

Full Length Research Paper

Anti-nutrient, vitamin and other phytochemical compositions of old and succulent moringa (*Moringa oleifera* Lam) leaves as influenced by poultry manure application

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The study was carried out to determine the anti-nutrient, vitamin and other phytochemical compositions of old and succulent leaves of *Moringa oleifera* plants as influenced by poultry manure application. Three levels of poultry manure, that is, 0, 5 and 10 tonnes ha⁻¹ were used for treatment. Poultry manure application insignificantly ($p > 0.05$) increased oxalate, phytate and saponin compositions of the leaves. The older leaves had higher values of tannin, oxalate, phytate and saponin than the succulent ones. The poultry manure levels did not show any significant differences ($p > 0.05$) in the proximate/chemical properties and some vitamins (vitamins A, B₁, B₂, B₆, and C). Succulent leaves had higher values of vitamins, proximate and chemical properties. The higher concentrations of the anti-nutrients in the older leaves and higher values of vitamins, proximate and chemical properties in the succulent ones provide a good guide to moringa leaf consumers, to harvest the younger succulent (first to fifth) leaves for consumption.

Key words: Anti-nutrients, moringa leaves, poultry manure, phytochemicals, vitamins.

INTRODUCTION

Anti-nutrients are substances which interfere with the metabolism and utilization of body nutrients; examples are phytates, oxalates, tannins and saponins. Moringa leaves have been found to contain little quantities of the

anti-nutrients (Moyo et al., 2011). Phytates decrease the availability of minerals and reduce protein digestion by the formation of phytic acid protein complex (Oz, 2013). Tannins have beneficial effects on health. They curb

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Abbreviations: RCBD, Randomized complete block design; OM, organic matter; MC, moisture content; IITA, International Institute for Tropical Agriculture; FLSD, Fisher's least significant difference.

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haemorrhage (haemostatic) and bare swelling. They are used for mouth and eye washes, vaginal douches and treatment of rectal disorders (Bamshaiye et al., 2011). At low and moderate quantities, tannins can improve protein digestion in the lumen of ruminants (Oz, 2013). Moringa leaves have been found to contain small quantities of saponins at levels that are relatively harmless to human health. Thus, moringa leaves are consumed with no side effects. Low dietary levels of saponins in soyabeans had been shown to increase growth in tilapia while high quantities tended to retard it (Fuglie and Sreeja, 2011). Oxalic acid combines with divalent metallic cations such as calcium (Ca^{2+}) and iron. Fresh and dried moringa leaves have been found to contain negligible quantities of oxalate which are not harmful to the body if the leaves are consumed in moderate quantities. However, fresh moringa leaves contain more oxalate than the dry ones (Amaglo, 2010; Moyo et al., 2011).

Previous research work by Fuglie and Sreeja (2011) had shown that moringa leaves contained up to 25.1% crude protein, 6.5% lipid, 12% ash, 27.1% protein, 2.3% fat, 38.2% carbohydrate, 19.2% fibre, 20.0% calcium (Ca), 1.37% magnesium (Mg), 0.20% phosphorus (P), 1.32% potassium (K), 0.03% iron (Fe) and 0.87% sulphur (S). Fuglie and Sreeja also obtained high levels of vitamins A, B, C and E in the dried leaves. Moringa is a multipurpose plant with high nutritional, agricultural, medicinal, domestic, industrial and environmental benefits. It is used to combat malnutrition, especially among infants and nursing mothers (Oz, 2014). The leaves are rich in B carotene, amino acids and ascorbic acids. Thus, they can be used to increase milk production in lactating mothers (Fuglie and Sreeja, 2011). The leaves of *Moringa oleifera* plant can be eaten fresh, cooked or stored as dried powder for many months without loss of vitality.

Analysis of poultry manure had shown that it was high in N, K and other nutrient elements (Ogbonna and Umarshaaba, 2011). Singh (2010) also reported increase in N, P, K Zn, protein and carbohydrate contents of corn (*Zea mays* L.) with poultry manure application. Poultry manure and other organic fertilizers increase the nutrient status of most soils and boost crop productivity (Annenber, 2010; Singh, 2010), but there is little information on the influence of poultry manure application on anti-nutrient, vitamin and other phytochemical compositions of old and succulent leaves of moringa (*Moringa oleifera*) plants.

