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Proximate Analysis and Nutritional Content of *Moringa Oleifera* Leaves Collected From Horticultural Garden in Gwagwalada, Federal Capital Territory, Abuja, Nigeria

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ABSTRACT: Moringa is a medium-sized growing tree that can reach 30 feet in height. Malnutrition is a great concern to human health. It occurs as a result of poor intake of food nutrients. Previous research has indicated that adding *Moringa oleifera* to animal feed can improve growth, blood chemistry, antibacterial activity, immune enhancer, antioxidant activity, and hypo-cholesterol effect. For this reason, this paper aimed to proximately analyze and determine the nutritional content of *Moringa oleifera* leaves taken from a horticultural garden in Gwagawlada, Federal Capital Territory, Abuja, Nigeria, using suitable standard methods. The nutritional contents of *M. oliefera* leaves were evaluated and the proximate composition shows that the moisture content recorded for the *M. oleifera* was 13.67%, the protein content was 28.50% while the fiber content of the three treatments recorded was 3.00%, the ash content recorded was 9.33% and the carbohydrate content was noticeably greater than other nutrient contents of the *M. oleifera* leaves being 56.50%. However, since *M. oleifera* is a cheap source of nutrients, it can serve as food supplementation, fortification, and complementation (especially in infant feed). Also, *Moringa oleifera* leaves can be utilized as a dietary supplement to boost cattle performance and efficiency of fodder or can be substituted for traditional crops for economic sustainability, environmentally friendly, safer, and low-cost production.

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Moringa belongs to the Moringaceae family which includes many species such as the famous ones *Moringa oleifera*, *Moringa peregrina* (Forssk), and *Moringa stenopetala*. This tree has been grown in a tropical and subtropical region around the world. Fahey (2015) reports that the moringa tree is versatile and can be used for food, natural medicine, feed, natural stimulants for fertilizers, and forage. Additionally, it serves as a significant source of vital amino acids and is an excellent source of numerous vitamins, including C, B, and A, riboflavin, pyridoxine, folic acid, beta-carotene, ascorbic acid, nicotinic acid, and alpha-tocopherol. It also has a high mineral content, including calcium and iron (Kumar *et al*., 2012). Dahot (2018) indicates that the tree is anti-tumor, anti-inflammatory, antioxidant, and antimicrobial activity. Moringa contains powerful fungi and antibiotics effectively used as a natural and inhibitory biomarker for many plant pathogens (Fahey *et al*., 2014). The most important traits of Moringa are that it has the biological and food values are high. It can be used as, green fertilizers, medicine, Bio-pesticides, human food, animal feed with high protein, carotenoids content with many vitamins, and minerals,

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and some phytocompounds with high levels (Kempifetrine, Isocercetrine, Rehamnite, Kempferol, and cercetin) (Fuglie, 2011). Also, Moringa was used to improve nutrition, and reproductive performance, and support immune functions of poultry and animals (Yang *et al*., 2016). A large improvement in resistance to pests and diseases was observed with the use of moringa leaf extract (MLE), with total yield Increases from 20% to 35% (Fuglie, 2011).

Some common names of *M. oleifera* are Drumstick, Ben oil, Horseradish, Al-Ban, or Life tree. It is medium in size and fast-growing, crown is semi-open with drooping pods and branches (Abd El-Hack *et al*., 2018). The moringa tree has a lovely gray bark and also can reach a height of 30 feet. Its compound tripinnate leaves have quite a distinctive shape, with three different pairs of paired leaves emerging from the main stem. Each pair has small, oval shaped leaflets with substantial bases (Nielsen L. 2022). The trunk can reach a diameter of 45-50 cm, and flowers are around 1.0–1.5 cm long and 2.0 cm in wide, with white color. The Flowers come out during the first 5-6 months of tree planting. The Pods of this tree are in droopy shape, brown capsule with three sides, 25–50 cm in length, pod color is dark brown, semi spherical seeds of about 0.5-1.0 cm of diameter. The seed has three transparent wings, for easy movement and transmit by wind and water (Abd El-Hack *et al*., 2018). Moringa tree is drought resistant and able to survive hot, dry conditions. (Wiginton, 2023).

