

Full Length Research Paper

## Nutritional characterization of Moringa (*Moringa oleifera* Lam.) leaves

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**Moringa (*Moringa oleifera* Lam. moringaceae) is a highly valued plant that is mostly cultivated in the tropics and subtropics. It is used for food, medication and industrial purposes. The objective of the study was to assess the nutritional value of Moringa leaves of the South African ecotype. Proximate and Van Soest methods were used to determine the nutritional value of Moringa leaves. The dried leaves had crude protein levels of 30.3% and 19 amino acids. The dried leaves had the following mineral contents: calcium (3.65%), phosphorus (0.3%), magnesium (0.5%), potassium (1.5%), sodium (0.164%), sulphur (0.63%), zinc (13.03 mg/kg), copper (8.25%), manganese (86.8 mg/kg), iron (490 mg/kg) and selenium (363 mg/kg). 17 fatty acids were observed with  $\alpha$ -Linolenic acid (44.57%) having the highest value followed by heneicosanoic (14.41%), g-linolenic (0.20%) palmitic (0.17%) and capric acid (0.07%). Vitamin E had the highest concentration of 77 mg/100 g than beta-carotene, which had 18.5 mg/100 g in the dried leaves. The fiber content was neutral detergent fibre (NDF) (11.4%), acid detergent fibre (ADF) (8.49%), acid detergent lignin (ADL) (1.8%) and acid detergent cellulose (ADC) (4.01%). The condensed tannins had a value of 3.2%, while total polyphenols were 2.02%. The values of amino acids, fatty acids, minerals and vitamin profiles reflect a desirable nutritional balance.**

**Key words:** South African, supplemental food, nutritional value, *Moringa oleifera*.

### INTRODUCTION

Moringa (*Moringa oleifera* Lam.) is native to the Indian subcontinent and has become naturalized in the tropical and subtropical areas around the world. The tree is known by such regional names as Benzolive, Drumstick tree, Horseradish tree, Kelor, Marango, Mlonge, Mulangay, Saijihan and Sajna (Fahey, 2005). The plant thrives best under the tropical insular climate. It can grow

well in the humid tropics or hot dry lands and can survive in less fertile soils and it is also little affected by drought (Anwar et al., 2007). It is considered as one of the World's most useful trees, as almost every part of the Moringa tree can be used for food, medication and industrial purposes (Khalafalla et al., 2010). People use its leaves, flowers and fresh pods as vegetables, while others use it as livestock feed (Anjorin et al., 2010). This tree has the potential to improve nutrition, boost food security and foster rural development (Hsu, 2006). Most people in South Africa, however, are not aware of the potential benefits of Moringa.

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Recently, a high degree of renewed interest was placed on the nutritional properties of Moringa in most countries where it was not native (Reyes et al., 2006; Oduro et al., 2008). This could be due to the claims that it increases animal productivity as it has nutritional, therapeutic and prophylactic properties (Fahey, 2005). Studies from other countries indicate that the leaves have immense nutritional value such as vitamins, minerals and amino acids (Anwar et al., 2007). As such, the leaves have been used to combat malnutrition, especially among infants and nursing mothers. In addition, nutrition plays a crucial role in both humans and livestock as short-term alternative to chemoprophylaxis. In animals, nutrition plays a major role in animal's ability to overcome the detrimental effects of parasitism and diseases (Anwar et al., 2007). A well-nourished animal resists diseases even when exposed to infection than the one, which is already weakened through malnutrition. When an animal is exposed to pathogens, the animal's immune system mounts a response to fight off infection. This includes raising antibodies to fight the infection, as well as using white blood cells to attack pathogens (FAO, 2002). To gain immunity, the animal needs energy, proteins for manufacture of antibodies and cells, minerals (zinc, copper and iron) and vitamins (A and E) in communicating messages in parts of the animal's body to fight infections (Conroy, 2005).

