Advances in Life Science and Technology
ISSN 2224-7181 (Paper) ISSN 2225-062X (Online)
Vol.24, 2014
www.iiste.org

Proximate Analysis and Chemical Composition of Raw and Defatted Moringa oleifera Kernel

Peter Taiwo Olagbemide [1]* Philip, C. N. Alikwe[2]
1.Biological Sciences Department, Afe Babbalola University, Ado-Ekiti, Nigeria
2.Animal Science Department, Niger Delta University, Wilberforce Island, PMB 071 Yenagoa, Bayelsa State
*Corresponding Author: Email: Petseko2004@Yahoo.Co.Uk

Abstracts
The proximate, mineral analyses and anti-nutrient compositions of *Moringa oleifera* (Drumstick) which are commonly used as nutritional and medicinal plant in Nigeria were carried out on both raw and defatted seeds. The nutrient and the anti-nutrients determination were done using various standards. Mean and standard error of means of the triplicate determinations were calculated. The result showed that defatting *Moringa oleifera* seeds increased the fibre, carbohydrate, vitamins B and C, iron and zinc content and significantly reduced the calcium, potassium and phosphate contents. The result also showed that defatting *Moringa oleifera* significantly decreased the tannin, alkaloids, saponin, phytate, oxalate levels but increased the cyanogenic glycosides level to a level lower than what is considered toxic to human beings and livestock. Hence, the defatted cake could be used in fortification of other food materials.
Keywords: defatted, anti-nutrients, *Moringa oleifera*, kernels.

1.0 Introduction

Moringa oleifera belongs to the genus Moringaceae. A single genus with 14 known species, M. oleifera is the most widely known and utilized of these (Morton, 1991). *Moringa oleifera* is a fast growing, aesthetically pleasing tree. The specie is characterized by its long, drumstick shaped pods that contain its seeds within the first year of growth. *Moringa* has been shown to grow up to 4 meters and can bear fruit within the same first year (Oleveria *et al.,* 1999). In different parts of the world, *M. oleifera* is known by divers name: among the Igbos, it is known as “Okwe Oyibo”, among the Hausas, it is called “Zogale”, among the Yorubas, it is called “Ewe ile”, among the Fulani, it is called “gawara”, “sonjna” in Marathi, “Nuggekai” in Canada, “Murungai” in Tamil, “Mashinga Sanga” in Malayalan, “Muringa” in Konkani. In English language *M. olefera* is also called Miracle tree, Mother’s best friend, Never die and Benzolive tree (Ramachandran *et al.,* 1980).

It is commonly known as the horse-radish or drumstick tree and is a native of the sub-Himalayan region of northwest India. The tree ranges in height from 5–12 m and the fruits (pods) are around 50 cm long. *Moringa oleifera* is esteemed as a versatile plant due to its multiple uses. The leaves, fruits, flowers and immature pods of this tree are edible and they form part of traditional diets in many countries of the tropics and sub-tropics (Siddhuraju & Becker, 2003; Anhwange *et al.*, 2004). The leaves of *M. oleifera* are a good source of protein, vitamin A, B and C and minerals such as calcium and iron (Dahot, 1988). Almost every part of the tree is of value for food. In Malaysia, the young tender pods are cut into small pieces and added to curries. Almost all parts of the tree have been utilized within traditional medicine practices and the oil is applied externally for skin diseases (Foidl *et al*., 2001). The flowers, leaves and roots are used for the treatment of ascites, rheumatism and venomous bites and as cardiac and circulatory stimulants in folk remedies. The roots of the young tree and also root bark are rubefacient and vesicant (Hartwell, 1995; Anwar & Bhanger, 2003). The seeds are sometimes removed from more mature pods and eaten like peas or roasted like nuts. Different parts of this plant contain a profile of important minerals, and are a good source of protein, vitamins, beta-carotene, amino acids and various phenolics (Anwar et al., 2007). The seed cake remaining after oil extraction may be used as a fertilizer (Rashid et al., 2008).

