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Nutrient composition of *Moringa oleifera* leaves from two agro ecological zones in Ghana

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***Moringa oleifera* Lam. (*MO*) is a small size multipurpose tree of approximately 5 to 10 m in height which is cultivated all over the world. The study was conducted in the Guinea Savanna and the semi-deciduous forest zones of Ghana in December 2011 to compare the nutrient levels of *MO* leaves from the two agro-ecological zones. Leaf samples were collected from three randomly selected districts in each ecological zone for proximate and chemical analysis of some macro and micro nutrient. The results show no significant difference in crude protein and carbohydrate levels of *MO* leaves from the two ecological zones, however *MO* leaves from the semi-deciduous forest zone recorded a slightly higher mean crude protein value of 26.54% than the Guinea savanna value of 25.65%. *MO* leaves from the semi-deciduous forest and the Guinea Savanna recorded mean calcium values of 1880 and 1474.33 mg per 100 g of leaf powder, respectively. The comparison of mean values of potassium and iron of *MO* leaves showed no significant difference between *MO* leaves from the two ecological zones. The research concluded that agro ecological zonation had no significant effect on the levels of most nutrients in *MO* leaves.**

Key words: *Moringa oleifera*, ecological zone, Guinea Savanna, semi-deciduous forest, nutrients.

INTRODUCTION

Moringa oleifera Lam *(MO)* is the most widely cultivated species of a monogeneric family, the *Moringaceae* (Fahey, 2005). The tree is an aboriginal of Indian subcontinent and has become naturalized in the tropical and subtropical areas around the world (Farooq et al., 2012). While it grows best in dry sandy or loamy soil that is slightly alkaline (Abdul, 2007; Anjorin et al., 2010), it is adaptable to various soil conditions from 4.5 to 8.0 pH, but does not tolerate water logging, freezing or frosts conditions (Radovich, 2011). India is rated as the largest producer of Moringa, with an annual production of between 1.1 to 1.3 million tonnes of tender fruits from an area of 380 km² (Rajangam et al*.,* 2011). In the past 5000 years, *MO* has been used as a regular component of conventional eatables in the Indian sub-continent (Anwar et al., 2005, Anwar and Bhanger, 2003). Its trunk is soft, white corky and branches bearing a gummy bark. Each tripinnately compound leaves bear several small leaflets. The flowers are white and the three wing seeds are scattered by the winds (Farooq et al., 2012).

According to Fuglie (2005), *MO* plant forms the basis for several nutritional programmes in many poor countries by charitable organizations, given that the leaves of *MO* tree are rich in essential nutrients.

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The leaves of *MO* are considered to give immense possibilities for those who are nutritionally challenged and may be regarded as a protein and calcium supplement (Rajangam et al., 2001). Bamishaiye et al. (2011) reported MO leaves of all stages having varying percentages of nutritional composition. Fuglie (1999) was quick to say the “so good to be called syndrome was the biggest challenge for Moringa”, it offers so much to us so that it’s so difficult to believe if such simple plant can be so useful. This little-plant has the potential to improve nutrition, boost food security and support sustainable landuse practices (Price, 2007). It is estimated that 82% of the population in developing countries depend on herbal treatment (Abbiw, 1990).

Researchers at the Asian Vegetable Research and Development Center (AVRDC, 2006) reported that leaves from four different *Moringa* species (*Moringa oleifera, Moringa peregrina, Moringa stenopetala* and *Moringa drouhardii*) all contained high levels of nutrients and antioxidants. Vitamin A was found to be at its peak during the hot-wet season, where as iron and vitamin C was highest during the cool-dry season (Price, 2007). Bureau of plant industry reported *MO* as an outstanding source of nutritional components. Its leaves (weight per weight) have the calcium equivalent of four times that of milk, the vitamin C content is seven times that of oranges, while its potassium is three times that of bananas, three times the iron of spinach, four times the amount of vitamin A in carrots, and two times the protein in milk (Kamal, 2008). In addition, the leaves can serve as a rich source of beta-carotene (Nambiar and Seshadri, 2001), vitamin C and E, and polyphenolics (Ross, 1999). Also, *Moringa* is suggested as a viable supplement of dietary minerals. The pods and leaves of *Moringa* contains high amount of Ca, Mg, K, Mn, P, Zn, Na, Cu and Fe (Aslam et al., 2005).