There are considerable variations among the nutritional values of Moringa, which depend on factors like genetic background, environment and cultivation methods (Brisibe et al., 2009). As such, it necessitates determination of the nutritive value of Moringa of South African ecotype, which could assist in the formulation of diets according to nutrients requirements. The nutritional composition of Moringa of the South African ecotype has to our knowledge not previously been evaluated; this is the first report that includes the profiling of chemical composition, fatty acids, amino acids and vitamins. Amino acids, fatty acids, minerals and vitamins are essential in animal feed. These nutrients are used for osmotic adjustment; activate enzymes, hormones and other organic molecules that enhance growth, function and maintenance of life process (Anjorin et al., 2010). Nutritional composition of the plant plays a significant role in nutritional, medicinal and therapeutic values (Al-Kharusi et al., 2009). In addition, the chemical composition of the fibre fractions affects the digestibility of the feed, which directly or indirectly affect the feed's utilization by animals. It was reported that nutritional content in the leaves of Moringa varies with location (Anjorin et al., 2010). This has prompted the study of nutritional composition of Moringa of South African ecotype. Therefore, the objective of the study was to determine the nutritional value of Moringa leaves of the South African ecotype.

## MATERIALS AND METHODS

### Plant collection and preparation

The plant leaves were collected at Sedikong sa Lerato in Tooseng village Ga-Mphahlele (24°26'57.10"S, 29°33'47.02"E), Limpopo Province of South Africa. The mean annual rainfall of the area is approximately 300 mm and the mean annual temperature is 15°C. The plant was authenticated at the University of Fort Hare, Department of Botany and a voucher specimen (BM 01/2009) was prepared and deposited in the Giffen Herbarium of the University of Fort Hare. The leaves were harvested green, air-dried under shade and milled into powder through 1 mm sieve using Restch Cross Beater Mill SK 100, Monitoring and Control laboratories (Pty) Ltd, Parkhurst, South Africa. They were stored in well-dried black plastic containers inside the storeroom at room temperature of 25°C.

### Nutritional composition determination

Dried powdered Moringa leaves were assessed for dry matter (DM), crude protein (CP), crude fat, calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P) zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), selenium (Se) and sodium (Na) using the Association of Official Agricultural Chemists (AOAC, 2005) procedures. Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), acid detergent cellulose (ADC) and hemi-cellulose were determined following the techniques established by Van Soest et al. (1991).

### Condensed tannins and total phenolics determination

Condensed tannins (CT) assays were performed calorimetrically with butanol-HCl method (Bate-Smith, 1981) using purified CT from *Desmodium intortum* as a reference standard. This method is based on oxidative cleavage of the interflavan bonds in the presence of mineral acids in alcoholic solutions at about 95°C to yield pink coloured anthocyanidins, which are measured at 550 nm. Total phenolics were assayed calorimetrically according to Price and Butler (1977). In this method, 6 ml of aqueous solution of phenolics, 50 ml of distilled water were mixed and 0.1 ml ferric chloride were added, immediately followed by timed addition of 3 ml of 0.008 M of ferricyanide solution. The absorbance at 720 nm was read after 10 min standing at room temperature. Distilled water was used as a the blank. The method exploits an oxidation-reduction reaction in which the phenolate ion is oxidized. The ferric ions are reduced to the ferrous state and detected by the formation of the Prussian Blue complex ( $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$ ) with a potassium ferricyanide-containing reagent.

### Fatty acid profile determination

Total lipids from plant material were quantitatively extracted, with a Soxhlet extraction (AOAC, 2005). The extracted fats were stored in a polytop (glass vial, with a push-in top) under a blanket of nitrogen and frozen at -20°C, pending analyses.

Approximately 10 mg of extracted lipids were transferred into a Teflon-lined screw-top test tube by means of a disposable glass Pasteur pipette. Fatty acid methyl esters (FAME) were prepared for gas chromatography by methylation of the extracted fat, using methanol- $\text{BF}_3$  (Christie et al., 2001). Fatty acid methyl esters were quantified using a Varian GX 3400 flame ionization GC, with a fused silica capillary column, Chrompack CPSIL 88 (100 m length,

**Table 1.** Chemical composition of dried leaves of Moringa (*M. oleifera* Lam.)

Nutritive value	Dry leaf	Standard error
Moisture (%)	9.533	0.194
Crude protein (%)	30.29	1.480
Fat (%)	6.50	1.042
Ash (%)	7.64	0.433
Neutral detergent fibre (%)	11.40	0.425
Acid detergent fibre (%)	8.49	0.348
Acid detergent lignin (%)	1.8	2.204
Acid detergent cellulose (%)	4.01	0.101
Condensed tannins (mg/g)	3.12	0.104
Total polyphenols (%)	2.02	0.390