Moringa Oleifera seeds are large and circular-shaped, and grow inside the lengthy pods of the *Moringa Oleifera* tree. *Moringa* seed pods can reach well over a foot in length and each pod can provide over a dozen large *Moringa* seeds. *Moringa* seeds are dark brown in colour, with 3 papery wings extending from the main kernel of the seeds. These flaps serve as wings to carry the seed away from the mother tree, and with the help of the wind, they move across the ground until they find a resting place to germinate. Unlike the fast-growing leaves of the *Moringa Oleifera* tree, *Moringa* seed pods do not grow back every few months. *Moringa* trees produce seed pods on an annual basis, much like other similar species in the plant kingdom. *Moringa* trees give off incredible volume of seed pods during their reproduction months. An average-sized *Moringa* tree of fifteen to twenty feet in height can produce hundreds or even thousands of seed pods, yielding countless *Moringa* seeds each and every year. *Moringa* seeds have long been used by the public as a tasty vegetable and water purifier because of its coagulant properties (Ayotunde et al. 2011).The cake remaining after oil extraction has been shown to retain the active ingredients for coagulation of various undesirable moieties from a solution, making it a marketable commodity (Folkard and Sutherland, 1996). *Moringa* press cake is used for water purification instead of common chemical coagulants such as aluminium sulphate. Proteins in the cake have a high positive charge (Folkard et al., 2001) and an antibiotic effect (Makkar et al., 2007) and have the potential to modify rumen fermentation (Ben Salem and Makkar, 2009). These proteins have also been shown to decrease degradability of feed proteins in an *in vitro* rumen system (Hoffmann et al., 2003; Makkar et al., 2007). In addition, it has been reported that *Moringa oleifera* seed processed with the right procedure can increase the soil aeration and richness of indigenous invertebrates, specialized endangered soil species, beneficial arthropods, earthworms, symbionts and microbes (FAO, 2010).

This study was conducted to evaluate the proximate composition, anti-nutrient factors, mineral and vitamin contents of raw *Moringa oleifera* seeds and defatted *Moringa oleifera* seeds. The seeds are defatted to create room for comparison and also to know if defatting can actually improve or inhibit the nutritional properties of the seeds.

MORINGA OLEIFERA SEEDS

MORINGA OLEIFERA KERNELS

2.0 Materials and Methods

2.1 Sample Collection and Processing

Moringa seeds were collected from a private farm in Ibadan, Oyo State. The seeds were dried under shade and were shelled by hand to obtain the Kernels. The kernels were ground in a coffee mill (National MX-J210PN), until a consistent powder was obtained and the powder was divided into two portions. Portion A was left as untreated *Moringa* seeds while the oil was extracted from portion B. Extraction of oil from the kernel was according to Ben Salem and Makkar, 2009. Proximate analysis, mineral contents, anti-nutritional compositions and vitamin contents were carried out on Portion A and on the extract residues of Portion B. Proximate analysis was carried out by the methods of the Association of Official Analytical Chemists (AOAC, 1990). Oxalate content was determined using the method of Nwinuka *et al.* (2005). Total tannins and condensed tannins were determined by spectrophotometric methods as described by Makkar *et al.* (1993). Total saponin content was determined using the spectrophotometric method described by Hiai *et al*. (1976). Phytate content was determined by a colorimetric procedure described by Vaintraub and Lapteva (1988). Total cyanogenic glucosides were assayed according to the procedure of Essers et al. (1993). The extraction of alkaloids was essentially according to Mulder-Krieger et al. (1982). Vitamin contents were determined using the method of chemical analysis of food described by Ekinci and Kadakal, 2005, Raghu *et al*., 2007.

2.2 Statistical Analysis

All assays were carried out in triplicate, and the means and standard error of means (SEM) were determined using SPSS version 20. Analysis of variance was performed to determine significant differences between the means. Differences in mean performance for each composition between the samples were tested by the Student's t-test. <0.05 implies significance.

