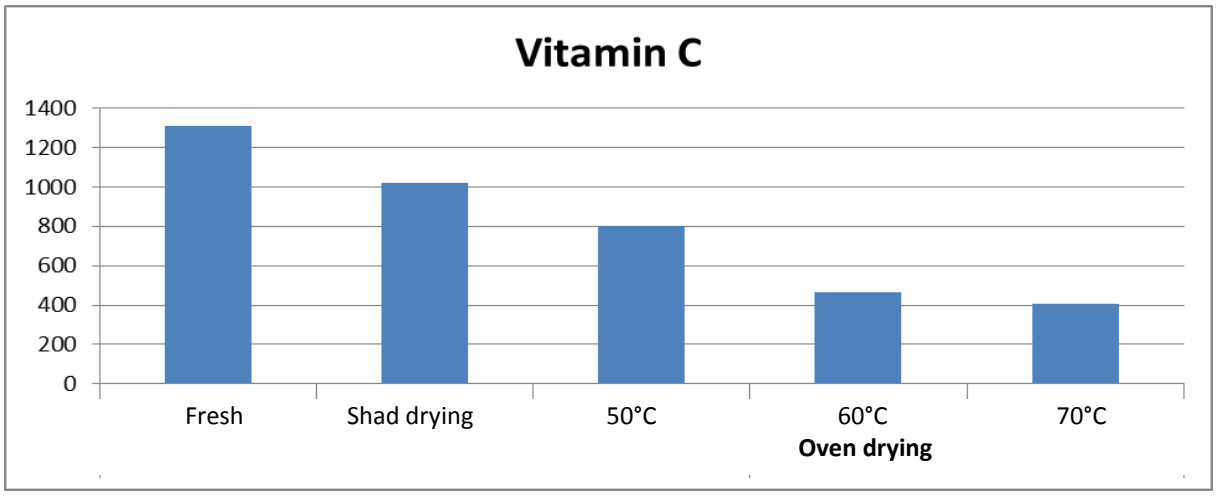

Fig. 3. Vitamin C content of fresh, shadow and oven dried moringa leaves

The content of vitamin E was 0.73 mg/ 100 g in moringa leaves dried at 70°C, compared with the fresh moringa leaves which was 1.84 mg/100g (Fig. 2). Similarly vitamin C content was 407.3 mg/100 g in moringa leaves oven dried at 70°C compared with the fresh moringa leaves which was 1312 mg/100 g (Fig. 3)

Data in Figs. 1, 2 and 3 shows that different drying temperatures led to decrease vitamins A, E and C contents. Moringa leaves dried in shadow were characterized by the highest vitamin content compared to oven dried samples.

These results are in agreement with those reported by Olabode *et al.* (2015), who found that ascorbic acid and ß-carotene (pro vitamin A) were decreased as a result of raising drying temperature from 60 to 80°C.

Mbah *et al.* (2012) found that shadow drying had the highest content of vitamin A compared to either fresh, or oven dried samples of moringa leaves.

Total Polyphenol Content of Fresh and Dried Moringa Leaves

Phenolic compounds and flavonoids are very important constituents due to antioxidant activity. The moringa leaves might be regarded as a promising rich source of phenolic compounds. Polyphenols content of fresh and dried moringa leaves are shown in Fig. 4.