0.25 mm ID, 0.2 µm film thickness). Analysis was performed using an initial isothermic period (40°C for 2 min). Thereafter, the temperature was increased at a rate of 4°C/min to 230°C. Finally, an isothermic period of 230°C for 10 min followed. Fatty acid methyl esters in *n*-hexane (1 µl) were injected into the column using a Varian 8200 CX Autosampler with a split ratio of 100:1. The injection port and detector were both maintained at 250°C. Hydrogen, at 45 psi, functioned as the carrier gas, while nitrogen was employed as the makeup gas. Varian Star Chromatography Software recorded the chromatograms. Fatty acid methyl ester samples were identified by comparing the retention times of FAME peaks from samples with those of standards obtained from Supelco (Supelco 37 Component Fame Mix 47885-U, Sigma-Aldrich Aston Manor, South Africa). The following fatty acid combinations and ratios were calculated: total saturated fatty acids (SFA), total mono-unsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), PUFA/SFA ratio (P/S) and *n*-6/*n*-3 ratio. All other reagents and solvents were of the analytical grade and obtained from Merck Chemicals (Pty) Ltd Halfway House. South Africa.

#### Amino acid determination

The samples were hydrolyzed with 6 M HCl at 100°C for 24 h under vacuum and amino acids were analyzed using an amino acid analyser (Bassler and Buchholz, 1993).

#### Beta-carotene and vitamin E determination

Beta-carotene was measured according to AOAC methods 974.29, 992.04 and 992.06 and the method of Thompson and Duval (1989). Vitamin E was measured according to the methods of McMurray et al. (1980), Cort et al. (1983) and Speek et al. (1985) on dried leaves.

#### Statistical analyses

Each nutrient analysis was done in triplicate. Data obtained was processed using SAS proc means (2003) which computed the means and standard errors.

## RESULTS AND DISCUSSION

The dried leaves of Moringa had a CP content of 30.3% (Table 1) with 19 amino acids (Table 2). The highest value of the amino acids was alanine, which had a value of 3.033% and the least content was cysteine with 0.01%. Calcium had the highest value of 3.65% followed by potassium (1.5%) and phosphorus had the least value of 0.30% among the macro-elements (Table 3). The highest value among the micro-minerals was Fe with 490 mg/kg followed by Se with 3.63 mg/kg. Copper had the least value of 8.25 mg/kg (Table 3). The dried Moringa leaves were found to contain 17 fatty acids and  $\alpha$ -linolenic acid (44.57%) had the highest value followed by heneicosanoic (14.41%),  $g$ -linolenic (0.20%) palmitic (0.17%) and capric acid (0.07%) (Table 4). Vitamin E had the highest level with 77 mg/100 g, while Beta-carotene had 18.5 mg/100 g. The fiber content been NDF, ADF, ADL and ADC of the leaves were 11.4, 8.49, 1.8 and 4.01%, respectively. The condensed tannins had a value of 3.2%, while total polyphenols were 2.02% (Table 1).

The study showed that Moringa leaves contain nutritious compounds. Noteworthy is the crude protein content of 30.3% observed in this study, although lower than sunflower seed cake's CP of 35.88% which is mostly used as protein concentrate (Mapiye et al., 2010). This makes the Moringa leaves to be a good potential source of supplementary protein in animal diets. Other studies have reported variable protein contents ranging between 16, 22.42, 23.27, 27.4 and 40% (Gidamis et al., 2003; Sarwatt et al., 2004; Nouala et al., 2006; Reyes-Sanchez et al., 2006; Oduro et al., 2008; Sanchez-Machado et al., 2009). This level of crude protein content is of particular nutritional significance as it may meet animal's protein and energy requirements and boost the immune system