The objective of the study was to determine the anti-nutrient, vitamin and other phytochemical compositions of old and succulent leaves of moringa plants as influenced by poultry manure application.

MATERIALS AND METHODS

The study was carried out in the Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka. Three levels of poultry manure (0, 5 and 10 tonnes ha^{-1}) were used. The experiment was a 3 × 3 factorial trial in a randomized complete

Table 1. Physical and chemical properties of the soil of the experimental site.

Parameter	Value
Clay (%)	22
Silt (%)	13
Fine Sand (%)	24
Coarse Sand (%)	42
pH (H_2O)	5
pH (KCl)	4.7
Carbon (%)	1.65
Organic matter (%)	1.02
Nitrogen (%)	0.06
Sodium ($\text{meq } 100 \text{ g}^{-1}$)	0.34
Calcium ($\text{meq } 100 \text{ g}^{-1}$)	0.6
Magnesium ($\text{meq } 100 \text{ g}^{-1}$)	1.8
CEC ($\text{meq } 100 \text{ g}^{-1}$)	14.9
Base salt (%)	21
H^+ ($\text{meq } 100 \text{ g}^{-1}$)	2.7
Phosphorus (ppm)	14.99

Table 2. Chemical properties of the poultry manure.

Chemical properties	Value
pH (H_2O)	7.3
pH (KCl)	6.7
Organic C (%)	19.89
Organic matter (%)	51
N (%)	1.73
Sodium (%)	0.08
Potassium (%)	0.08
Calcium (%)	4.65
Magnesium (%)	1.35
Phosphorus (%)	1.39

block design (RCBD) with three replications. The poultry manure was incorporated into the soil before planting the seeds. The seeds were planted at stake on the field at planting distance of 1 m × 1 m. The moringa seeds used were collected from three locations of Nigeria; Nsukka (Enugu State with rainforest vegetation), Dutse (Jigawa State with semi-arid vegetation) and Jos (Plateau State with savannah vegetation). Prior to seed planting, the field was tractor-ploughed and harrowed. Soil samples were collected from different locations of the field, bulked to form a composite sample and analyzed in the laboratory for physical and chemical properties. The poultry manure was analyzed for N, P, K, Ca, Mg, sodium (Na), pH, organic matter (OM) and organic carbon (C). Tables 1 and 2 represent the physical and chemical properties of the soil of the experimental site and the poultry manure used for the experiment. The poultry manure was incorporated into the soil at the different rates before planting. The moringa seeds were planted two/hole on shallow seed beds of 5 m long × 1 m wide × 15 cm high. Two weeks after emergence, the seedlings were thinned down to

Table 3. Anti-Nutrient contents of succulent and older leaves of *Moringa oleifera* plants.

Anti-nutrient	Succulent leaves	Older leaves	Mean	t _(0.05)
Tannin (g 100 g ⁻¹)	6.11	6.48	6.30	Ns
Oxalate (g 100 g ⁻¹)	2.51	3.24	2.87	Ns
Phytate (g 100 g ⁻¹)	8	9.75	8.88	Ns
Saponin (g 100 g ⁻¹)	3.77	4.32	4.04	Ns

ns = Non-significant.

one/whole. Samples of the leaves were taken monthly for laboratory analyses. Sampling was done for three months after planting. First to fifth leaf from the shoot-tip and older leaves from the base were used for laboratory analyses. The leaves were dried and ground into powder for analyses. Analyses of the leaf samples were done at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. The samples were analyzed for vitamins, proximate and chemical properties using the standard methods of the Association of Analytical Chemists (AOAC, 2005). The procedures used for anti-nutrient analyses are stated below:

Determination of tannin content

One gram of the leaf sample (powder) was weighed and macerated with 50 ml of distilled water and filtered. Five milliliter of the filtrate was then pipetted and to it 0.3 ml of 0.1 N ferric chloride in 0.1 N HCl added. Next, 0.3 ml of 0.008 potassium ferricyanide was added to the mixture. Absorbance was measured at 720 nm