MO leaf extracts are rich in pterygospermin and other related compounds such as isothiocyanates which is used in the treatment of many skin infections because of its antibiotic and fungicidal properties (Price, 2007).

It is generally known in the developing world as a vegetable, a medicinal plant and a source of vegetable oil (Bennet et al., 2003). Six tablespoons full of *MO* leaf powder will provide nearly the woman’s daily iron and calcium during pregnancy and breastfeeding hence *MO* has been used to combat malnutrition among infants and nursing mothers (TFL, 2011). *M. oleifera* can survive in harsh climatic condition including impoverished soils without being much affected by drought (Morton, 1991). It can tolerate wide range of rainfall requirements estimated at 250 mm and maximum at over 3000 mm and a pH of 5.0 to 9.0 (Palada and Chang, 2003). Easy cultivation of *Moringa* within adverse environmental condition and wide availability attract attention for economic and health related potential in resource limited developing countries (Farooq et al., 2012).

The mineral contents in *M. oleifera* and their bioavailability continue to be a subject of tremendous interest. There are however limited reports on the influence of variation in geographical locations or agro-ecology of *M. oleifera* on the mineral composition in various organs of the plant. Aslam et al. (2005) suggested the contents of different minerals in leaves and pods of *M. oleifera* to significantly differ from region to region in Pakistan. Anjorin et al. (2010) confirmed that there were variations in macro and trace minerals in *M. oleifera* leaves, pods and seeds from different locations in Nigeria. The increasing conviction and confidence in the consumption of this plant calls for a need to document well the nutritional comparison of *Moringa* leaves from different agro ecological zones in Ghana. The objective of this study was to investigate and compare the nutritional components of *MO* leaves in two agro-ecological zones of Ghana.

MATERIALS AND METHODS

Study area

The study was conducted in the Guinea Savanna (GS) and the semi-deciduous forest (SDF) zones of Ghana in December 2011. Leaf samples were taken from three selected districts in the Guinea Savanna zone of Ghana: Tolon-Kumbungu District (latitude 09° 25″N and longitude 0° 58″W in the Northern region), Kassena-Nankana East District (Latitude 10°53′5″N and longitude 01°5′25″W in the Upper East region) and the Sissala West District (Latitude 10° 11″ N and Longitude 02°13′36″ in the Upper West region). The Guinea Savanna records a unimodal rainfall pattern (Figure 1), which starts in April and ends in September-October. The mean annual rainfall ranges between 900 -1100 mm (NAES, 1991). The vegetation of the area is generally grassland with few trees interspersed (NAES, 1993). The temperature of the zone ranges between a minimum of 15°C in January and a maximum of 42°C in March.

The semi-deciduous forest zone is considered the most important for timber production in Ghana (Owusu et al., 1989). Leaf samples were taken from three randomly selected districts of the semi-deciduous forest zone of Ghana: Techiman municipality (Latitude 7°35′13″N Longitude 1°56′06″W), Wenchi municipality (latitudes 7° 30′ and 8°05′N and longitudes 2°15′ W), and Nkoranza South District (Latitudes 7°20′55″N and Longitudes 1°10′55″W) all in the Brong Ahafo Region. The zone records a bimodal rainfall pattern (Figure 2). The major raining season starts in early March and reaches its peak in June, and tapers off gradually through July. The minor season starts in late August and reaches its peak in September/November. The mean annual rainfall figures range from 1150 to 1250 mm. The mean monthly temperature is between 24°C in August and 30°C in March. The relative humidity is also high ranging between 90 and 95% in the rainy season.