**Table 2.** Amino acids composition of dried Moringa (*M. oleifera* Lam.)leaves

Amino acid	Quantity (mean+/- %)	Standard error
Arginine	1.78	0.010
Serine	1.087	0.035
Aspartic acid	1.43	0.045
Glutamic acid	2.53	0.062
Glycine	1.533	0.060
Threonine*	1.357	0.124
Alanine	3.033	0.006
Tyrosine*	2.650	0.015
Proline	1.203	0.006
HO-Proline	0.093	0.006
Methionine*	0.297	0.006
Valine*	1.413	0.021
Phenylalanine*	1.64	0.006
Isoleucine*	1.177	0.006
Leucine*	1.96	0.010
Histidine*	0.716	0.006
Lysine*	1.637	0.006
Cysteine	0.01	0.000
Tryptophan*	0.486	0.001

\*General essential amino acids.

against diseases (Kyriazakis and Houdijk, 2006; Brisibe et al., 2009). General growing ruminants like goats require 16% CP (Luginbuhl and Poore, 1998). The CP supplied by Moringa is above the protein of goats making it ideal for use as a protein supplement.

Moringa is reported to have high quality protein which is easily digested and that is influenced by the quality of its amino acids (Foidl et al., 2001). In this study, the dried Moringa leaves contained 19 amino acids, which slightly differ from the findings of Foidl et al. (2001) and Sanchez-Machado et al. (2009) who reported 18 and 16 amino acids respectively. Only glutamine was not detected from the common 20 amino acids, however, glutamine can be derived from glutamic acid (Misner, 2008). Out of the 19 amino acids observed, 10 were classified as essential amino acids namely threonine, tyrosine, methionine, valine, phenylalanine, isoleucine, leucine, histidine, lysine and tryptophan. Alanine had the highest value of 3.03%, which differed with Sanchez-Machado et al. (2009) who reported the value of 1.25%. In their work, Sanchez-Machado et al. (2009) reported leucine having the highest value of 1.75%, which is lower than that of our findings (1.96%). Findings from this study showed the presence of HO-proline, cystine and tryptophan which was detected in Sanchez-Machado et al. (2009) work. Cystine and HO-proline had the least values followed by methionine, which is commonly deficient in green leaves. Methionine and cystine are powerful antioxidants that

help in the detoxification of harmful compounds and protect the body from radiation (Brisibe et al., 2009). HO-proline is a major component of the protein collagen; it plays a key role in collagen stability. The variations in the amino acid composition could be influenced by protein quality and the origin of the plant (cultivated or wild). This may indicate that the Moringa was grown in fertile soils. Usually cultivated plants are fertilized, which could influence the quality of proteins (Sanchez-Machado et al., 2009).

Amino acids are organic compounds that combine to form proteins; as such, they influence the quantity and quality of protein. Amino acids are classified as essential and non-essential, which vary according to animal species and their production system (Swanepoel et al., 2010). Rumen microbes synthesize the essential amino acids from other amino acids or from nitrogen containing substances. The efficiency of rumen microbial growth and activity in the rumen is enhanced by the presence of adequate amino acids, peptides and most macro and micro minerals (Swanepoel et al., 2010). Each amino acid has a specific function in the animal's body. In general, amino acids are required for the production of enzymes, immunoglobins, hormones, growth, repair of body tissues and form the structure of red blood cell (Brisibe et al., 2009). In addition, they contribute to the formation of glucose, acting as a buffer when other precursors are in short supply (Swanepoel et al., 2010).

**Table 3.** Mineral contents of dried Moringa (*M. oleifera* Lam.) leaves.

Mineral	Dry leaf	Standard error
Macro-elements (%)		
Calcium %	3.65	0.036
Phosphorus %	0.30	0.004
Magnesium %	0.50	0.005
Potassium %	1.50	0.019
Sodium %	0.164	0.017
Sulphur %	0.63	0.146
Micro-elements (mg/kg)		
Zinc (mg/kg)	31.03	3.410
Copper (mg/kg)	8.25	0.143
Manganese (mg/kg)	86.8	3.940
Iron (mg/kg)	490	49.645
Selenium (mg/kg)	363.00	0.413
Boron (mg/kg)	49.93	2.302

Amino acids also affect the function of other nutrients in the animal's body such as presence of lysine, which ensures adequate calcium absorption and aids in the antibody production.