Determination of phytate content

A test sample of 0.5 g of *Moringa* leaves was weighed into a 500 ml flat bottom flask. The flask with the sample was placed in a shaker and extracted with 100 ml of 2.4% HCl for 1 h at room temperature, and then decanted and filtered. Five milliliters of the filtrate was pipetted and diluted to 25 ml with distilled water. To 10 ml of diluted sample, 15 ml of sodium chloride was added and the solution passed through an ampertraisen, then 15 ml of 0.7m sodium chloride was added. The absorbance was taken at 520 nm wavelength. A standard curve and blank were prepared. Absorbance was read at the same wavelength and the concentration of phytate in the test sample was calculated.

Determination of oxalate

Two grams of leaf sample was weighed into a 300 ml flask. Twenty millilitres of 30% HCl was added and allowed to stand for 20 min. Forty grams of ammonium sulphate was added to the solution and allowed to stand for 30 min. The solution was filtered into a 250 ml volumetric flask and made up to the mark with 30% HCl. Ten ml of the filtrate was transferred into a 100 ml centrifuge tube and 30 ml diethyl ether added. The pH was adjusted to x with ammonium hydroxide, then centrifuged at 10 000 g for 15 min. Decantation into a 250 ml conical flask followed. The decant was titrated with 0.1 M potassium tetraoxomanganate (VII) (KMnO₄). The volume was recorded and calculations done as follow:

$$\% \text{ Oxalate} = \frac{\text{Titre} \times \text{mol KMnO}_4 \times \text{DF} (12.5)}{\text{Weight of sample}} \times 100$$

Determination of saponin

One gram of the leaf sample was weighed and macerated with 10 ml of petroleum ether. Decantation into a beaker followed. Another 10 ml of petroleum ether was added to the residue left out, macerated and decanted into a beaker. The filtrates were combined and evaporated to dryness. The residue was dissolved with 6 ml of ethanol. Two ml were then transferred into a test tube and 2 ml colour reagent added. This was allowed to stand for 30 min at room temperature. Absorbance was measured at 550 nm.

Statistical analysis

Statistical data collected were analyzed using analysis of variance (ANOVA). The T-test was used to compare two sets of data obtained on two comparable variables, for example, old and succulent leaves. Significant means were compared using Fisher's least significant difference (FLSD) at 5% probability according to Obi (2002). The statistical package used was Genstat 3.0 release 4.23 Discovery Edition (2008).

RESULTS

The older leaves of the moringa plants had higher concentrations of tannin, oxalate, phytate and saponin than the succulent leaves. There were no significant differences ($t > 0.05$) in the anti-nutrient contents of both leaf ages (Table 3). The effect of poultry manure rates on the anti-nutrient contents of moringa leaves is presented in Table 4. The different poultry manure levels showed no significant differences ($p > 0.05$) in the anti-nutrient compositions of the leaves. However, the highest value (6.48 g 100 g⁻¹) of tannin in the leaves was obtained at 0 tonne ha⁻¹ while the least value (6.19 g 100 g⁻¹) was obtained at 5 tonnes ha⁻¹ treatment. The highest value (2.91 g/100 g) of oxalate was obtained at 10 tonnes ha⁻¹ followed by 5 tonnes ha⁻¹ (2.87 g 100 g⁻¹) and 0 tonne ha⁻¹ (2.84 g 100 g⁻¹) in that order. The highest values of phytate and saponin (9.41 g 100 g⁻¹ and 4.63 g 100 g⁻¹) were obtained when the poultry manure was applied at 5 tonnes ha⁻¹ while the least values (8.47 g 100 and 3.65 g 100 g⁻¹) were obtained at the 0 tonne ha⁻¹ (control). The different poultry manure levels showed no significant differences ($p > 0.05$) in the anti-nutrient compositions of the leaves (Table 4). The levels of the poultry manure did not have any significant effects ($p > 0.05$) on the

Table 4. Effect of poultry manure on anti-nutrient contents of *Moringa oleifera* leaves.