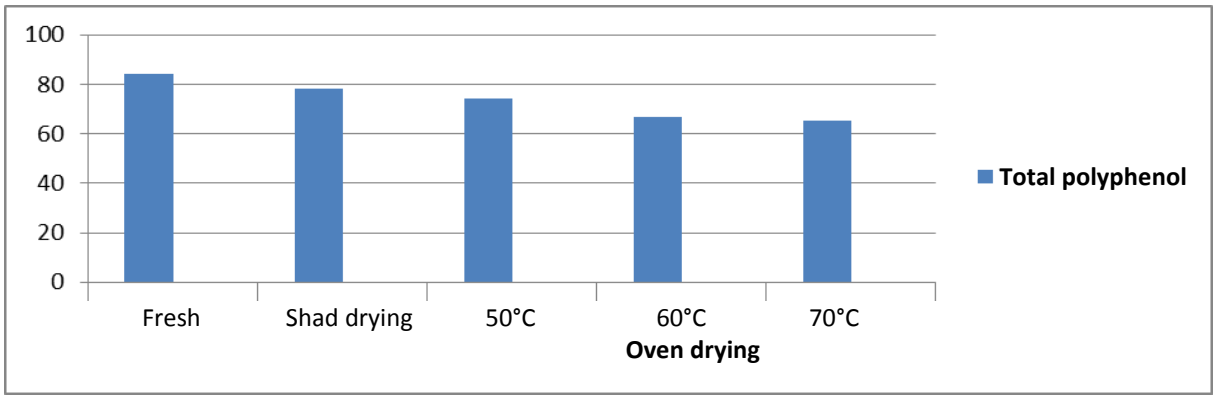

Fig. 4. Total Polyphenol content of fresh and dried moringa leaves (expressed as mg/100g sample)

The highest total polyphenol content was recorded in fresh samples (84.2 mg/100g) followed by shadow dried samples which was (78.00). The lowest total polyphenol content was recorded for the oven dried samples at 70°C (65.5 mg/100g).

These results are in agreement with those reported by Singh and Prasad (2013), they found that the total polyphenol content of moringa leaves ranged from 23.57 to 155.15 mg/100g depending on the drying temperature, particle size and blanching process. El-Masry *et al.* (2013) reported that total polyphenol contents were reduced as a result of drying process in comparison with fresh samples.

Based in the presented data of amino acids, fatty acids, vitamins, and minerals, it can be included that the drying of fresh moringa leaves, using shadow drying was found to be the best method, thus, shadow dried moringa leaves powder was subjected to analysis of phenolic compounds composition, antioxidant activity, and sugar composition.

Twenty three phenolic compounds were identified in shadow dried moringa leaves. The major phenolic compounds were e-vanillic (893.99 ppm), alpha-coumaric (518.85 ppm), pyrogallol (172.72 ppm), and salycilic acid (171.11 ppm), while the lowest contents were, ellagic (5.81 ppm), 3-OH-tyrosol (8.25 ppm), cinnamic (9.75 ppm), reversetrol (118.84 ppm) and iso-ferulic (11.62 ppm).

These results disagree with those reported by El-Masry *et al.* (2013) they found that, the major phenolic compounds in moringa leaves were rutin, caffeic acid, ferulic acid and quercetin, while the minor phenolic compounds were kampferol, syringic acid and ellagic acid.

The antioxidants activity was observed in dried moringa leaves powder being 92.46%.

Twelve sugars were identified in shadow dried sample of moringa leaves by HPLC analysis. The detected sugars were in the form of neutral such as stachyose (1009.75 mg/100g), raffinose (607.89 mg/100g), sucrose (608.68 mg/100g), lactose167.49 mg/100g), xylose (314.76 mg/100g), galactose (102.45 mg/100g), mannose (221.55 mg/100g) and ribose(12.28 mg/100g), acidic sugars such as glucouronic (876.59 mg/100g) and galactouronic (164.33 mg/100g) as well as alcoholic sugar such as manitol and sorbitol were detected in shadow dried moringa leaves powder (Table 6). The higest sugar concentration was stachyose being 1009.75 mg/100g followed by glucuronic (876.59), sucrose (608.88 mg/100g) and raffinose (607.89 mg/100g)

On the other hand ribose, sorbitol and manitol were present in low concentration, being 12.28, 18.25 and 35.63 mg/100g, respectively. Moderate concentration of xylose, mannose, lactose, and galacturonic (314.76, 221.55, 167.49 and164.33 mg/100g, respectively, were also detected. Leone *et al.* (2015) analyzed sugars of *Moringa oleifera* leaves in chad, Sahrawi refugee camps, and Haiti. Sugar content was very different among the samples. Sucrose content was higher in the leaves collected in the Sahrawi camps, 7.96 g/100 g while the leaves collected in Haiti were the richest in glucose and fructose 4.57, 4.81 g/100 g, respectively.