The dry leaves could serve as a protein supplementary source in animal and human diets. This protein content is of particular nutritional significance since it has been suggested that amino acids supplementation is important in meeting a substantial proportion of an animal's protein and energy requirements (Brisibe et al., 2009). Diets rich in amino acids help to boost the immune system against gastro intestinal parasites infestations (Kyriazakis and Houdijk, 2006). Proteins are also essential for continuous replenishment of the endogenous protein that is lost due to infections with gastro-intestinal helminthes (Coop and Holmes, 1996).

This study identified 17 fatty acids in the dried leaves of Moringa, of which 11 were classified as the saturated fatty acids; however, they had lower values. Henicosanoic had the highest value of 14.41% followed by palmitic (11.79%) and capric, which had the least value of 0.07%. Three polyunsaturated fatty acids were detected namely  $\alpha$ -linolenic, linoleic and  $\gamma$ -linolenic with  $\alpha$ -linolenic having the highest value of 44.57%. Sanchez-Machado et al. (2009) reported  $\alpha$ -linolenic having a higher value of 56.87%. Of interest was  $\alpha$ -linolenic, which is an  $n$ -3 fatty acid that belongs to the group of the essential fatty acids. Our findings differ 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. Sanchez-Machado et al. (2009), however, reported that caprylic acid (0.96%), palmitic acid (3.66%) and arachidonic acid (0.12%) had

the lowest in value, whereas we found that capric, palmitic and  $\gamma$ -linolenic had the lowest values. Of these three fatty acids, only lauric was found in our analysis. As observed in this study, Moringa contains more dietary polyunsaturated fatty acids than the saturated fatty acids. A higher content of PUFA and lower amount of SFA is desirable (Hoffman and Wiklund, 2006), as such, its inclusion in the diet is recommended as it prevents the occurrence of diseases thereby promoting good health. Wood et al. (2008) recommended more consumption of  $\alpha$ -linolenic acid, which promote the endogenous synthesis of long chain  $n$ -3 fatty acids.

Polyunsaturated fatty acids are important for human and animal health. They are of interest because they are precursors of long chain  $n$ -3 PUFA in the eicosanoids biosynthesis, which are viewed as important bioregulators of many cellular processes (Khotimchenko, 2005). They are linked to the development and functionality of the immune system. Consumers have preference of food low in saturated fatty acids (SFA) because they are associated with an increased risk of cardio-vascular diseases and some cancers (Griffin, 2008; Alfaia et al., 2009). Human nutritionists urge consumers to increase intake of polyunsaturated fatty acids (PUFA), particularly the  $n$ -3 PUFA at the expense of  $n$ -6 PUFA (Hoffman and Wiklund, 2006; Alfaia et al., 2009). The quantity and composition of fatty acids in the animals' body are related to the presence of some of their precursors in the diet, since some of the fatty acids are absorbed in the body unchanged (Wood et al., 2003).

The observed low concentration of acid detergent fibres and neutral detergent fibres in the study compared with most forage plants is of interest because, fibre fraction

**Table 4.** Fatty acids composition of dried Moringa (*M. oleifera* Lam.) leaves.

Fatty acid	Quantity (mean+/- %)	Standard error
Ether extract	6.50	0.041
Capric (C10:0)	0.07	0.064
Lauric (C12:0)	0.58	0.402
Myritic (C14:0)	3.66	1.633
Palmitic (C16:0)	11.79	0.625
Palmitoleic (C16:1c9)	0.17	0.056
Margaric (C17:0)	3.19	0.155
Stearic acid (C18:0)	2.13	0.406
Oleic (C18:1c9)	3.96	2.000
Vaccenic (C18:1c7)	0.36	0.038
Linoleic (C18;2c9,12(n-6)	7.44	0.014
$\alpha$ -Linolenic (C18:3c9,12,15(n-3)	44.57	2.803
g-Linolenic (C18:3c6,9,12 (n-6)	0.20	0.013
Arachidic (C20:0)	1.61	0.105
Heneicosanoic (C21:0)	14.41	0.194
Behenic (C22:0)	1.24	0.383
Tricosanoic (C23:0)	0.66	0.025
Lignoceric (24:0)	2.91	0.000
Total saturated fatty acids (SFA)	43.31	0.815
Total mono unsaturated fatty acids (MUFA)	4.48	1.984
Total poly unsaturated fatty acids (PUFA)	52.21	2.792
Total Omega-6 fatty acids (n-6)	7.64	0.012
Total Omega-3 fatty acids (n-3)	44.57	2.805
PUFA: SFA (PUFA:SFA)	1.21	0.096
n-6/n-3	0.17	0.016
PUFA: MUFA (PUFA:MUFA)	14.80	7.168