3.0 Results

The proximate composition of raw *Moringa oleifera* seeds and defatted *Moringa oleifera* seeds is presented in Table 1. The moisture content for raw sample (9.97± 0.09%) was significantly higher when compared with the defatted (9.40±0.10%). The protein content of raw sample (35.97±0.19%) was significantly higher than that of defatted sample (17.13±0.13%). The crude fat content of the raw sample (38.67±0.03%) was significantly higher than the crude fat content of defatted sample (8.59±0.18%). The crude fibre levels of the raw and defatted samples were 2.87±0.03% and 3.33±0.08% respectively. The fibre in defatted sample was not significantly higher than that of raw sample. The ash contents of the raw and defatted samples were 3.87±0.09% and 3.47±0.07 respectively. The ash in the defatted sample is not significantly different from that of the raw sample. The carbohydrate content in raw sample was 8.67±0.12% and 57.77±0.12% for the defatted sample.

Table 1. Proximate composition (mg/100g) of raw and defatted *Moringa oleifera* seeds

Nutrients	Raw samples	Defatted samples
Moisture contents	9.97±0.09[a]	9.40±0.10[b]
Protein	35.97±0.19[a]	17.13±0.13[b]
Crude fat	38.67±0.03[a]	8.57±0.18[b]
Ash	3.87±0.09[a]	3.47±0.07[a]
Crude fibre	2.87±0.03[a]	3.33±0.09[a]
Carbohydrates (By difference)	8.67±0.12[a]	57.77±0.12[b]

Values are means (±SEM) of triplicate samples. Means with different superscripts in the same row show significant difference ($P < 0.05$).

The data on the mineral composition for raw and defatted samples were shown in Table 2. Defatted *Moringa* samples had higher values in iron, magnesium and zinc while the raw *Moringa* samples had higher values in calcium, potassium and phosphorus.

Table 2. Mineral composition (mg/100 g) of raw and defatted *Moringa oleifera* seeds

Minerals	Raw samples	Defatted samples
Iron	5.20±0.15[a]	8.23±0.09[b]
Zinc	0.05±0.00	0.10±0.00
Magnesium	45.00±0.00[a]	61.67±1.67[b]
Calcium	751.67±4.41[a]	371.67±18.93[b]
Potassium	75.00±0.00[a]	50.00±2.89[b]
Phosphorus	635.00±8.66[a]	273.33±7.26[b]
Ca/P	1.18±0.02[a]	1.36±0.07[a]
Ca/K	10.02±0.06[a]	7.51±0.64[a]
Ca/Mg	16.71±0.10[a]	6.11±0.27[b]

Values are means (±SEM) of triplicate samples; means with different superscripts in the same row show significant difference ($P < 0.05$). Ca (calcium), K (potassium), P (phosphorus), Mg (magnesium).

The anti-nutrient compositions for raw *Moringa oleifera* seed and defatted *Moringa oleifera* seeds were presented in Table 3. The study showed that the anti-nutrients in defatted moringa samples were lower than that of raw *Moringa* samples. The phytate, oxalate and tannin, saponnin and alkaloid contents of the defatted *Moringa* seed flour were higher than that of raw *Moringa* samples. The mean differences in the oxalate, phytate, tannin and alkaloid contents between the raw and defatted samples were significant. Minimal quantity of cyanogenic glycosides was found in the defatted sample while it was not detected in raw *Moringa* seed samples.

Table 3. Anti nutritional factors (mg/100g) of raw and defatted *Moringa oleifera* seeds

Anti-nutrients	Raw samples	Defatted samples
Alkaloids	291.67±33.33[a]	13.33±1.67[b]
Cyanogenic Glycosides	Not detected	0.05±0.00
Phytates	175.00±0.00[a]	113.33±3.33[b]
Tannins	131.67±1.67[a]	30.00±2.89[b]
Saponins	33.33±1.67	10.00±0.00
Oxalates	110.00±2.89[a]	38.33±1.67[b]

Values are means (±SEM) of triplicate samples; means with different superscripts in the same row show significant difference ($P < 0.05$).