Field work

Moringa leaves and soil samples were taken from both the savannah (Tolon-kumbugu,Kassena-Nankana and Sissala West) and transitional zones (Techiman, Wenchi and Nkoranza). Leaf samples were plugged from tree growing points across the lower, mid and upper parts of tree canopy. Leaves were defoliated from rachis and samples from aforementioned districts within each zone were bulked and thoroughly mixed. Final samples were kept in to

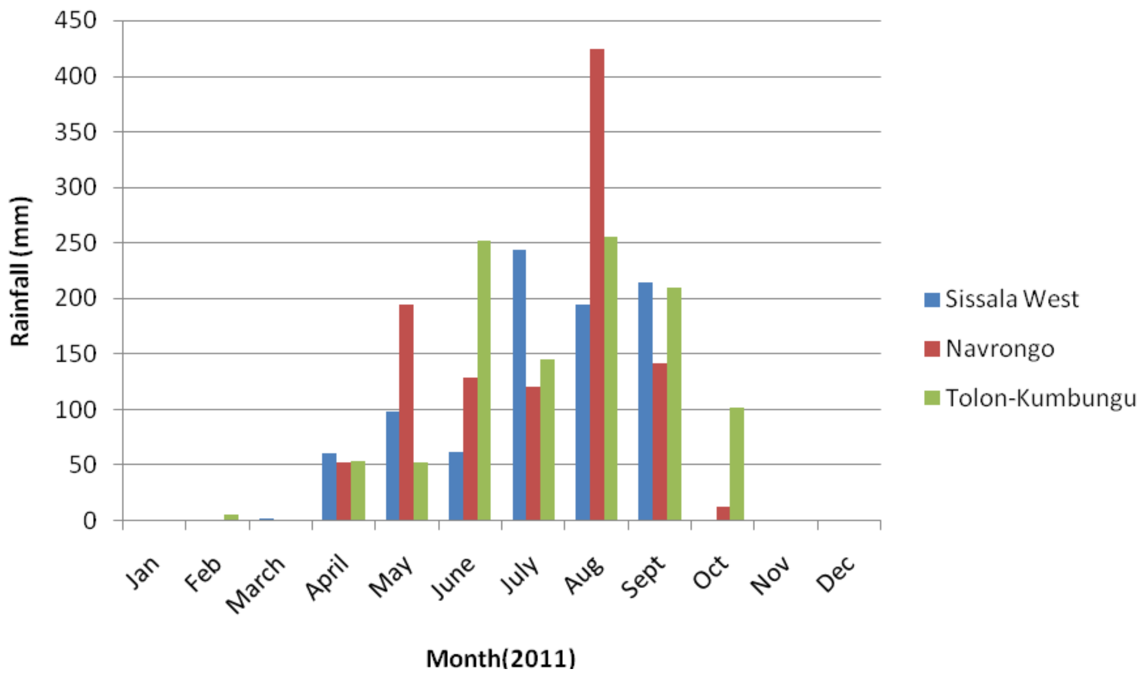

Figure 1. Monthly figures showing unimodal rainfall for areas sampled in the Savanna zone