Table 5. Phenolic compounds of shadow dried on moringa leaves

Phenolic compound	Concentration of phenolic compound(ppm)
Gallic	10.86
Pyrogallol	172.72
4-Amino-benzoic	42.58
3-oH-Tyrosol	8.25
Protocatchuic	41.27
Chlorogenic	126.87
Catechein	126.12
Catechol	39.13
Caffeine	18.39
P-OH-benzoic	144.46
Caffeic	65.04
Vanillic	90.21
p-coumaric	34.22
Ferulic	18.08
ISO-ferulic	11.62
Reversetrol	118.84
Ellagic	5.81
e-vanillic	893.99
Alpha-coumaric	518.85
3,4,5 methoxy-cinnamic	21.48
Coumarin	13.86
Salycilic	171.11
Cinnamic	9.75

Table 6. Sugars composition of shadow dried moringa leaves powder

Sugar	Concentrate (mg /100g)
Stachyose	1009.75
Raffinose	607.89
Sucrose	608.68
Xylose	314.76
Galactose	102.45
Mannose	221.55
Manitol	35.63
Sorbitol	18.25
Ribose	12.28
Glucuronic	876.59
Galacturonic	164.33

Conclusion

From the previous results,it can be concluded that the shadow drying method was the best method for drying moringa leaves. It characterized by high retention of nutrients like protein, fats as well as crude fiber, minerals compared to drying by oven. The abundantly available inexpensive leaves of moringa can serve as a rich source of nutrients and can be used in the developing countries to combat malnutrition.

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تأثيـــــر طـــــــرق التجفيـــف علـــــى التركيـــب الكيمـــــــاوى لمســـــحـــوق أوراق المورينجا

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فى هذا البحث تم جمع الأوراق من نبات المورينجا اوليفيرا من محطة بحوث الشيخ زويد بشمال سيناء التابعة لمركز بحوث الصحراء وتم غسلها جيدا بالماء للتخلص من الأتربة وتم تجفيف الأوراق (فى الظل - وفى أفران على درجات حرارة 50، 60 و70 درجة مئوية) ثم تم طحن الأوراق المجففة تمهيدا لإجراء التقديرات الكيميائية (رطوبة – بروتين - دهن – ألياف – رماد – كربوهيدرات) وأظهرت النتائج وجود فروق معنوية ذات دلالات احصائيه بين العينات، كما تم تحليل الأحماض الأمينية وأظهرت النتائج احتوائها على 15 حمض أمينى منها 8 أساسية، السائد منها الليسين واللليوسين والفينيل الانين و٧ غير أساسية، أهمها الجلوتاميك والإسبارتك، كما أوضحت النتائج ان اوراق المورينجا تحتوى على 17 حمض دهنى ووجدت الأحماض الدهنية الآتية بتركيزات مرتفعة (α-Linolenic - Linoleic – Palmitic) كما أن الأوراق المجففة ذات محتوى جيد من فيتامينات A, E, C بتركيزات 48.57 – 6.09 – 1020 على الترتيب، أيضاً وجد أن لمسحوق أوراق المورينجا المجفف فى الظل نشاط قوى مضاد للأكسدة مقداره 92.46%، بعد تحليل أوراق المورينجا المجففه فى الظل باستخدام جهاز HPLC فى تفريد المركبات الفينولية، أوضحت النتائج أن التجفيف في الظل هى الطريقة الافضل فى محتواها من المركبات الفينولية، وأظهرت النتائج أن المركبات السائدة ما بين 23 مركب أعلاها تركيزا e-vanillic، كما تم عمل تفريد للسكريات لأوراق المورينجا المجففة فى الظل ووجد 12 نوعا من السكر وأن السكريات التى تميزت بتركيز عالى هي على التوالى: Raffinose - Sucrose - Glucuronic - Stachyose، من خلال النتائج التي تم التحصل عليها في تلك الدراسة أظهرت أن طريقه التجفيف في الظل لأوراق المورينجا قد حافظت على المركبات الفعالة بصوره ملحوظة مقارنة بالتجفيف على درجات الحرارة المختلفة بالفرن الكهربائي.

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