The vitamin compositions (mg/100g) of the raw and defatted *Moringa oleifera* were presented in Table 4. Ascorbic acid and Thiamin were significantly higher in the defatted samples than in the raw samples while Niacin was significantly higher in the raw samples than in the defatted samples. However, equal quantity of Riboflavin was detected in both the raw samples and the defatted samples.

Table 4. Vitamin composition (mg/100g) of raw and defatted *Moringa oleifera* seeds

Vitamins	Raw samples	Defatted samples
Ascorbic Acid	4.5±0.17[a]	12.43±0.23[b]
Thiamin	0.05±0.00[a]	0.08±0.01[b]
Niacin	0.20±0.00[a]	0.12±0.01[b]
Riboflavin	0.06±0.00	0.06±0.01

Values are means (±SEM) of triplicate samples. Means with different superscripts in the same row show significant difference ($P < 0.05$).

4.0 Discussion

The observed low moisture content in the defatted *Moringa* samples observed in this study is an indication that the activity of the microorganisms would be reduced and thereby increases the shelf life of the defatted *Moringa* samples. This observation is in agreement with the report of Adeyeye and Adejuyo (1994) and Olitino *et al.* (2007). The defatted *Moringa* samples had higher values in the crude fibre and carbohydrate contents. The higher values were as a result of the displacement of oil from the defatted samples thereby increasing other parameters. The result also explains that defatting of the seeds improves the fibre content of *Moringa oleifera* seeds and the high fibre content may improve bowel function and provide faecal bulk digestion. However, it is not too high to make it useless to non-ruminant animals. The crude fibre necessary for African catfish growth is 3-6% (Robinson, *et al*., 2001).

The undefatted *Moringa* samples had higher fat content of 38.67 %. The value was lower than the value (42%) reported by Ogunsina *et al*., (2011) and higher than the value (30.36-35.20%) reported by Anwar *et al*., (2006) for raw *Moringa* seed flour. This variation in crude fat content, according to Okuda *et al.* (1999), can be attributed to the region where *Moringa* is planted and the growing conditions of the plant, and may diverge in a range from 30 to 42% of lipids. It may also be due to the extraction efficiency. The high crude fat of the raw *Moringa* samples suggests that the kernel is a good source of quality vegetable oil for both domestic and industrial purposes.

The results on the mineral composition of the raw *Moringa* samples and defatted *Moringa* samples in

Table 2 show that defatting *Moringa* seeds do not affect the chemical composition of the seeds in the same way. While it brings increment in minerals like iron, zinc and magnesium, it brings reduction in the contents of minerals like calcium, potassium and phosphorus. Nzikou *et al*. (2009) reported calcium, magnesium and potassium values of 83.75 mg /100 g; 251 mg /100 g and 36.53 mg /100 g respectively for defatted *Moringa* flour. Zn values in raw *Moringa* samples were lower than the values observed by Compaoré et al. (2011) for seeds. These differences were attributed to geographical, soil composition, cultivation climate, ripening stage, the harvesting time of the seeds and the extraction method used Compaoré et al. (2011). Ca/P ratios are indices of bone formation. If the Ca/P is low (low calcium, high phosphorus) more than the normal amount of calcium may be lost in the urine thereby decreasing the calcium level in bones (Adeyeye and Fagbohun, 2005). The high Ca/P ratio observed in this study is of nutritional benefit, particularly for children and the aged who need higher intakes of calcium and phosphorus for bone formation and maintenance. Food is considered 'good' if the ratio is above one and 'poor' if the ratio is less than 0.5 while Ca/P ratio above two helps to increase the absorption of calcium in the small intestine (Niemann *etal*., 1992). The Ca/P ratio of raw *Moringa* samples and that of defatted *Moringa* samples was 1.18 and 1.36 respectively. This indicates that Ca/P ratio of defatted sample was better than that of raw *Moringa* sample. However, both the raw *Moringa* samples and defatted *Moringa* samples had good Ca/P ratio for animal feeds formulation (Niemann *et al*., 1992). According to ARL (2012), Ca/Mg and Ca/K ratios for defatted *Moringa* samples in this study were better than those of raw *Moringa* samples and thus defatted *Moringa* samples serve as better representation of homeostatic balances and predictive of future metabolic dysfunctions than the raw samples.