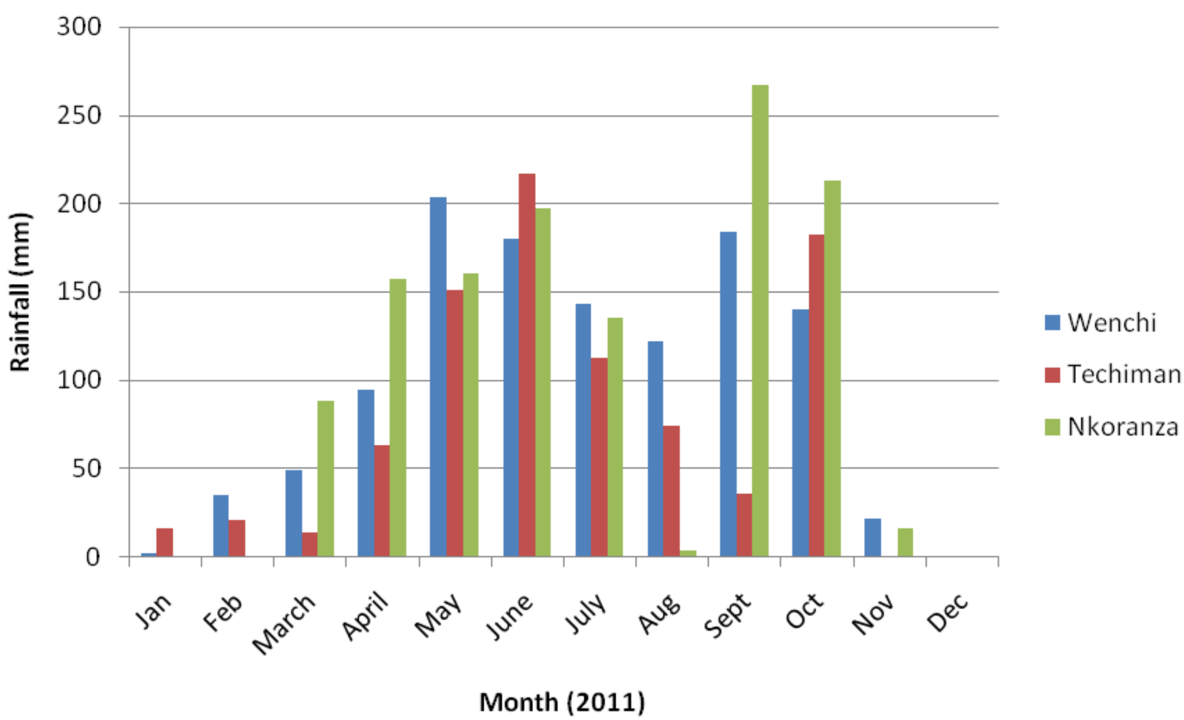

Figure 2. Monthly figures showing bimodal rainfall for areas sampled in the semi-deciduous forest zone.

ice-chest and transported to the laboratory. The harvested *Moringa* leaves were air dried in shade to ensure they retain their greenish coloration and to ensure that their nutritional values were maintained. The dry leaves were milled and sieved. The powder was then packaged into small containers and labeled based on ecological zones to ensure that right samples were picked.

Soil samples were taken at 0-15 m from the spots where the *MO* leaves were sampled. This was done using the soil auger. The soils of various zones were sieved and packaged in their labeled containers based on their ecological zones.

Table 1. Comparison of mean levels of nutrients per 100 g of *MO* soils from the Guinea Savanna and semi-deciduous forest of Ghana.

Ecological zone	N (%)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
Semi-deciduous forest	0.11	4.61	202.67	813.33	202.50
Guinea savanna	0.05	9.36	207.00	505.33	136.18

Analysis of soil samples

Three samples of soil were assayed from each agro ecological zone and analyzed individually in triplicate. The amount of phosphorus present in the soil sample was determined using bray 1 extraction with the help of the spectrophotometer. Ammonium acetate was used to extract potassium, calcium and magnesium, however, in determining the rate of nitrogen present in the soil, a sample weight of soil of 0.2 g was added to 10 ml concentrated sulphuric acid. One Kjeldahl was added and placed on the block digester. The Kjeldahl distillation process was used to determine the rate of soil nitrogen.

Determination of minerals in *MO* leaves

Three samples of leaves were assayed from each agro ecological zone and analyzed individually in triplicate. Moisture content was determined by air drying, and protein by the Kjedahl method (AOAC, 1990). The pH of *Moringa* leaves was taken with an electronic pH metre (Bates, 1954). The amount of carbohydrate was determined by the calometric method (AOAC, 1990). Calcium was measured directly on the atomic absorption spectrophotometer using 1 g of the sample solution which was topped to 100 ml. The potassium was measured using the Barnes et al. (1954) method while iodine and iron were analyzed calorimetrically using the ultra violet visible spectrophotometer (Hald, 1946).

Data was subjected to Analysis of Variance (ANOVA) and differences among the mineral components and pH of the leaves were determined with Duncan Multiple Range Test, using SAS 9.0 Statistical Package. *P*-values ≤ 0.05 was considered statistically significant. Comparison was made of minerals content and pH in leaf of *MO* from savanna and semi-deciduous forest.

