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Effect of drying temperature on the nutritional quality of *Moringa oleifera* leaves

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Moringa oleifera **leaves are generally consumed in the dry powdered form. Therefore, this research was carried out to investigate the effect of temperature on the nutritional quality of** ***M. oleifera*** **leaves powder. The leaves were dried under the shade at 30°C for two weeks and in the oven at temperature range from 40 to 70°C for 2 h. The results show that temperature affects nutrient composition of the leaf powder. As the drying temperature increased, crude protein decreased significantly (p≤0.05). The samples from shade drying had protein content value of 28.44 g/100 g, while samples those dried at 70°C had 19.89 g/100 g. Similar trends were observed for fat content which was 2.69 g/100 g for shade drying and 2.46 g/100 g at 70°C. The ash, fibre and carbohydrate contents of leaf powder increased with drying temperature. Samples from shade drying had 4.55, 16.33, and 32.75 g/100g for ash, fibre and carbohydrate respectively. However, the amounts of ash, fibre and carbohydrate increased significantly to 5.20, 17.66 and 52.30 g/100 g, respectively when dried at 70°C. The beta-carotene which is the precursor of vitamin A significantly (p<0.05) decreased from 5,220.20 mg/100 g in shade dried leaves to 4,946.20 mg/100 g in oven dried at 70 °C. Vitamin C content decreased slightly from 27.39 mg/100 g for shade dried to 25.70 mg/100 g, dried at 70°C. The minerals investigated generally showed significant increase with temperature. In general, the nutritional parameters of** ***M. oleifera*** **leaves dried in the shade varied closely with those dried in the oven at 40 and 50°C for 2 h.**

Key words: *Moringa oleifera*, drying, temperature effect, nutritional quality.

INTRODUCTION

Moringa oleifera (*Moringa pterygosperma*) is the most widely cultivated specie of the genus Moringa (Fuglie, 2001). Other English common names are benzolive tree and West Indian ben. It is also known as drumstick tree, from the appearance of long, slender, triangular seed pods (Mishra et al., 2012; Jed and Fahey, 2005). The tree is slender and with drooping branches that grow to approximately 10 m in height. In cultivation, it is often cut-back annually to 1-2 m and is allowed to re-grow, so the pods and leaves remain within arm's reach (Fuglie,

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2001). *M. oleiferatree* is rich in iron, potassium, calcium, zinc, magnesium, and produces man with useful vitamins, and vitamin A, four times the amount in carrots (Willis, 2003). The beta-carotene found in *M. oleifera* is a precursor of retinol.

Fahey (2005) considered *M. oleifera* leaves to contain significant source of essential nutrients such as Beta-carotene, Vitamin C, protein, iron, potassium, calcium and phosphorus and are commonly dried and crushed into a powder and stored without refrigeration for months without loss of nutritional values). The leaves contain 7.5 mg water, 6.7 mg protein, 1.7 mg fat, 14.3 mg total carbohydrate, 0.9 mg Fibre, 2.0 mg ash, 440 mg Calcium, 70 mg Phosphorous, 7 mg Iron, 110 mg Copper, 5.1 mg/l, 11.300 mg vitamin A, 120 mg vitamin B, 0.8 mg nicotinic acid, 220 mg ascorbic acid and 7.4 mg tocopherol per100 mg. Estrogenic substances, including the anti-tumor compound, beta-sitosterol, and a pectine-sterase are also reported. Leave amino acid include 6.0 mg arginine, 2.0 mg methionine, 4.9 mg threonine, 9.3 mg leucine, 6.3 mg isoleucine and 7.1 mg valine (Olushola, 2006).

Almost every part of *M. oleifera* is of food value, no part of the plant is useless as both human beings and animals have one thing or the other to gain from the plant (Adeniyi, 2007). Foliage is eaten as green in salad, in vegetable curries, as pickles and for seasoning. The seeds yield 38-40% of non-drying oil, known as Ben oil, and is used in arts for lubricating machines and other delicate machinery. The oil is clear and odourless, never becoming rancid. Consequently, it is edible and is used in the manufacture of perfumes and hairdressings. Wood yields blue dye (Duke, 1982).

The roots are shredded and used as a condiment; however, it contains the alkaloid called spirochim, a potentially fatal nerve paralyzing agent. The flowers can be processed and used for the production of pesticides because they contain certain natural chemical for which insects and other pest cannot withstand (Adeniyi, 2007).

M. oleifera leaves have been used successfully in its dried state or powdered form to augment and make delicious meals and porridge diets for pregnant expectant mothers, nursing mothers, infants and young children, as well as adults of all age groups. In Africa, nursing mothers have been shown statistically to produce far more milk when they add *M. oleifera* leaves to their daily diets and malnourished children have made significant weight gains when nursing mothers and care-givers add them to their diets as well (Duke, 1982).