Makkar (1993) defined anti-nutrients as "substances which by themselves or through their metabolic products arising in living systems interfere with food utilization and affect the health and production of animals". Francis *et al.* (2001) also stated that most of the alternative plant derived nutrients sources are known to contain a wide variety of anti-nutritional substances whose effects can be deleterious when included unprocessed in fish diet. The antinutrients have been shown to have both adverse and beneficial effects in humans (Yoon *et al*. 1983; Sidhu and Oakenful 1986; Thompson *et al.* 1988; Jariwalla *et al*. 1990; Oakenfull and Sidhu 1990; Elemo *et al*. 2001; Dingynan *et al*. 2003; Soladoye and Chukwuma 2012). Saponin has been shown to have both beneficial and deleterious properties and to exhibit structure dependent biological activities (Price *et al*., 1987). Phytates are known to pose threat to leguminous seeds and also associated with increased cooking time in legumes (Nwokolo and Bragg, 1977; Osagie, 1998). The study showed that the anti-nutrients in defatted samples were lower, except in cyanogenic glycosides, than that of raw *Moringa* sample. This observation shows that defatting significantly reduced the anti-nutrients components of *Moringa* seeds than in the raw *Moringa* seeds. Tannin contents of the samples were lower than those reported by Fasoyiro *et al*. (2006) for groundnut seeds (450.00 mg/100 g); Ayodele and Kigbu, (2005) for Cajanus cajan (550.00mg/100g) and Elemo *et al*., (2001) for sorghum grains (280.00 mg/100g). The cyanogenic glucoside levels observed in the present study for both defatted and raw samples were much lower than those considered safe by EC regulations, <100 mg HCN equivalent kg^{-1} for cassava and almond cakes and <250 mg HCN equivalent kg-1 for linseed meal. In addition, European Commision (EC) regulations for livestock, the cyanogen levels in a complete feed should not exceed 50 mg HCN equivalent kg^{-1}, except for chickens whose safe level is fixed at 10 mg HCN equivalent kg^{-1}. For human consumption, a safety limit of 10 mg HCN equivalent kg^{-1} flour has been fixed by FAO/WHO (1991). In the variety of *Moringa oleifera* with bitter kernels, the bitter taste is generally attributed to alkaloids, saponins, cyanogenic glucosides, glucosinolates (Makkar and Becker, 1977) which were reduced by defatting in this study, suggesting that the bitter taste would not limit the use of *Moringa oleifera* seeds in animal diets.

The higher values of Ascobic acid, Thiamin of the defatted samples when compared with the raw samples revealed that defatting *Moringa oleifera* seeds increases vitamin content of *Moringa oleifera* seeds. It also explains that defatted *Moringa* seeds serve as the better source of this nutrient than the raw sample.

5.0 Conclusion

Moringa oleifera seed is a good source of edible oil, protein and essential minerals. Its nutritional potentials enable it to be useful in formulations and fortifications of animal feeds. However, the defatted seed is better because of the low anti-nutritional factors.

6.0 Acknowledgements

The authors wish to thank Mr. M. I. Adarabioyo for helping with the statistical analyses; Dr. T.I. Ojiezeh and Dr. P. A. Okiki for assistance they rendered to make this paper a reality.

References

A. O. A. C. (1990). *Official Methods of analysis*. 15th edition. Association of Official Analytical Chemist, Washington D. C.

Adeyeye, E. I. and Ayejuyo, O. O. (1994). Chemical composition of *Cola accuminata* and *Garcina kola* seeds grown in Nigeria. *Int. J. Food Sci. Nutr*., 45: 223-230.

Adeyeye, E. I. and Fagbohun, E. D. (2005). Proximate, mineral and phytate profiles of some selected spices found in Nigeria. *Pak J Sci Ind Res*. 48(1):14-22.