defines the extent and rate of feed digestibility (Rubanza et al., 2005). The values of NDF and ADF of 11.4 and 8.49% differed from that of the findings of Foidl et al. (2001) that showed NDF and ADF values of 21.9 and 11.4%, respectively, suggesting that the leaves used in this study were of high digestibility. These variations of NDF and ADF values may be due to differences in agro-climatic conditions, age of the trees and possibly due to different stages of maturity of leaves. The observed concentrations of acid detergent lignin (ADL) in this study were however, consistent with values reported by Foidl et al. (2001).

Another interesting aspect of the results reported here is the low percentages of anti-nutritional factors in the leaves, which though present were negligible. The value of condensed tannins was 3.12%, while Foidl et al. (2001) reported 1.4% of tannins and did not detect the condensed tannins. Drying is reported to reduce or remove extractable condensed tannins by 15 to 30% relative to fresh foliage (Vitti et al., 2005). The decrease

of condensed tannins after drying may be due to decomplexation between tannins and proteins and depolymerisation and oxidation of tannins (Makkar, 2003). The content of total phenols (2.02%) in this study was lower than previously reported values of 2.7 and 4.3% (Gupta et al., 1989; Foidl et al., 2001). At these concentrations, simple phenols do not produce any adverse effects when consumed by animals (Foidl et al., 2001). However, these phenols have been reported to have multiple beneficial biological effects that include antioxidant activity, anti-inflammatory action, inhibition of platelet aggregation, antimicrobial activities and antitumor activities (Thurber and Fahey, 2009)

It is also of remarkable interest that the dried Moringa leaves have high deposit of mineral elements. Calcium was observed to be higher compared with other plant sources (Nkafamiya et al., 2010). It is required for formation and maintenance of bones and teeth thus, preventing osteoporosis. It is also needed for normal blood clotting and nervous function. Interestingly, even

Fe, which is commonly deficient in many plant-based diets, was found in abundance in this plant's leaves. Iron is a necessary component of haemoglobin and myoglobin for oxygen transport and cellular processes of growth and division (Kozat, 2007). Iron is also an essential trace element for normal functioning of the central nervous system and in the oxidation of carbohydrates, proteins and fats (Umar et al., 2007). Iron also has a role in energy metabolism as it facilitates transfer of electrons in the electron transport chain for the formation of ATP (Kozat, 2007).

The presence of Zn in high amounts is of special interest in view of the importance of the inclusion of Zn in the diet of animals and humans. Results from this study had higher levels of zinc (31.03 mg/kg) than the findings of Barminas et al. (1998) who reported 25.5 mg/kg in dried Moringa leaves. Zinc is essential for the synthesis of DNA, RNA, insulin and function and/or structure of several enzymes (Brisibe et al., 2009). Zinc is also required for cell reproduction and growth especially sperm cells. In addition, Zn is known for its anti-viral, anti-bacterial, anti-fungal and anti-cancer properties (Brisibe et al., 2009).

The Moringa dried leaves contained Cu, which is considered to have strong effects on the immune system (Anwar et al., 2007). Copper is involved in stimulating body defence system, as it is active in neutrophil production and affects phagocyte killing ability. It is required for antibody development and lymphocyte replication (Burke and Miller, 2006). Copper in combination with Zn, plays a role in superoxide dismutase activity and the removal of oxygen free radicals. It is therefore, a key component in the protective mechanism of cellular membranes against superoxide free radicals damage (Guo et al., 2010). In addition, the copper containing enzyme, ceruloplasmin has been shown to exhibit anti-inflammatory activity, which may prove beneficial in mastitis cases (Guo et al., 2010). Copper has been found to reduce internal parasite namely *Haemonchus contortus* load in sheep and goat (Burke and Miller, 2006). Moringa has sulphur that is necessary for efficiency of rumen microbial growth and activity (Brisibe et al., 2009). Moringa mineral composition plays a significant role in nutritional, medicinal and therapeutic values (Al-kharusi et al., 2009).