For pregnant and breast feeding-nursing women, the leaves can do much to preserve the mothers' health and pass on strength to the foetus or nursed child. 100g portion of the leaves could provide a woman with over one-third of her daily requirement of calcium and gives her important quantities of iron, protein, copper, sulphur, B-vitamin (Price, 2000). The leaves are used in areas of nutrition, water purification; livestock feed, vegetable dyes, herbal medicine and oil production (Adeniyi, 2007).

For purposes of preservation, packaging, transportation and distribution, *M. oleifera* leaves are most commonly available and consumed in the dried form. It is generally believed and advised that *M. oleifera* leaves dried under shade is the way to preserve nutrient content (Olushola, 2006). This method is generally adopted by local processors of the material. However, with the renewed campaign and interest in *M. oleifera* consumption, it may become increasingly difficult to produce sufficient leaf powder by drying naturally under the shade to meet the growing demand. Therefore, it is needed to conduct a laboratory study on the effect of drying temperature on the nutrient content of moringa leaves. This study will be useful when considering industrial drying of the leaves for large scale production of *M. oleifera* leaf powder. It will serve as a guide to industrialist to select optimum drying temperature to maximize nutrient retention.

The objective of this work was therefore to evaluate the effect of drying temperatures on the nutritional value of *M. oleifera* leaves.

MATERIALS AND METHODS

Sample preparation

The preparation of the oven dried *M. oleifera* leaves and room dried *M. oleifera* leaves were carried. The stalks were cut from the tree and brought to the laboratory, where the leaves were removed from the stalks. The leaves were immersed in a large volume of clean potable water and shaken in order to remove dirt and impurities on the leaf surfaces. The washed leaves were spread out on racks for 20 minto drain out water. Four portions of the leaves were then dried successively in an electric oven for 2 h at 40, 50, 60 and 70°C. Another portion which served as control was dried for two weeks under the shade. The dried leaves were milled using kitchen blender, packaged in a translucent or coloured polythene bag and kept in a plastic container with cover and stored at room temperature of 30 ± 2°C for chemical analysis.

Chemical analysis

The crude protein and water soluble and insoluble ash contents were determined using the method of AOAC (2000). The moisture, fat and crude fibre contents were determined using the method described by AOAC (2005), while carbohydrate was by difference (Ihekoronye and Ngoddy 1985). Vitamin C content was determined titrimetrically using the method of British pharmacopoeia (2000). While total carotenoid content was determined using the method described by Akpapunam and Ibiama (1985). The mineral composition was determined using the atomic absorption spectrophotometer (UNICAM 960 series) as described by AOAC (2005).

Statistical analysis

Data obtained was analyzed by analysis of variance (ANOVA) using a split-split plot model according to the methods of Gomez and Gomez (1984). When significant ($P<0.05$), Duncan's new multiple range test (Duncan, 1975) was used to separate means.

Table 1. Effect of drying temperature on proximate composition (%) of *M. oleifera* leaves.

Parameters	Fresh leaves	Samples (dried leave powder)					LSD
		A	B	C	D	E	
		(30±2°C)	40°C	50°C	60°C	70°C	
Moisture	80.04^{a}±0.03	15.01^{b}±0.01	12.60^{c}±0.06	10.33^{d}±0.33	5.00^{e}±0.00	2.50^{f}±0.00	0.43
Fat	1.52^{a}±0.01	2.67^{b}±0.08	2.71^{b}±0.01	2.65^{c}±0.03	2.47^{b}±0.03	2.46^{b}±0.00	0.13
Ash	2.00^{a}±0.00	4.55^{b}±0.06	4.60^{b}±0.06	4.70^{b}±.0.06	5.22^{c}±0.00	5.20^{c}±0.00	0.13
Fibre	3.51^{a}±0.01	16.33^{b}±0.33	17.46^{c}±0.03	17.40^{c}±0.06	17.61^{c}±0.01	17.66^{c}±0.01	0.43
Protein	10.93^{a}±0.02	28.44^{b}±0.01	26.24^{c}±0.01	21.18^{d}±0.33	20.75^{e}±0.03	19.89^{f}±0.00	0.42
Carbohydrate	6.42^{a}±0.00	32.57^{b}±0.21	36.44^{c}±0.01	46.34^{d}±0.33	49.08^{e}±0.00	52.30^{f}±0.00	0.50

Values are means of triplicate determinations. Means with different superscripts within the same column are significantly different from each other (p>0.05). A = Shade dried, B = oven dried at 40°C, C = oven dried at 50°C, D = oven dried at 60°C, E = oven dried at 70°C. lime spray drying (LSD).

RESULTS AND DISCUSSION

Effect of drying temperature on proximate composition

The proximate composition of fresh, shade dried and oven dried *M. oleifera* leaves samples is presented in Table 1. The results shows that all the parameters significantly (p<0.05) changed when the leaves were dried either under the shade or in oven.