RESULTS

Nutrient content of soils where *MO* samples were taken from in the two ecological zones

The soils under the sample plants of *MO* in both ecological zones were fairly fertile. Soils under *MO* plants from the semi-deciduous forest and the Guinea savanna zones recorded 4.61 and 9.36 mg/kg of phosphorous (P), respectively (Table 1), but there was no significant difference. Levels of K in soils similarly showed no significant difference recording 202.67 and 207 mg/kg for the semi-deciduous forest and the Guinea Savanna zones, respectively. Levels of Ca were higher in the semi-deciduous forest zone (813.33 mg/kg) than in the Guinea savanna (505.33 mg/kg) however, there was no statistical difference between the two zones. Magnesium (Mg) in soils of the semi-deciduous forest were similarly higher (202.5 mg/kg) than soils from the Guinea savanna (136.18 mg/kg) but not significantly different. Percentage nitrogen was low but not significant in soils from semi-deciduous forest (0.11%) and the Guinea Savanna soils (0.05%), respectively.

Proximate results and pH of *Moringa* leaves from the two ecological zones

A comparison of the mean values of moisture, crude protein, carbohydrate and pH of *Moringa* leaves from the Guinea Savanna and the semi-deciduous forest zone are shown in Figure 3. *Moringa* leaves from the semi-deciduous forest recorded a higher average moisture content of 71.34%. Analysis of variance at P>0.05 showed no significant difference in moisture content of *Moringa* leaves from the two ecological zones.

Crude protein and carbohydrate in *MO* leaves from the two ecological zones recorded similar mean values. Analysis of variance at P>0.05 showed no significant difference in crude protein and carbohydrate of *MO* leaves from the two ecological zones. There was however a significant difference in pH (Table 2) of *MO* leaves from the two ecological zones (P>0.05).

Levels of macro and micro nutrients in *MO* leaves from the two ecological zones

MO leaves from the semi-deciduous forest and the Guinea savanna zones recorded 1209.67 mg/100 g and 997.3 mg/100 g of potassium (K), respectively as shown in Table 2. There was a significant difference (P>0.05) in calcium (Ca) levels between *MO* leaves from the two ecological zones. The mean levels of iron (Fe) in *MO* leaves from the semi-deciduous forest and the Guinea savanna zones recorded close mean values of 26.83 mg/100 g and 25.043 mg/100 g, respectively (Table 2).

DISCUSSION

Effect of agro ecological zone on crude protein, carbohydrate and pH levels of *MO* leaves

Crude protein levels of *MO* leaves from the two ecological zones ranges between 25.34 and 26.98 g in every 100 g of *MO* leaf powder (Figure 3). This is similar to the findings of Fuglie (2005) that suggested *MO* as