Parameter	Manure rate			Mean	FLSD _(0.05)
	0 tonne ha ⁻¹	5 tonnes ha ⁻¹	10 tonnes ha ⁻¹		
Tanin (g 100 g ⁻¹)	6.48	6.19	6.23	6.30	ns
Oxalate (g 100 g ⁻¹)	2.84	2.87	2.91	2.87	ns
Phytate (g 100 g ⁻¹)	8.47	9.41	8.74	8.89	ns
Saponin (g 100 g ⁻¹)	3.65	4.63	3.86	4.04	ns

ns = Non-significant.

Table 5. Effects of poultry manure on the proximate, vitamin and chemical properties of *Moringa oleifera* leaves.

Proximate values	Manure rates			Mean	FLSD _(0.05)
	0 tonne ha ⁻¹	5 tonnes ha ⁻¹	10 tonnes ha ⁻¹		
Ash	6.64	6.53	6.47	6.54	ns
% Protein	12.37	12.26	12.57	12.40	ns
% M.C	29.57	27.13	28.58	28.43	ns
% Fat	0.17	0.20	0.20	0.19	ns
% Crude Fibre	16.96	16.29	15.99	16.41	ns
% Carbohydrate	40.93	44.13	42.67	42.58	ns
Vitamins					
Vit A (ppm)	0.57	0.60	0.59	0.58	ns
Vit B1 (ppm)	0.27	0.31	0.27	0.29	ns
Vit B2 (ppm)	0.66	0.66	0.66	0.66	ns
Vit B6 (ppm)	1.06	1.11	1.04	1.07	ns
Vit C (ppm)	0.38	0.33	0.35	0.36	ns
Vit E (ppm)	0.87	1.13	1.00	0.99	0.21
Chemical properties					
% Mg	0.77	0.73	0.75	0.75	ns
% K	0.38	0.35	0.37	0.36	ns
P (ppm)	71.20	71.00	71.20	71.10	ns
Na (ppm)	13.86	15.26	13.68	14.27	ns
Mn (ppm)	22.85	21.95	24.00	22.94	ns
Fe (ppm)	61.30	58.00	62.20	60.50	ns
I (ppm)	1.10	1.01	1.05	1.05	ns
Cu (ppm)	1.43	1.26	1.43	1.38	ns
Zn (ppm)	2.58	2.65	2.86	2.70	ns
% N	1.98	1.96	2.01	1.98	ns

ns = Non-significant.

proximate qualities of the moringa leaves sampled at three months after planting (Table 5). Five tonnes ha⁻¹ of poultry manure gave the least values of percentage ash and protein and greatest value of percentage carbohydrate. Ten tonnes ha⁻¹ gave the least values of percentage ash and crude fibre, and highest protein value. Zero tonne ha⁻¹ gave the least values of

percentage carbohydrate and fat contents in the leaves. The poultry manure levels did not show significant differences ($p > 0.05$) in the values of vitamins A, B and C but vitamin E (Table 5). Five tonnes ha⁻¹ poultry manure gave the greatest values of vitamins A, B₁, B₆, and E and the least value of Vitamin C in the leaves compared to other levels. Zero tonne ha⁻¹ gave the highest value of

Table 6. Effects of ages of leaves on the proximate, vitamin and chemical properties of *Moringa oleifera* leaves.

Proximate value	Age		Mean	t _{0.05}
	Older	Succulent		
Ash	6.35	6.73	6.54	ns
% protein	11.63	13.17	12.40	ns
% M.C	29.03	27.82	28.43	ns
% fat	0.19	0.19	0.19	ns
% crude fibre	14.87	17.94	16.41	ns
% carbohydrate	44.28	40.87	42.58	ns
Vitamin				
Vit A (ppm)	0.53	0.64	0.58	ns
Vit B1 (ppm)	0.16	0.41	0.29	ns
Vit B2 (ppm)	0.66	0.65	0.66	ns
Vit B6 (ppm)	0.97	1.16	1.07	ns
Vit C (ppm)	0.30	0.41	0.36	ns
Vit E (ppm)	0.88	1.12	0.99	ns
Chemical properties				
% Ca	2.03	2.21	2.12	ns
% Mg	0.74	0.76	0.75	ns
% K	0.34	0.39	0.36	ns
P (ppm)	67.40	74.90	71.10	5.59
Na (ppm)	14.02	14.52	14.27	ns
Mn (ppm)	19.87	26.00	22.94	3.18
Fe (ppm)	54.80	66.20	60.50	6.52
I (ppm)	1.05	1.05	1.05	ns
Cu (ppm)	1.48	1.27	1.38	Ns
Zn (ppm)	2.98	2.60	2.70	Ns
% N	1.86	2.11	1.98	Ns

ns = Non-significant.