As expected, Table 1 shows that the moisture content of the leaves decreased with increase in drying temperature. The moisture content of the wet leaves was higher than samples dried in the shade and at 40 to 70°C. Moisture content decreased significantly (p<0.05) from 80.0% for fresh leaves to 15.00% for shade dried leaves. This further decreased significantly (p<0.05) in oven dried samples as the temperatures increased. Sample B showed the highest moisture content (12.50%) while C, D and E had 10.00, 5.00 and 2.50% respectively.

Crude protein of fresh leaves was 10.93 g/100 g, which is more than double that of cow's milk (3.20 g/100 g), and was about three times the amount obtainable in spinach (Gernah and Sengev, 2011). As the drying temperature increased from shade drying (30±2°C) to 70°C, crude protein decreased significantly (p<0.05). While samples dried in the shade had protein content value of 28.44 g/100 g, samples dried at 40°C had 26.24 g/100 g and that dried at 70°C had the value of 19.89 g/100 g. Similar trends were observed for fat content which had values of 2.69 g/100 g at 30°C, 2.46 g/100 g at 40°C and 2.46 g/100 g at 70^{o}C. As drying temperature increased there was corresponding increase in protein denaturalization resulting to significant decrease in both protein and fat. These results are in agreement with the report of Gernah and Sengev (2011) and Sengev et al. (2013). According to the authors and the report of Muller (1988), during pregnancy and breastfeeding a woman should consume about 38.00 g of protein daily. A meal of 100 g fresh and dry leaves will provide a good percentage of her protein requirements.

Table 1 also shows that the ash, fibre and carbohydrate content increased significantly (p<0.05) with drying temperature of *M. oleifera* leaves. While samples dried in the shade (30±2°C) had ash content of 4.55 g/100 g, fibre content of 16.33 g/100 g and carbohydrate content of 32.75 g/100 g, the values increased significantly to 5.20, 17.66 and 52.30 g/100 g respectively when the leaves were dried at 70°C. This is in agreement with what was reported by Gernah and Sengev (2011). Kumar et al. (2014), reported that mild drying conditions with lower temperature may improve the product quality but decrease the drying rate.

The crude fibre of all samples, ranging from 16.33to 17.66 g/100 g, is lower than the recommended average daily requirement for an adult (16-32 g). Similarly, the carbohydrate content of samples ranging from 32.75 to 52 g/100 g is lower than the recommended daily allowance (Gamman and Sherrington, 1990). In general, 100 g of all samples can supply more than one quarter of nutrient requirement of the body. The result shows that dry leaves are better source of fat, fibre, protein and carbohydrate than the fresh leaves. The trend in change in the proximate composition of the *M. oleifera* leaves at different drying conditions agrees with the work of Adeyemi et al. (2014).

Effect of drying temperatures on vitamins

Table 2 shows the carotenoid and vitamin C contents of *M. oleifera* leaves. The beta-carotene of fresh leaves was 6,010 mg/100 g, in the range reported by Gernah and Sengev (2011) and Olushola (2006). Beta-carotene of sample A was 5,220.20 mg/100 g, which was higher than that of sample B (5,150.25 mg/100 g). This further decreased in sample C to 5,025.20 mg/100 g in sample D to 4,958.53 mg/100 g at 60°C and finally decreased to 4,946.25 mg/100 g in sample E dried at 70°C.

The reductions in total carotenoids from 6,010 mg/100 g in fresh leaves to 4,946.25 mg/100 g in sample E of oven dried leaves at 70°C for a constant drying time of 2

Table 2. Effect of drying temperature on vitamin content (mg/100g) of *M. oleifera* leaves.

Parameters	Fresh leaves	Samples (dried leave powder)					LSD
		A	B	C	D	E	
		(30±2°C)	40°C	50°C	60°C	70°C	
Carotenoids	6010.00^{a}±5.77	5223.50^{b}±3.33	5140.20^{c}±0.33	5024.90^{d}±0.33	4824.50^{e}±3.40	4946.20^{f}±00	168.94
Vitamin C	220.00^{a}±5.77.	27.39^{b}±0.33	27.85^{b}±0.33	26.53^{c}±0.33	25.70^{d}±0.33	25.70^{e}±0.00	0.75

Values are means of triplicate determinations. Means with different superscripts within the same column are significantly different from each other (p>0.05). A = Shade dried, B = oven dried at 40°C, C = oven dried at 50°C, D = oven dried at 60°C, E = oven dried at 70°C. lime spray drying (LSD).

Table 3. Effect of drying temperature on mineral content (mg/100 g) of M. oleifera leaves.