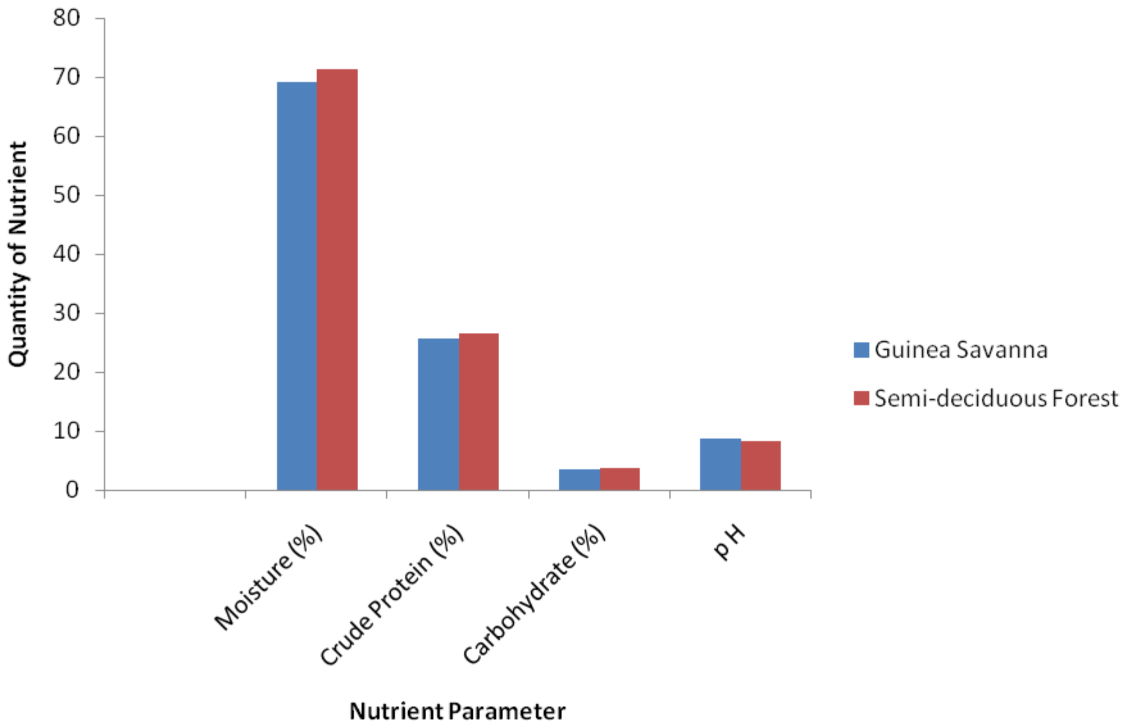

Figure 3. Comparison of mean proximate values and pH of *MO* leaf powder from the Guinea Savanna and the semi-deciduous forest of Ghana.

Table 2. Comparison of mean levels of macro and micro nutrients per 100 g of *MO* leaf powder from the Guinea Savanna and semi-deciduous forest of Ghana.

Ecological zone	Macro nutrient		Micro nutrient	
	K (mg/kg)	Ca (mg/kg)	Fe (mg/kg)	I (mg/kg)
Semi-deciduous forest	1209.67	1880.00	26.83	0.674
Guinea savanna	997.33	1474.33	25.043	0.517

containing high amount of proteins. The crude protein of *MO* leaves from the semi-deciduous forest of Ghana was higher than that of Guinea Savanna though there was no significant differences (P>0.05). These variations may be due to the periodic higher temperatures in the Guinea Savanna at certain times of the year. Temperatures in Guinea Savanna rise beyond the actual climatic requirements of the *MO* plant (25 - 35°C) to a maximum of about 42°C in March.

Although increasing tempe-ratures activates enzymatic activities, higher tempera-tures beyond the plant requirement causes many cell proteins that function as enzymes or structural com-ponents to become unfolded or misfolded, there by leading to loss of proper structure and activity (Taiz and Zeiger, 2002). This agrees with the findings of Modi (2007) that reported that cool environmental conditions are associated with high total protein in leafy vegetables while hot temperatures had a significant decrease in leaf protein content. Apart from the higher temperatures in the savanna, the long periods of drought during the dry season could be a contributing factor.

The higher levels of carbohydrates in the samples from the semi-deciduous forest zone than that of the Guinea Savanna could be due to higher temperatures. Although photosynthesis and respiration are inhibited at higher temperatures, photosynthetic rates drop before the respiration (Modi, 2007). At any temperature above the plant temperature compensation point, photosynthesis cannot replace the carbon used as a substrate for respiration. As a result, carbohydrate reserves decline, and also lead to loss of sweetness as well. Taiz and Zeiger (2002) reported imbalances between photosyn-thesis and respiration and associated it to the deleterious effects of high temperatures on plant development.

The mean pH values of *MO* leaves from the semi-deciduous forest zone and the Guinea Savanna were 8.35 and 8.71, respectively (Figure 3). The pH reading of

Table 3. ANOVA of pH values, Ca and I nutrients per 100 g of *MO* leaf powder from the Guinea Savanna (GS) and semi-deciduous forest (SDF) of Ghana.

Source of variation	d.f	s.s	m.s	v.r	F.pr.
ANOVA for pH of *MO* leaves from the GS and the SDF zone.					
Treatment	1	0.98067	0.98067	383.26	0.001
Residual	4	0.00207	0.00052		
Total	5	0.20008			
ANOVA for Ca per 100 g *MO* leaf powder from the GS and the SDF zone					
Treatment	1	246848	246848	47.54	0.002
Residual	4	20771	5193		
Total	5	267619			
ANOVA for I per 100 g of *MO* leaf powder from the GS and the SDF zone					
Treatment	1	0.03373	0.03373	119.39	0.001
Residual	4	0.00125	0.00031		
Total	5	0.03854			

MO leaves from both ecological zones falls within the slightly alkaline range of the pH scale. The analysis of variance showed a significant difference in pH (Table 2). Research by Diet.myfit (2012) indicates that there exist no recommended dietary pH for food substances, but the human body operates best within a pH range of 7.35 - 7.45. Therefore, the consumption of any food with a higher or lower pH value is an indication of it being alkaline or acidic to the human body.