vitamin C and least values of vitamins A and E. There were no significant differences ($p > 0.05$) in the effects of the poultry manure levels on N, P, K, Ca, Mg, Mn, Zn, iron (Fe) and copper (Cu) contents of the leaves. However, 10 tonnes ha⁻¹ poultry manure gave the highest values of Mn, Fe, Zn and N (Table 5). Data presented in Table 6 showed that the succulent leaves had higher values of ash, crude protein, crude fibre, and vitamins A, B₁, B₆, C and E. The succulent leaves also had higher values of N, P, K, Ca, Mg, Mn and Fe. There were no significant differences ($t > 0.05$) between the two leaf types in their proximate and vitamin compositions. Both, also, did not differ significantly ($t > 0.05$) in their chemical compositions except in P, Mn and Fe contents (Table 6).

The source of seeds did not have any significant ($p > 0.05$) effect on the proximate and vitamin contents of the leaves except vitamin A (Table 7). Similarly, there were no significant differences ($p > 0.05$) in the chemical compositions of the leaves of plants grown from seeds

collected from the different locations except Na and Zn contents (Table 7). Nsukka accession had the highest contents of vitamin A and Zn, while Jos accession had the highest leaf Na content. Figures 1 and 2 show the interactions in the effects of poultry manure levels, seed sources and ages of the leaves on proximate and vitamin contents of moringa leaves. Figure 1 shows clearly that crude fibre, protein and ash contents were higher in the young succulent leaves. Young leaves from Dutse (Jigawa State) which received no manure treatment had the highest fibre content. Carbohydrate was higher in the older leaves. Fat was high in the succulent leaves of the plants grown from the seeds collected from Dutse and Jos accessions. Succulent and older leaves from Nsukka, treated with 5 tonnes/ha poultry manure were also high in fats. Older leaves from Nsukka had the highest concentration of moisture. Figure 2 depicts a preponderance of vitamins A, C, B₁ and E in the young succulent leaves mainly from the plants that received some doses

Table 7. Effects of seed source on the proximate, vitamin and chemical properties of *Moringa oleifera* leaves

Proximate value	Accession				FLSD _(0.05)
	JOS	NSK	DTS	Mean	
Ash	6.43	7.04	6.17	6.54	ns
% Protein	11.79	12.71	12.69	12.40	ns
% M.C	28.83	27.97	28.47	28.43	ns
% Fat	0.18	0.20	0.18	0.19	ns
% Crude Fibre	15.27	16.96	17.00	16.41	ns
% Carbohydrate	43.92	42.16	41.66	42.58	ns
Vitamin					
Vit A (ppm)	0.50	0.66	0.59	0.58	0.12*
Vit B1 (ppm)	0.28	0.30	0.28	0.29	ns
Vit B2 (ppm)	0.70	0.62	0.66	0.66	ns
Vit B6 (ppm)	1.11	1.14	0.96	1.07	ns
Vit C (ppm)	0.33	0.38	0.36	0.36	ns
Vit E (ppm)	0.93	1.00	1.07	0.99	ns
Chemical properties					
% Ca	2.12	2.22	2.02	2.12	ns
% Mg	0.75	0.79	0.71	0.75	ns
% K	0.37	0.38	0.34	0.36	ns
P (ppm)	72.70	71.80	69.00	71.10	ns
Na (ppm)	17.77	12.86	12.17	14.27	3.20*
Mn (ppm)	22.92	23.01	22.89	22.94	ns
Fe (ppm)	59.00	62.50	60.00	60.50	ns
I (ppm)	1.06	1.05	1.06	1.05	ns
Cu (ppm)	1.46	1.38	1.28	1.38	ns
Zn (ppm)	2.46	3.02	2.62	2.70	0.42*
% N	1.89	2.03	2.03	1.98	ns
NSK = Nsukka (Enugu state)					
DTS = Dutse (Jigawa State)					
JOS = Jos (Plateau State)					

ns = Not significant.

of poultry manure. In contrast, B₃ was highest in older leaves from Dutse grown without manure. Nsukka and Jos accessions treated with 10 tonnes/ha of poultry manure also contained high levels of Vitamin B₂. The highest concentration of Vitamin B₆ was got in older leaves of Jos accession treated with 5 tonnes/ha poultry manure.

DISCUSSION

The higher values of the anti-nutrients (oxalates, phytates and saponins) obtained in the manure-treated moringa leaves suggested positive influence of poultry manure on the composition of the anti-nutrients in the plants. Poultry manure probably had substances which could have

contributed to the anti-nutrient compositions of the leaves. Fuglie and Sreeja (2011) reported values of 2.73, 3.1 and 4.1%, respectively for tannins, phytates and oxalates in untreated moringa leaves as against 6.23, 9.41 and 2.91% which were the highest values of these anti-nutrients obtained in the present study for the leaves of poultry manure-treated plants. Oxalates had been found to be negligible or relatively absent in dried leaves of moringa plants according to Fuglie and Sreeja (2011). The higher concentration of the anti-nutrients in the older leaves is an indication of the fact that older leaves are better accumulators of these anti-nutrients. The cells of the older leaves are usually tougher, larger and broader than those of the succulent ones. There was likely to be little or no mobility of the anti-nutrients from the older leaves to the succulent ones as the leaves were aging.

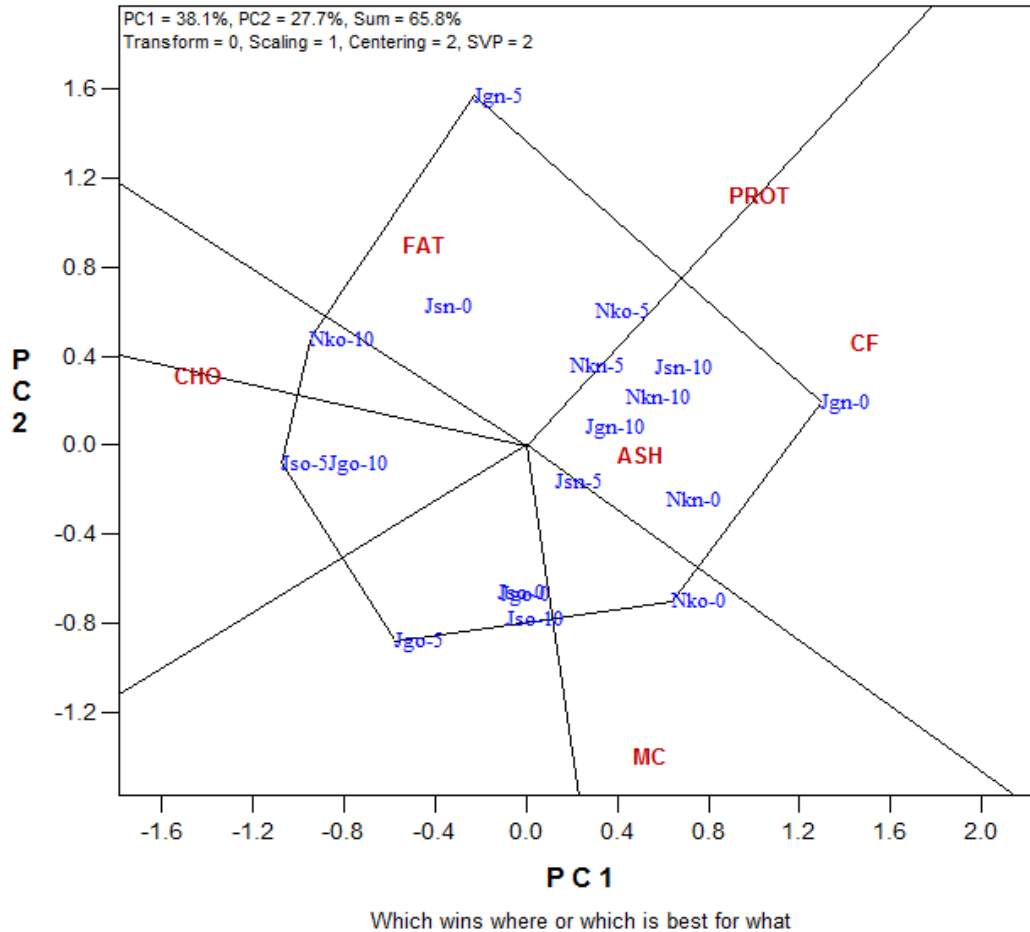


Figure 1. GGE Biplot analysis on effects of poultry manure; accession and age on the proximate compositions of leaves of *M. oleifera*. CHO = carbohydrate; MC = moisture content; CF = crude fibre; PROT = protein; Jso-0; Jso-5 and Jso-10 = Jos older leaves with 0; 5 and 10t/ha PM respectively; Jsn-0; Jsn-5 and Jsn-10 = Jos succulent leaves with 0; 5 and 10t/ha PM respectively; Nko-0; Nko-5 and Nko-10 = Nsukka older leaves with 0; 5 and 10t/ha PM respectively; Nkn-0; Nkn-5 and Nkn-10 = Nsukka succulent leaves with 0; 5 and 10t/ha PM respectively; Jgo-0; Jgo-5 and Jgo-10 = Jigawa older leaves with 0; 5 and 10t/ha PM respectively; Jgn-0; Jgn-5 and Jgn-10 = Jigawa succulent leaves with 0; 5 and 10t/ha PM. PM = poultry manure.