Malnutrition is a great concern to human health, it occurs as a result of poor intake of food nutrients. *M. olefera* is highly nutritive. People in many countries in Africa consume all components of *M. Oleifera* tree in different ways (Fahey, 2015). Each component of this tree, including the flowers, leaves, roots, and young plant pods, has been used to make high-protein supplements with a variety of pharmacological and therapeutic properties (Anwar *et al*., 2017; Pandey *et al*., 2019). The leaves and seeds of the moringa tree contain highly valued compounds like Ascorbic acid, vitamins, minerals, protein, iron, calcium, and Antioxidant compounds like carotenoids, flavonoids, and Phenol, (Sultana and Anwar, 2018). Both macro and micronutrients needed by the body are found in moringa leaves. Due to their role in the processing of breaking down macro-nutrients, micro-nutrients are crucial to the body's functioning. The body depends heavily on vitamins and minerals. Vitamins are critical for the body's energy metabolism. Moringa leaves powder is a good source of vitamins as it contains vitamins such as vitamin A, vitamin B (pyridoxine, folic acid, and nicotinic acid), vitamin C, vitamin D and vitamin E. Minerals like calcium and zinc are crucial for the development and support physiological growth (Islam Z. *et al*., 2021). Moringa leaves contain many amino acids, such as Histidine, isoleucine, leucine, lysine, valine, methionine, phenylalanine, threonine, and tryptophan (Gopalakrishnan *et al*., 2016 sus). *Moringa oleifera* leaves can be utilized as a dietary supplement to boost cattle performance and efficiency of fodder or can be substituted for traditional crops for economic sustainability, environmentally friendly, safer, and low-cost production (aregheore, *et al*., 2012). Grubben and Denton (2014) indicated about two alkaloid kinds in Moringa roots bark, i.e. maurinine and mornin. The findings by Nouman *et al*. (2013) show moringa harvested leaves at 30 cm height in raining season will give a maximum value of biomass (472 g plant–1) with a higher minerals content, It is concluded that the moringa tree can be cultivated as a field crop as a good alternate for livestock fodder due to its antioxidant activities and higher minerals content. Point to note that nutrient variation by climate, location, and environmental factors varies greatly on the food content of the tree. These leaves taken from plants are dried and used in the form of medicinal capsules and are nutritious feed for cattle. Therefore, cattle heads can be produced using the moringa plant. moringa leaves, if added to animal feeds increase in meat production and also a 45-65% increase in milk output (Gopalakrishnan *et al*., 2016).

Moringa leaf powdery substance is one of the natural ingredients used to make soap which also has antibacterial characteristics that can help eliminate bacteria like staphylococcus aureus (Waris *et al*., 2023). The total flavonoid composition is analyzed by following a spectrophotometric method of Anwar *et al*. (2017). The antioxidant capacities were evaluated by using scavenging assays of 1,1-diphenyl-2-picrylhydrazyl radical (DPPH), ferric reducing antioxidant power. Using the Anwar *et al*. (2017) approach, the total phenolic content of *M. oleifera* leaf extract was determined based on gallic acid. Total Antioxidant activity 1701.8/100gm Ascorbic acid equivalent, this higher value was agreed with the results reported that the antioxidant activity in oil from the dried seeds is higher than BHT and alpha-tocopherol. The antioxidant potential exerted by *M. olifera* may be attributed to the presence of phenolic compounds like Gardenin, which were found to be present in greater concentrations (21.52%) (Anwar et al., 2017). The *M. oleifera* leaf extracts have been said to exhibit antioxidant activity both inside and outside the body of an organism due to phenolic and flavonoid content (Khor *et al*., 2018). Thus, the free radical scavenging ability of *M. peregrina* could provide health benefits to humans by protecting against

oxidative. Some researchers stated that *M. oleifera* leaves have a high content of chlorogenic acid, kaempferol, and quercetin glycosides (Khor *et al*., 2018).

Moringa trees have many medical uses likewise their high value in food (sultana *et al*., 2014). All parts of *M. oleifera* are mostly used as natural medicines in many countries such as Pakistan, India, Philippines, Thailand and Niger etc. This plant has many pharmaceutical effects interventions to treat several diseases in the traditional medicinal system (Anwar *et al*., 2017). However, moringa is mostly accepted in the Unani and Ayurvedic systems of medicine to prevent and treat many diseases. Also, moringa can be used as an aphrodisiac (Anwar *et al*., 2017). The methanolic and ethanolic extracts of moringa seeds and leaves have shown anti-ulcer anthelmintic and anti-tumor activity. *M. oleifera* serves as a remedy for asthma as used by many ayurvedic practitioners. