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RESEARCH ARTICLE

Comparative Studies of the Physicochemical Properties and Mineral Elements of *Moringa oleifera* Lam. Leaves in the Guinea Savannah of Nigeria

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ABSTRACT

This study was conducted to evaluate the efficacy of the different methods used for preserving *Moringa oleifera* in the Guinea Savannah Vegetation Zones of Nigeria. Leaves of *M. oleifera* were randomly collected from three locations in Guinea Savanna Vegetation Zones. viz: Abuja (Nyanyan), Kaduna (Barnawa) and Zamfara (Gausa). The leaves wet leaves were weighed and distributed to five batches for Sun, Room, and Oven drying at varied temperatures of 50^{o}C, 60^{o}C, and 70^{o}C. The physicochemical and nutrient analysis, energizing values of proteins, total sugars, and lipids, were determined. The SPSS software Version 16 was used for the analyses in a one way Analysis of Variances (ANOVA). The difference was considered significant at $P<0.05$. The result showed Room; 70^{o}C, 60^{o}C and 50^{o}C oven drying methods as the best drying methods for *M. oleifera.* They retained high amount of nutrients in terms physicochemical properties while Room drying method, also retained the best amount of Sodium, phosphorus, Magnesium, Iron, Molybdenum, Boron, Fat, Fiber, Ash, Total Sugar, Energy. In addition the 70^{o}C oven drying method retained Protein, Calcium, Potassium, Titanium, and good for Moisture content while 60^{o}C and 50^{o}C dehydrating methods, respectively retained Manganese, Sulphur, and Zinc. *Moringa oleifera* leaves from the three various locations studied were rich in the following nutrients: Abuja (Nyanya), Fat, Fiber, Boron, and Titanium. Kaduna (GRA Barnawa): Ash, Calcium, Sulphur, Sodium, Phosphorus, Magnesium, Iron, Molybdenum. Zamfara (Gausa, Kaura Road): Protein, Total Sugar, Energy, Potassium, Manganese; Zinc, and Vanadium.

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INTRODUCTION

Green leafy vegetables are rich in macro and micronutrients that the body needs to function effectively. The vegetables are available, accessible, and affordable at the least costs to every household, both the rich and the poor. Most vegetables are perishable items; some are seasonal, while others grow throughout the year, like the *Moringa oleifera* (Lam). Evidently, drying directly under the sun and under the shade, are the common practices used in most parts of Africa to preserve vegetables, fruits, and seeds for off season consumption (Lyimo *et al.*, 1991; Atega, 2001; Awogbemi and Ogunleye, 2009), in order to prevent the growth of mold and bacteria, which ultimately affects the nutrient potential. Different processing and preservative methods of foods, seeds and vegetables may significantly affect the availability and concentration of proximate and mineral compositions of food samples (Price, 1985).

Peculiar problems associated with green leafy vegetables are processing, preservation, and the infestation of micro-organisms. These account for great loss of produce to farmers. Byaruhanga *et al.* (2001) reported that 30-40% post-harvest losses of farm produce led to high nutritional and economic losses. Preservative techniques which after post-harvest, retain an appreciable amount of nutrient quality of produce, market values, and make produce available during scarcity are lacking. Hence, the need to study and identify appropriate processing and preservative methods that minimizes nutrient loss, retains good amount of nutrient quality.

M. oleifera plant is abundant virtually all over Nigeria. Moringa products serve multipurpose values to meet recent human challenges which include malnutrition, diseases, hunger, portable water, and employment. Health workers now treat malnutrition in small children and pregnant and nursing women with *M. oleifera* leave powder. The iron content of the leave is very high and is prescribed for the treatment of anaemia in the Philippines (Sofowora, 1982; Price, 1985). *M. oleifera* leave is often the only source of protein, vitamins and minerals to the less privileged in the society. *M. oleifera* leaves are used in the treatment and control of diabetes and hypertension (Dalziel, 1956; Price, 1985; Fahey, 2005). Essentially, *M. oleifera* leaves have all the nutrient potentials required by the human body for healthy living, and it is a source of empowerment to the rural populace. But an appropriate drying method which does not affect the nutrient quality adversely has hardly been documented in Nigeria, and that is why this study was undertaken.

MATERIALS AND METHODS

Sampling

Leaves of *Moringa oleifera* were randomly collected from three locations in Guinea Savanna Vegetation Zones. They are: Abuja (Nyanyan) in Southern Guinea Savanna; Kaduna (GRA, Barnawa) in Northern Guinea Savanna, and Zamfara (Gausa, Kaura road) in Sudan Guinea Savanna of Nigeria, late in the evening to avoid nutritional deterioration, particularly, vitamins A and C that that can be destroyed by UV in sunlight.

Processing of material

The leaves were plucked from the branches to the leaf petioles. Discolored, damaged, insect infected, wilted and decayed leaves were sorted out and discarded; while the fresh, green and undamaged leaves were retained and washed thoroughly for 4 to 5 times with plenty of clean water, to remove dirty and stain. Thereafter, the leave petioles were tied together in small bunches and hung in an airy space to drain excess water for 15 minutes and air dried for 30 minutes. The leaves were weighed fresh on an analytical weighing balance (Ohaus Adventurer) and were subjected to six different drying methods namely: Fresh leave, Sun dry, Room drying, Oven drying at 50^{o}C, 60^{o}C, and 70^{o}C.

Analytical methods

The Physicochemical and Nutrient analysis of the dry sample was done with the AOCS, (1990) procedure.

Determination of Total Sugar Content: Total sugar content was estimated according to Tollier and Robin method (1979).

Determination of Energizing Values: The energizing values of proteins, total sugars, and lipids, were determined by Merrill and Watt (1955) coefficients adopted by the Food and Agriculture Organization in 1970. The energizing values of the samples were gotten by:

P x 4 Kcal + G x 4 Kcal + L x 9 Kcal = X Kcal/100g
Where; P = Percentage of protein
G = Percentage of sugar
L = Percentage of lipids
X = Energizing values

Determination of nutrient element composition

Phosphorus (P), Potassium (K), Sodium (Na), Magnesium (Mg), Calcium (Ca), Iron (Fe), Zinc (Zn), Manganese (Mn), were determined in the samples after the mineralization according to Houba, *et al.* (1989). The Atomic Absorption Spectrophotometer was used for the determination of the respective nutrient element.

Statistical analysis

The data were subjected to statistical analyses to verify and evaluate the differences within the physicochemical compositions and nutrient elements of the samples. The SPSS software Version 16 for windows was used for the analyses in a one way Analysis of Variances (ANOVA). The difference was considered significant at $P<0.05$.

RESULTS AND DISCUSSION

Table 1 shows the variation of the moisture content of the leaves of *M. oleifera* obtained from different region of Nigeria. The leaf sample from Zamfara, in Sudan Guinea Savanna Vegetative Zone of Nigeria, recorded the highest moisture content (70.9%), while the samples from Kaduna in the Northern Guinea Savanna vegetative Zones of Nigeria, recorded the lowest Moisture Content (70.2%). Differences in the moisture content of the dried leaves of *M. oleifera* subjected to different forms of drying medium gave moisture content that were statistically significantly different with the varying modes (Table 1). *M. oleifera* leave Oven dried at 70^{o}C gave significantly lower moisture content compared with the other forms of drying irrespective of zones of collection.

Protein contents were high in dried samples and varied both in location and drying methods (Table 1). The minimum protein content occurred in fresh leaves of the different locations. Zamfara sample of *M. oleifera*, recorded the highest protein contents of over 25% in the drying methods of Sun drying (25.1%), Room drying (25.67%), Oven drying at 50^{o}C (25.72%), Oven drying at 60^{o}C (25.87%) and Oven drying at 70^{o}C (25.91%). The protein content in the dried leave powder ranged from 22.52-25.91%, when compared with the fresh leave samples of 6.7% and 6.9% respectively. This is due to the concentration in chemical nutrients by dehydration in the dried powdered samples. Variations in the protein content based on the drying methods and location of collection of sample which were statistically significant when compared with the value of protein in the fresh leaf treatment could be attributed to differences in soil factor of geographical location and the efficacy of the drying methods.

Fat content of the studied leave samples varied from 1.5-4.067% (Table 1). The highest was in the room dried treatment but this is not significantly different with the oven dried leaves but significantly higher than the fat contents of the fresh and sun dried leaves while the lowest fat occurred in the fresh leave treatment (Table 1). Variations in fat contents of the samples could be linked

Table 1: Proximate compositions of *Moringa oleifera* leaves at various locations (g/100g DWB)

Locations	Treatment		Nutrients (%)						
			Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Total sugar (%)	Energy (Kcal)
	Fresh leave		70.7[a]	6.8[a]	1.6[a]	0.9[a]	2.7[a]	12.9[a]	93.2[a]
	Sun Dried Powdered leaves (%)		6.8[c]	22.58[b]	3.882[b]	10.8[b]	6.6[b]	28.90[b]	240.885[b]
Abuja	Room Dried Powdered leaves (%)		7.7[b]	22.69[b]	4.042[c]	13.6[c]	6.18[b]	29.58[c]	245.467[b]
	Oven Dried	50°C	6.1[d]	22.71[b]	4.001[c]	12.0[d]	6.9[b]	29.35[c]	244.249[b]
	Powdered leaves (%)	60°C	6.0[e]	22.77[b]	4.000[c]	12.5[e]	7.0[b]	29.12[c]	243.56[b]
		70°C	5.8[f]	22.81[b]	4.000[c]	12.7[e]	7.10[b]	29.08[c]	243.56[b]
	Fresh leaves		70.23[a]	6.9[a]	1.5[a]	0.8[a]	2.0[a]	12.0[a]	93.1[a]
	Sun Dried Powdered leaves (%)		6.9[c]	22.52[b]	3.251[b]	10.6[b]	7.10[b]	28.89[b]	234.899[b]
Kaduna	Room Dried Powdered leaves (%)		7.8[b]	22.67[b]	4.025[c]	13.2[c]	7.99[b]	29.57[c]	245.185[b]
	Oven Dried	50°C	6.2[d]	22.70[b]	4.012[c]	11.8[d]	7.86[b]	29.32[c]	244.188[b]
	Powdered leaves (%)	60°C	6.0[e]	22.78[b]	4.010[c]	12.2[e]	7.90[b]	29.10[c]	243.51[b]
		70°C	5.9[f]	22.80[b]	4.001[c]	12.6[e]	7.98[b]	29.09[c]	243.589[b]
	Fresh leaves		70.9[a]	6.7[a]	1.7[a]	0.7[a]	2.3[a]	13.2[a]	94.9[a]
Zamfara	Sun Dried Powdered leaves (%)		6.6[c]	25.1[b]	3.126[b]	10.9[b]	6.82[b]	28.90[b]	244.134[b]
	Room Dried Powdered leaves (%)		7.9[b]	25.67[b]	4.067[c]	12.9[c]	6.80[b]	29.59[c]	257.643[b]
	Oven Dried	50°C	6.1[d]	25.72[b]	4.002[c]	11.9[d]	6.86[b]	29.37[c]	256.378[b]
	Powdered leaves (%)	60°C	6.0[e]	25.87[b]	4.001[c]	12.6[e]	6.88[b]	29.11[c]	255.929[b]
		70°C	5.8[f]	25.91[b]	4.000[c]	12.8[e]	6.98[b]	29.09[c]	256.0[b]
	± SEM		5.45	1.45	3.52	9.91	6.33	26.21	213.88

a –f Means in the same column but with different superscript differ significantly (P<0.05)

to plant cultivar, geographical location and oxidation that is dependent on the drying methods. Zamfara sample recorded the highest (4.067%) while Kaduna recorded the lowest fat content (1.5%) in the studied samples (Table 1). This suggested that either room drying or oven drying techniques were ideal for preserving the fat content of *M oleifera* from oxidation.

Fiber Content of the investigated samples varied between 0.7% in fresh leaves and 13.6% in room dried leaves (Table 1). The highest fiber content room dried treatment accounted for 93.38% increase in the dried leaf powder compared with the fresh leaf treatment. The high increase in fiber content of dried sample was due to the concentration in chemical compositions of nutrients as a result of drying methods. Abuja sample had the fiber content while Zamfara sample recorded the lowest. These differences can be associated to the variations in the ecological zones of collection of samples i.e. Southern Guinea Savanna and Northern Guinea Savanna Vegetation Zone of Nigeria respectively (Table 1). The obtainment of higher fiber content of room dried *M. oleifera* leaves suggested the room drying method as the best preserving method for preserving fiber quality in the leave of *M. oleifera*.

The Ash Content ranges from 2.0-7.99% (Table 1). The highest Ash content occurred in the Room dried *M. oleifera* leaves obtained from Kaduna State (Table 1), and it represented 74.96% increase in the dried leaf powder compared to the fresh leaf value, while the lowest Ash content was recorded in the Abuja samples. Significantly higher ash contents were obtained with the various methods of drying *M. oleifera* leaves gotten from Zamfara State while other fresh samples in the sampled states had significantly lower ash contents. This can be deduced to be as a result of increase in concentration in chemical composition of nutrients as influenced by drying methods.

Total sugar of the dried samples ranged from 28.89-29.59% the highest total sugar in the dried samples was recorded in the Room dried treatment, and the lowest sugar was found in the Sun dried treatment. Zamfara, sample recorded the highest total sugar value, while the lowest total sugar value was in the Kaduna sample (Table 1). The total sugar content in the dried leaf powder increased from 55.00-55.39% compared to the fresh samples (Table 1). There was a distinct statistical significance among the total sugar when compared with the fresh sample.

Calculated Energy Content of the *M. oleifera* leaves was in the range of 93.1-257.643 Kcal (Table 1). The maximum energy was in the Room dried samples while the minimum energy content of the dried samples occurred in the Sun dried sample (Table 1). Zamfara and Kaduna samples respectively recorded the highest and the lowest energy content in the treatments. The energy content in the dried leaf sample increased from 60.37-63.17% when compared with the fresh sample. The energy contents of the dried *M. oleifera* were statistically significant when compared with the energy content of the fresh leaf sample.

In addition, the nutritional valuable minerals of *M. oleifera* leaves investigated were given in Table 2. The nutrient profile in respect of major elements such as calcium, potassium, sodium, phosphorus, magnesium, iron, sulphur, and trace elements of zinc, molybdenum, manganese, boron, titanium, and vanadium were analysed. The concentration in sodium content was low among the minerals assayed; this could be due to geographical location and soil factor. The preponderance of highest mineral elements of *M. oleifera* leaves investigated were: Calcium content 4354 mg/100g (70°C oven dried sample) > Potassium content 2340 mg/100g (70°C oven dried sample) > Magnesium content 388.0 mg/100g (room dried sample) > Phosphorus content 268.0 mg/100g (room dried sample) > Sulphur content 239.0 mg/100g (room dried sample) > Sodium content 40.80 mg/100g (Fresh leaves sample) > Iron content 28.84 mg/100g (70°C oven dried sample) > Molybdenum content 26.0 mg/100g (room dried sample) > Baron 9.5 mg/100g (room dried sample) > Manganese content 2.98 mg/100g (60°C oven dried sample) > Zinc content 1.95 mg/100g

Table 2: Mineral composition of dried *Moringa oleifera* leaf (mg/100g leaf powder) at various locations

Location	Treatment	Nutreints (mg/100g)												
		Ca	K	S	Na	P	Mg	Fe	Mo	Ba	Mn	Zn	Ti	V
	Fresh leaves	568^{a}	222.0^{a}	78.9^{a}	40.8^{a}	33.6^{a}	23.9^{a}	12.0^{a}	11.0^{a}	1.98^{a}	1.5^{a}	0.45^{a}	0.85^{a}	0.12^{a}
	Sun dried (mg)	4168^{c}	2230^{b}	211.9^{b}	34.8^{b}	250.0^{b}	249.0^{b}	24.0^{b}	20.8^{b}	8.0^{b}	2.8^{b}	1.45^{b}	0.52^{b}	0.85^{b}
Abuja	Room dried (mg)	4236^{e}	2236^{b}	226^{a}	36.9^{a}	259.0^{d}	250.0^{b}	24.8^{b}	21.04^{b}	9.5^{c}	2.85^{b}	1.58^{b}	0.65^{b}	0.88^{b}
	Oven 50^{o}C	4183^{b}	2239^{b}	209.9^{a}	30.6^{c}	258.0^{c}	250.1^{b}	24.1^{b}	19.86^{b}	8.3^{b}	2.7^{b}	1.48^{b}	0.55^{b}	0.84^{b}
	Dried 60^{o}C	4304^{d}	2291^{b}	239^{a}	25.5^{d}	260.0^{c}	251.6^{b}	23.9^{b}	19.96^{b}	8.6^{b}	2.88^{b}	1.55^{b}	0.65^{b}	0.82^{b}
	(mg) 70^{o}C	4354^{F}	2244^{b}	200^{a}	20.8^{d}	261.0^{c}	251.8^{b}	24.4^{b}	19.92^{b}	8.7^{b}	2.95^{b}	1.45^{b}	0.66^{b}	0.86^{b}
	Fresh leaves	570.40^{a}	225^{a}	81.8^{a}	40.2^{d}	36.4^{a}	24.3^{a}	10.2^{a}	10.0^{a}	2.0^{a}	1.3^{a}	0.4^{a}	0.96^{a}	0.1^{a}
	Sun Dried (mg)	4283^{c}	2208^{b}	214.88^{a}	36.3^{b}	253.0^{b}	378^{b}	25.83^{b}	21.0^{b}	7.9^{b}	2.2^{b}	1.1^{b}	0.6^{b}	0.8^{b}
Kaduna	Room dried (mg)	4305^{e}	2210^{b}	229.8^{a}	39.0^{a}	268.0^{d}	388^{b}	28.84^{b}	26.0^{b}	8.8^{c}	2.9^{b}	1.4^{b}	0.3^{b}	0.95^{b}
	Oven 50^{o}C	4031^{b}	2220^{b}	227.9^{a}	29.0^{c}	260.0^{c}	382^{b}	23.82^{b}	25.0^{b}	7.8^{b}	2.6^{b}	1.0^{b}	0.004^{b}	0.85^{b}
	Dried 60^{o}C	4152^{d}	2240^{b}	226.8^{a}	26.1^{d}	263.0^{c}	386^{b}	23.81^{b}	24.8^{b}	7.7^{b}	2.5^{b}	1.01^{b}	0.13^{b}	0.82^{b}
	(mg) 70^{o}C	4367^{f}	2260^{b}	200.1^{a}	20.12^{d}	265.0^{c}	387^{b}	23.86^{b}	24.8^{b}	7.3^{b}	2.6^{b}	1.01^{b}	0.03^{b}	0.82^{b}
	Fresh leaves	590^{a}	228^{a}	80.9^{a}	39.8^{a}	35.8^{a}	24.8^{a}	11.8^{a}	11.01^{a}	1.92^{a}	1.52^{a}	0.50^{a}	0.92^{b}	0.14^{a}
Zamfara	Sun dried (mg)	4251^{c}	2312^{b}	213.9^{a}	24.0^{b}	259.0^{b}	252^{b}	24.8^{a}	21.2^{b}	8.1^{b}	2.9^{b}	1.50^{b}	0.50^{b}	0.95^{b}
	Room dried (mg)	4331^{e}	2335^{b}	228.9^{a}	28.9^{a}	260.0^{d}	259^{b}	25.0^{b}	21.6^{b}	8.9c	2.0^{b}	1.58^{b}	0.59^{d}	0.98^{b}
	Oven 50^{o}C	4267^{b}	2338^{b}	220.9^{a}	26.9^{c}	256.0^{c}	256^{b}	25.4^{b}	20.3^{b}	7.0^{b}	2.95^{b}	1.95^{b}	0.65^{b}	0.92^{b}
	Dried 60^{o}C	4310^{d}	2339^{b}	225.9^{a}	22.13^{d}	253.0^{c}	250^{b}	25.7^{b}	20.2^{b}	7.7^{b}	2.98^{b}	1.0^{b}	0.56^{b}	0.94^{b}
	(mg) 70^{o}C	4319^{f}	2340^{b}	199.9^{a}	19.8^{d}	255.0^{c}	248^{b}	25.9^{b}	20.5^{b}	6.9^{b}	2.85^{b}	1.1^{b}	0.16^{b}	0.96^{b}
	± SEM	333.318	185.113	109.302	1.752	20.400	28.181	1.265	1.110	.574	.131	.103	.069	.070