Thus, leaf senescence can be said to be synonymous with and directly proportional to leaf anti-nutrient accumulation. This fact gives a good direction to the consumers to take small quantities of older leaves or concentrate more on the young succulent leaves which contain lesser quantities of anti-nutrients. The insignificant effect of the poultry manure on the proximate qualities, chemical properties and vitamin contents of the moringa leaves within the three months of study could be attributed to the slow nutrient release nature of the manure into the soil coupled with soil factor as well as the physiological conditions of the plants. This agreed with the work of Demir et al. (2010) who also obtained insignificant effects of poultry manure on N, Mg and Mo concentrations of tomato leaves and fruits. It suggests that short-duration crops may not benefit much from

poultry manure application. Ndubuaku et al. (2014) observed that poultry manure increased the nutrient status of the soil and boost crop productivity.

According to Ojeniyi et al. (2012), application of liquid agro-industrial by-products increased soil-plant nutrient supply by releasing structurally bound elements such as N, P and Ca in soil solution during decomposition thereby increasing crop growth and yield. However, the values of the proximate properties obtained in this study did not differ significantly from the levels reported by previous workers. Moyo et al. (2011) reported 8.4% ash and 7.9% crude fibre in moringa leaves as against 7.64% ash and 6.54% crude fibre obtained in the current study. Fuglie and Sreeja (2011) in Philippines reported higher values of vitamins A (16.3 ppm against 0.29 ppm obtained in this study). The variations in the levels of the nutrients