Anhwange, B. A., Ajibola, V. O. and Oniye, S. J. (2004). Chemical studies of the seeds of *Moringa oleifera (Lam)* and *Detarium microcarpum (Guill and Sperr)*. *J. Biol. Sci*., 4: 711-715.

Anwar, F., Bhanger, M. I. (2003). Analytical characterization of *Moringa oleifera* seed oil grown in temperate regions of Pakistan. *J. Agric. Food Chem*. 51, 6558–6563.

Anwar, F., Latif, S., Ashraf, M. and Gilani, A. H. (2007). Moringa oleifera: a food plant with multiple medicinal uses. *Phytother Res*. 21(1):17-25.

Anwar, F., Zafar, S. N. and Rashid, U. (2006). Characterization of Moringa oleifera seed oil from drought and irrigated regions of Punjab. *Grasasy Aceites*, 57(2): 160-168.

ARL (2012). Mineral Ratios. Analytical Research Labs Inc. 2225 West Alice Avenue Phoenix, AZ 85021, USA.

Ayodele, J. T. and Kigbu, P. E. (2005). Some antinutritional factors in *Cajanus cajan, Sterculia setigera* and *Vigna dekindtiana*. Biol. Environ. Sci. J. Tropics 2:43–45.

Ayotunde, E. O., Fagbenro, O. A. and Adebanyo, O. T. (2011). Toxicity of aqueous extract of *Moringa oleifera* seed powder to Nile tilapia (Oreochromis niloticus) fingerlings. *Int. Res. J. Agric. Sci.* 1:142–150.

Ben Salem, H. and Makkar, H. P. S. (2009. Defatted *Moringa oleifera* seed meal as a feed additive for sheep. *Anim. Feed Sci. Tech.* 150:27–33.

Compaoré, W. R., Nikièma,P. A., Bassolé, H. I. N., Savadogo, A., Mouecoucou, J., Hounhouigan, D. J. and Traoré, S. A. (2011). Chemical Composition and Antioxidative Properties of Seeds of Moringa oleifera and Pulps of Parkia biglobosa and Adansonia digitata Commonly used in Food Fortification in Burkina Faso. Current Research. *Journal of Biological Sciences* 3(1): 64-72.

Dahot, M.U. (1988). Vitamin contents of flowers and seeds of *Moringa oleifera. Pak. J. Biochem.,* 21: 21-24.

Dingynan, F., Yingran, S. and Chavez, E. R. (2003). Effectiveness of different processing methods in reducing hydrogen cyanide content of flaxseed. *J. Sci. Food Agric*. 8:836–841.

Ekinci, R. and Kadakal, Ç. (2005). Determination of seven water-soluble vitamins in Tarhana, A traditional Turkish cereal food, by High-Performance Liquid Chromatography. *Acta Chromatographica,* No. 15: 289-297.

Elemo, B. O., Elemo, G. N., Agboola,O. O. and Oyedun, A. B. (2001). Studies on some anti-nutritive factors and in-vitro protein digestibility of Thaumatococcus danielli (Benth) wastes. *Niger. J. Biochem. Mol*. Biol. 16:43–46.

Essers, S. A. J. A., Bosveld, M., Van der Grift, R. M. and Voragen, A. G. J. (1993). Studies on the quantification of specific cyanogens in cassava products and introduction of a new chromogem. *Journal of the Science of Food and Agriculture* 63, 287-296.

FAO (2010). Soil Biota and Biodiversity: "The "Root" of Sustainable Development"; ftp://ftp.fao.org/docrep/fao/ 010/i0112e/i0112e07.pdf.

FAO/WHO (1991). *Joint FAO/WHO Food Standard Programme*, *Codex Alimentariius Commission*, *XII*, *Supplement 4*. Rome: FAO/WHO.

Fasoyiro, S. B., Ajibade, S. R., Omole, A. J., Adeniyan, O. N. and Farinde, E. O. (2006). Proximate, minerals and antinutritional factors of some underutilized grain legumes in south-western Nigeria. *Nutr. Food Sci*. 36:18–23.

Foidl, N., Makkar, H. P. S., & Becker, K. (2001). *The potential of Moringa oleifera for agricultural and industrial Uses.* In J. Lowell & C. T. A. Fuglie (Eds.), The miracle tree: The multiple uses of (pp. 45–76). Wageningen: The Netherlands.

Folkard, G., Sutherland, J. and Al-Khalili, R. S. (2001). Water clarification using *Moringa oleifera* seed coagulant. In: *Lowell Fuglie, J. (*Ed.). The Miracle Tree: The Multiple Attributes of Moringa. CTA Publication,Wageningen, The Netherlands, pp. 77–81.

Folkard, G. K. and Sutherland, J.P. (1996). *Moringa oleifera*—a tree and a litany of potential. *Agroforestry Today* 8 (3), 5–8.

Francis, G. Makkar, H. P. S. and Becker, K. (2001). Anti-nutritional Factors present in plant – derived alternative fish feed ingredients and their effects in fish. *Aquaculture* 99: 197 – 227.

Hartwell, J. L. (1995). Plants used against Cancer. A Survey. *Lloydia*, 30-34.

Hiai, S., Oura, H. and Nakajima, T. (1976). Color reaction of some saposenins and saponins with vanillin and sulfuric acid. *Planta Medica* 29, 116-122.

Hoffmann, E. M., Muetzel, S., and Becker, K. (2003). Effects of *Moringa oleifera* seed extract on rumen fermentation in vitro. *Archives of Animal Nutrition* 57: 65 – 81.

Jariwalla, R. J., Sabin, R., Lawson, S. and Herman, Z. S. (1990). Lowering of serum cholesterol and triglycerides and modulation by dietary phytates. *J. Appl. Nutr*. 42:18–28.

Makkar, H. P. S. (1993). Antinutritional factors in foods for livestock. In *Animal Production in Developing*

Countries, *Occasional Publication No. 16*, *British Society of Animal Production* (Eds M. Gill, E. Owen, G. E. Pollott & T. L. J. Lawrence), pp. 69-85. Edinburgh: British Society of Animal Production.

Makkar, H. P. S. and Becker, K. (1977). Nutrients and antiquality factors in different morphological parts of the *Moringa oleifera* tree. *Journal of Agricultural Science*, 128, 311-322.

Makkar, H. P. S., Blümmel, M., Borowy, N. K. and Becker, K. (1993). Gravimetric determination of tannins and their correlations with chemical and protein precipitation methods. *Journal of the Science of Food and Agriculture* 61, 161-165.

Makkar, H. P. S., Francis, G. and Becker, K. (2007). Bioactivity of phytochemicals in some lesser-known plants and their effects and potential application in livestock and aquaculture production systems. *Animal* 1, 1371–1391.

Morton, J. F. (1991). The Horse radish tree, *Moringa pterygosperma*. A boon to arid lands? *Economic Botany*, 45, 318–333.

Mulder-Krieger, Th., Verpoorte, R., Water, A., Gessel, M., Oeveren, B. C. J. A. and Svendsen, A. B. (1982). Identification of the alkaloids and anthraquinones in *Cinchona ledgeriana* callus cultures. *Planta Medica* 46, 19-24.

Nieman, D. C., Butterworth, D. E. and Nieman, C. N. (1992). Pp. 237–312 *in Nutrition*. WmC. Brown, Dubuque, IA.

Nwinnuka, N. M., Ibeh, G. O. and Ekeke, G. I. (2005). Proximate composition and levels of some toxicants in four commonly consumed spices. *Journal of Applied Sciences and Environmental Management,* 9 (1):150-155.

Nwokolo, E. N., Bragg, B. B. (1977). Influence of phytic acid and crude fiber on the availability of minerals from protein supplements in growing chicks. *J Anim Sci*. 57:475-477.

Nzikou, J. M., Atos, L. M., Moussounga, J. E., Ndangui, C. B., Kimbonguila, A., Silou, T. H., Linder, M. and Desobry, S. (2009). Characterization of Moringa oleifera seed oil variety Congo Brazzaville. *J. Food Technol*., 7(3): 59-65.

Oakenfull, D. and Sidhu, G. S. (1990). Could saponins be a useful treatment for hypercholesterolaemia? *Eur. J. Clin. Nutr*. 44:79–88.

Ogunsina, B. S., Indira, T. N., Bhatnagar, A. S., Radha, C., Debnath, S. and Gopala Krishna, A.G. (2011). Quality characteristics and stability of Moringa oleifera seed oil of Indian origin. *Journal of Food Science and Technology* DOI 10.1007/s13197-011-0519-5.

Okuda, T., Baes, A. U., Nishijima, W. and Okada, M. (1999). Improvement of extraction method of coagulation active components from Moringa oleifera seed. *Water Research*, vol. 33, pp. 3373-3378.

Olitino, H. M., Onimawo, I. A. and Egbekun, M. K. (2007). Effect of germination on chemical compositions, biochemical constituents and antinutritional factors of soybean (Glycine max) seeds. *J. Sci. Food Agric*. 73:1–9.

Oliveira, J. T., Silveia, S. B., Vasconcelos, K. M., Cavada, B. S., Morira, R. A. (1999). Compositional and Nutritional Attributes of Seeds from the Multipurpose Tree, *Moringa oleifera* Lamarck. *J. Sci. and Food Agric.* 79 (6): 815-20.

Osagie, A.V. (1998). *Nutritional Quality of Plant Foods.* Published By The Post Harvest Research Unit; Department of Biochemistry, University of Benin, Benin-city, Nigeria, pp: 53-83: 221-244.

Price, K. R., Johnson, T. I. and Fenwick, G. R. (1987). The chemical and biological significance of saponin in foods and feeding. *Crit. Rev. Fd. Sci. Nitre*., 26: 27-135.

Raghu, V., Patel, K., Srinavasan, K. (2007). Comparison of ascorbic acid content of Emblica offcinalis fruits by different analytical methods*. J. food Composition and Analysis*, 20 (6): 529-533.

Ramachandran, C. A., Peter, K. V., Gopalakrishnan, P. K. (1980). Drumstick (*Moringa oleifera):* a multipurpose Indian vegetable. *Economic Botany* 34 (3): 276-83.

Rashid, U., Anwar, F., Moser, B. R. and Knothe, G. (2008). "Moringa oleifera oil: a possible source of biodiesel". *Bioresour Technol* 99 (17): 8175-9.

Robinson *et al*., (2001). A Practical Guide to Nutrition, Feeds, and Feeding of Catfish*. Mississippi Agricultural and Forestry Experiment Station.* Bulletin 1113, pp. 12.

Siddhuraju, P. and Becker, K. (2003). Antioxidant properties of various solvent extracts of total phenolic constituents from three different agro-climatic origins of drumstick tree (*Moringa oleifera* Lam.). *J. Agri. Food Chem.,* 15, 2144-2155.

Sidhu, G. S., and Oakenful, D. G. (1986). A mechanism for the hypocholesterolemic activity of saponins. *Br. J. Nutr*. 55:643–649.

Soladoye, M. O. and Chukwuma, E. C. (2012). Quantitative phytochemical profile of the leaves of Cissus populnea Guill. and Perr. (Vitaceae) – An important medicinal plant in central Nigeria. *Arch. Appl. Sci. Res*. 4:200–20

Thompson, L. U., Button,C. L. and Jenkins, D. J. A. (1988). Phytic acid and calcium affect the in vitro rate of navy bean starch digestion and blood glucose response in humans. *Am. J. Clin. Nutr*. 46:467–473.

Vaintraub, I. A. and Lapteva, N. A. (1988). Colorimetric determination of phytate in unpurified extracts of seeds and the products of their processing. *Analytical Biochemistry* 175, 227-230.

Yoon, J. H., Thompson, L. U. and Jenkins, D. J. (1983). The effect of phytic acid on in vitro rate of starch digestibility and blood glucose response. *Am. J. Clin. Nutr.* 38:835–842.