a – f Means in the same column but with different superscripts differ significantly (P<0.05).

(50^{o}C oven dried sample) > Vanadium content 0.98 mg/100g (room dried sample) > Titanium content 0.96 mg/100g (fresh sample) while the lowest chemical compositions were observed decreasing thus: Calcium content 568 mg/100g (50^{o}C oven dried sample); Potassium content 222 mg/100g (sun dried sample); Magnesium content 23. 9 mg/100g (fresh leaf sample); Sulphur content 78.9 mg/100g (fresh leaf sample); Sodium content 19.8 mg/100g (70^{o}C oven dried sample); Phosphorus content 23.9 mg/100g (fresh leaf sample); Manganese content 1.3 mg/100g (fresh leaf sample); Iron content 10.2 mg/100g (fresh leaf sample); and Vanadium content 0.1 mg/100g (fresh leaf sample) Molybdenum content 10.0 g/100g (fresh leaf sample); Baron 1.92 mg/100g (fresh leaf sample); Zinc content 0.4 mg/100g (fresh leaf sample) ; Titanium content 0.004 mg/100g (50^{o}C oven dried sample).

Considering the nutritive value of the samples of *M. oleifera* based on location revealed that the highest contents of Calcium, Sulphur; Phosphorus; Magnesium; Molybdenum were obtained from samples collected from Kaduna State while highest contents of Potassium; Iron; Manganese and Zinc were recorded in samples collected from Zamfara State (Table 2). The established differences in the obtained mineral values of the studied samples based on the varying methods of drying adopted in this study showed a statistically significantly different mineral content of the samples collected from the different ecological zones of Nigeria. Of note is the fact that the results of the proximate analysis and the chemical composition of the leaves analyzed were slightly greater than the values obtained in Thailand (Thanapat *et al.,* 2010) and by Asian Vegetable Research Development Council (Price, 1985). This could be attributed to be as a result of variations in environmental factors such as: soil, geographical/ ecological location, postharvest handling of the plant as well as the genetic make-up of the resources.

Conclusion

The best drying methods from the investigation that retained high amount of major nutrients in the studied leave samples from various locations of Nigeria include: room drying; and oven drying at 70 ^{o}C; 60 ^{o}C; and 50 ^{o}C. Room drying method, retained the best amount of Sodium, phosphorus, Magnesium, Iron, Molybdenum, Boron, Fat, Fiber, Ash, Total Sugar, Energy. The 70 ^{o}C oven drying method, retained Protein, Calcium, Potassium, Titanium, and good for Moisture content; while 60 ^{o}C and 50 ^{o}C dehydrating methods, respectively retained Manganese, Sulphur, and Zinc. *M. oleifera* leaves from the three locations were rich in the following nutrients: Abuja, Fat, Fiber, Boron, and Titanium. Kaduna: Ash, Calcium, Sulphur, Sodium, Phosphorus, Magnesium, Iron, Molybdenum. Zamfara: Protein, Total Sugar, Energy, Potassium, Manganese; Zinc, and Vanadium.

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