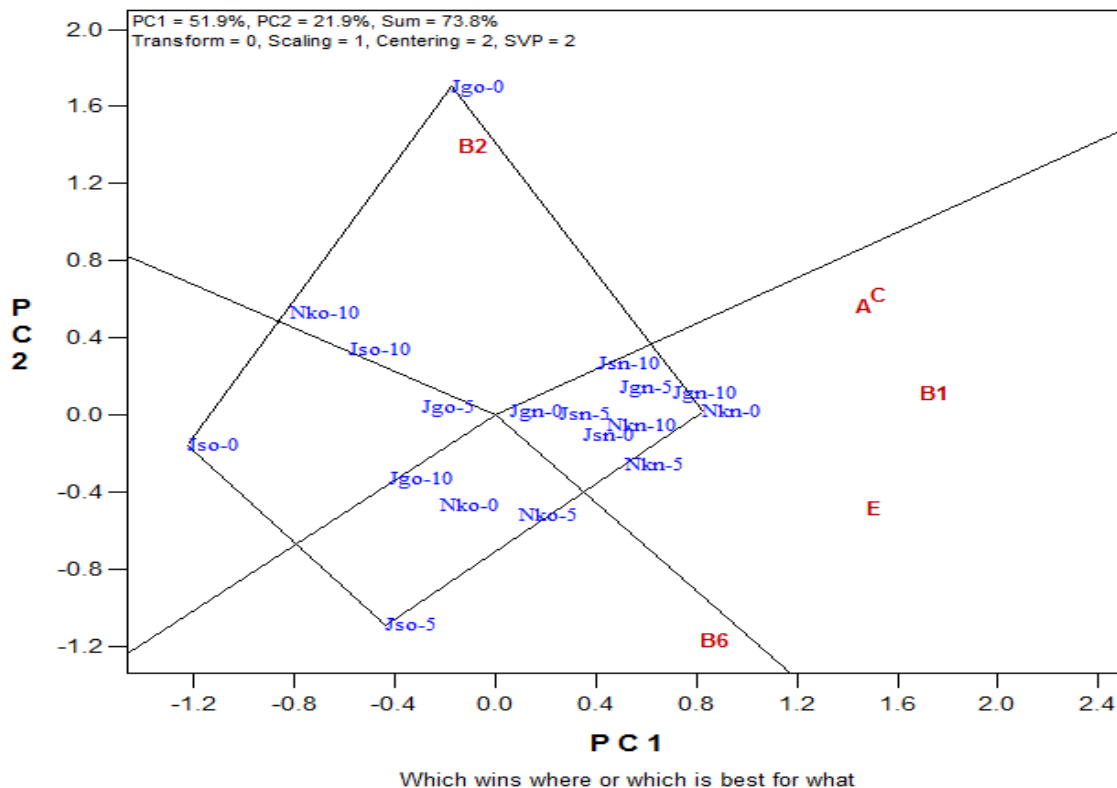


Figure 2. GGE Biplot analysis of the effects of poultry manure; accession and age on the vitamin content of leaves of *Moringa oleifera*. Jso-0; Jso-5 and Jso-10 = older leaves from Jos without PM; with 5 tons/ha and 10 tons/ha PM; respectively; Nko-0; Nko-5 and Nko-10 = older leaves from Nsukka without PM; with 5 tons/ha and 10 tons/ha PM; respectively; Jgo-0; Jgo-5 and Jgo-10 = older leaves from Jigawa without PM; with 5 tons/ha and 10 tons/ha PM; respectively; Jsn-0 = succulent leaves from Jos without PM; with 5 tons/ha and 10 tons/ha PM; respectively; Nkn-0; Nkn-5 and Nkn-10 = succulent leaves from Nsukka without PM; with 5 tons/ha and 10 tons/ha; respectively; while Jgn-0; Jgn-5 and Jgn-10 = succulent leaves from Jigawa without PM; with 5 tons/ha and 10 tons/ha PM; respectively.

obtained by the various workers could be due to the differences in the study locations and the environmental conditions. The higher values of vitamins, proximate and chemical properties in the succulent leaves compared to the older ones could be as a result of higher metabolic activities in the succulent leaves. There is usually translocation of nutrient elements like N from the lower (older) leaves to the younger (succulent) leaves during senescence. This can also account for the higher composition of N in the succulent leaves than the older ones. This is a good direction for moringa leaf consumers, to harvest the younger succulent leaves instead of the older ones for consumption.

Plants of moringa seeds collected from different locations of Nigeria gave no significant differences in their leaf compositions of vitamins, proximate and chemical properties indicating non-phenotypic influences on the genetic constitutions of the seeds. The performances of the plants were determined by the environmental factors prevalent in the study area (Nsukka) which would have also determined the physiological conditions of the plants.

Conclusion

Succulent leaves had higher values of vitamins, proximate and chemical properties. The higher concentrations of the anti-nutrients in the older leaves and higher values of vitamins, proximate and chemical properties in the succulent ones provide a good guide to moringa leaf consumers, to harvest the younger succulent (first to fifth) leaves for consumption.

Conflict of interests

The authors did not declare any conflict of interest.

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