The results showed that the dried powdered Moringa leaves have high levels of vitamin E and  $\beta$ -carotene. Moringa powder has been reported to be rich in beta-carotene, thiamine, riboflavin, niacin, pyridoxine, biotin, ascorbic acid, cholecalciferol, tocopherol and vitamin K (Broin, 2006). As such in our study, we investigated the presence of beta-carotene and vitamin E in the dried leaves. The reason been that under normal conditions, healthy ruminants synthesize adequate amounts of B vitamins as well as vitamin C and K (Rinehart, 2008).

Beta-carotene is the most potent precursor to vitamin A. The animals are able to convert beta-carotene into vitamin A within their body (Panday and Tiwari, 2002). Moringa is reported to be rich in vitamin C which increases iron absorption in the animal's body (Anwar et al., 2007). Vitamin A is necessary for many functions in the ruminants including vision, bone growth, immunity and maintenance of epithelial tissue. In addition, vitamin A also maintains adequate levels of iron in plasma that supply the different body tissues including the bone marrow (Thurber and Fahey, 2009). Supplementation of diets with both iron and vitamin A may increase the iron status as measured by haematological indices like haemoglobin and haemocrit (Babu, 2000).

Beta-carotene rich Moringa leaves can thus be an important source of vitamin A, can be used for releasing the bound iron status and thus, help in reducing anaemia as well as prevalence of vitamin A deficiency. Vitamin A and E are some of the specific nutrients that assist animals to develop disease resistance. Our findings are in agreement with that of Fuglie (2001), where the amount of vitamin was 113 mg/100 g of the dried leaves. Vitamin E is known to help maintain and increase the storage of vitamin A and iron in the body. Moringa powder is, however, rich in vitamin such that it is one of the richest plant sources of vitamin (Anwar et al., 2007).

Vitamin E with selenium contains antioxidant that work co-dependently in the body to help destroy free radicals (Rock et al., 2001). The interaction of selenium and immune function focuses around the selenoprotein, glutathione peroxidase. Glutathione peroxidase inactivates oxygen radicals such as hydrogen peroxide and prevents them causing cellular damage. Also, supplementing dairy cattle with adequate levels of selenium (0.3 ppm of dry mater) reduce the prevalence, severity and duration of mastitis (Rock et al., 2001). Looking at all the properties of the plant leaves, this probably explains the traditional use of the plant as an herbal tonic in India, because of its high levels of readily available essential nutrients and mineral resources, which may be required for the maintenance of electrical potential of nervous tissues and cell membranes. It can as well be used for the treatment of blood related disorders that is necessary for the improvement of the overall well-being of the body (Khalafalla et al., 2010).

The nutritional variations observed among the studies could be attributed to the genetic background of the plant, in terms of ecotype and cultivar, environmental factors that include the soil and climate (Sanchez-Machado et al., 2009). In addition, the cultivation method used encompasses the frequency of harvesting and age of the plant or leaves. Mode of conservation between collection and analysis (drying, refrigeration, freezing) might influence the leaves' nutritional composition (Barminas et al., 1998; Broin, 2006).

In conclusion, the data derived from nutrient characterization of Moringa are clear indications that the plant leaves are rich in nutrients and has potential to be used as a feed additive with multiple purposes. These include serving as a protein, fatty acid, mineral and vitamin resource for animal and human feed formulations. High nutritional content found in the dried leaves are important nutritional indicators of the usefulness of the plant as a likely feed resource. Drying the leaves assists to concentrate the nutrients, facilitate conservation and consumption, as such, it can be used during the time when feed is scarce or can be transported to areas where it is not cultivated. It is suggested that Moringa should be consumed in the powder form. Moringa has been reported to possess some medicinal properties (Fahey, 2005); its inclusion in the diets could function as curative and therapeutic therapy. As such, it can be used to improve health and nutrition in sub-Saharan countries.

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