Effect of agro ecological zone on moisture content of *MO* leaves

Samples from the two ecological zones recorded high moisture content ranging from 67 to 75% of the weight of fresh leaves (Figure 3). The leaf samples from the semi-deciduous forest zone recorded higher average moisture content than leaves from the Guinea Savanna. The low moisture values recorded in *MO* leaves from the Guinea Savanna zone may be associated with hot and dry winds of the harmattan during sample collection (December) which comes with high rates of evapotranspiration. Modi (2007) reported that transpiration rates are at their peak in hot dry/windy environment. The effects of annual harmattans are more severe in the Guinea savanna than the semi-deciduous forest. During this period, atmospheric humidity becomes very low in the Guinea savanna. However, with plant leaves relative humidity between cells approach 100%, therefore when stomata opens, water vapour inside the leaf moves out forming a bubble of higher humidity around the plant. The difference in relative humidity around the stomata and adjacent air regulates transpiration rates and pulls water up through the xylem tissues (Taiz and Zeiger, 2002).

Moringa leaves from the Guinea Savanna zone recorded higher mean dry matter content of 30.92% than that of the semi-deciduous forest zone of 28.66%. The high dry matter content of savanna leaves makes them more favourable for animal fodder. Bell (2006) indicated that the higher the dry matter of fodder, the higher its digestibility (the proportion of a feed an animal can use to satisfy its nutritional requirements). He further reported that digestibility is positively related to the energy content and protein of animal fodder. Nuhu (2010) also indicated that *MO* leaf meal (MOLM) could be used to improve daily weight gain, dry matter (DM) and crude protein (CP) digestibility of rabbits. In the current situations where natural rangelands are getting extinct due to rapid encroachment, *MO* can be incorporated into agroforestry practices to provide fodder to increase animal production in the savanna regions of Ghana.

Effect of agro ecological zones on macro and micro nutrients of *MO*

There was no significant differences in K and Fe levels of *MO* leaf samples (P>0.05) from the two ecological zones. Although savanna soils are known to be low in soil organic matter as compared to that of the semi-deciduous forest, high levels of soil nitrogen in the semi-deciduous forest zone did not influence the accumulation of some nutrient elements in *MO* leaves. This agrees with Ore-Oluwa et al. (2003) where nitrogen application did not record any significant effect on the accumulation of Ca, K, Na, Cu and Zn in tropical leafy vegetables however, decreasing levels of soil nitrogen reduces the Fe content of tropical vegetables.

Also, significant difference in calcium and iodine (Table 3) may be due to the long droughts in the Guinea Savanna which makes soils dry for longer periods of time inhibiting the absorption of soil nutrients for leaf development. Potassium, calcium and phosphorus move primarily by diffusion therefore the drier the soil, the lesser the flow of these nutrients to the plant root. Kessel (2005) reported that calcium and potassium levels in leaves decreased with decreasing soil moisture. However, the low levels of Ca and iron recorded in the Guinea Savanna zone as compared to the semi-deciduous forest contradicts the findings of Modi (2007) were mineral elements, calcium and iron increased in the leaves in response to increasing temperatures. Aslam et al. (2005) reported that mineral content in the leaves and seeds of *MO* varied in Pakistan with location while Anjorin et al. (2010) reported significant variation in macro and micro elements in *MO* leaves, pods and seeds from different regions in Nigeria.

MO leaves generally contain significant quantities of some macro and micro food nutrients needed by the human body. The research revealed that agro ecological zones have no significant effect on the levels of most nutrients of *MO* leaves in Ghana. However, *MO* leaf samples from the semi-deciduous forest zone recorded slightly higher nutrient values than that of the Guinea savanna.

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