Parameters	Fresh leaves	Samples (dried leave powder)					LSD
		A	B	C	D	E	
		(30±2°C)	40°C	50°C	60°C	70°C	
Ca	0.81^{a}±0.01	1.37^{b}±0.01	1.80 ^{c}±0.10	2.44^{d}±0.01	3.17^{e}±0.06	3.67^{f}±0.02	0.08
Mg	0.46 ^{a}±0.01	0.69^{b}±0.01	0.78 ^{c}±0.01	0.88^{d}±0.01	0.94^{e}±0.06	1.13^{f}±0.06	0.06
K	0.31 ^{a}±0.01	0.46^{b}±0.06	0.63^{c}±0.01	1.15^{d}±0.01	1.37^{e}±0.01	1.79^{f}±0.01	0.06
P	0.07^{a}±0.01	0.09^{b}±0.00	0.09^{b}±0.01	0.13^{a}±0.01	0.18^{d}±0.01	0.18^{d}±0.01	-
Fe	3.17^{a}±0.01	4.29^{b}±0.60	4.23^{b}±0.01	4.71^{bc}±0.01	5.08^{c}±0.01	5.40^{c}±0.01	0.15
Zn	4.65^{a}±0.01	5.13^{b}±0.01	5.60^{c}±0.10	6.20±0.10	6.86^{e}±0.01	7.34^{f}±0.01	0.10

Values are means of triplicate determinations. Means with different superscripts within the same column are significantly different from each other (p>0.05). A = Shade dried, B = oven dried at 40°C, C = oven dried at 50°C, D = oven dried at 60°C, E = oven dried at 70°C. lime spray drying (LSD).

h indicated the effect of temperatures on the vitamins, and was in agreement with Eskin (1979) and Goodwin (1980). Olushola (2006) reported that only 20 – 40% of carotenoid in leaves were probably retained when the dried by solar drying and 50 – 80% by shade drying.

Vitamin C of fresh leaves was 220.45 mg/100 g in agreement with the value of 220.00 mg/100 g reported by Duke (1983). Moreover, it was higher than values reported by Muller (1988) for orange being 20.00 mg/100 g. Vitamin C content of shade dried leaves decreased slightly from 27.72 to 27.52 mg/100 g for leaves dried at 40°C sample B, and further decreased to 26.08 mg/100 g in sample C, dried at 50°C, and finally to 25.75 mg/100 g in sample E dried at 70°C. The vitamin C content of all samples is adequate for the daily need of adults based on the recommended daily allowance (Oslon and Hodges (1987).

The reduction in vitamin C content of the leaves could be due to drying temperature. This is consistent with the reports of Duke (1983), Olushola (2006), Mbah et al., 2012 and Gernah and Ajir (2007), that high temperature can cause huge losses of vitamin C.

Effect of drying temperature on mineral content of *M. oleifera* leaves

Table 3 presents the results of the effects of drying temperatures on the mineral composition of *M. oleifera* leaves. The mineral contents of fresh leaves were generally lower than dried samples and generally showed significant (p<0.05) increase with temperature.

The calcium content of fresh leaves was significantly (p<0.05) lower than the shade dried samples. However, there was significant difference (p≥0.05) in calcium content of samples dried at 40 – 70°C. The calcium content of fresh leaves was higher than value reported by Gernah and Sengev (2011), many times more than that of cow milk (Gordon, 1999) and higher than the recommended daily allowance (Olson and Hodges, 1987). Calcium builds healthy, strong bones and teeth and also assists blood clotting (Gordon, 1999). Deficiency can cause rickets, bone pain and muscle weakness. Taking *M. oleifera* fresh leaves and that dried in the shade and at 40 -70°C will meet the calcium need of adults and children based on RDA of 0.6 – 0.8 g (Glewe et al., 2001).

Table 3 reveals that other minerals studied especially magnesium, potassium, phosphorous, iron and zinc showed significant difference (p<0.05) between the fresh and shade dried leaves and increased significantly (p<0.05) with drying temperature. The general increase in mineral contents with increase with drying temperature is attributable to concentration factor due to moisture removal, which resulted in higher level of total soluble solid. The finding is in agreement with those of Gamman and Sherrington (1990).

Table 3 shows that increase in drying temperature did not deplete the mineral content of samples and therefore

did not have negative effect on the nutritional content of the samples. In general, the mineral content was above recommended daily allowance (Gamman and Sherrington, 1990).

Conclusion

In summary, it can be concluded that fresh *M. oleifera* leaves, which are normally consumed as vegetables and as food supplement, are rich in macronutrients and micronutrients required for proper growth and good health for human. Temperature affects the nutrient content of *M. oreifera*. *M. oleifera* leaves dried at 40 and 50°C compares favourably with that dried in the shade for two weeks (672 h). Oven drying should not exceed 50°C for optimum nutrient quality.

Conflict of interests

The author(s) did not declare any conflict of interest.

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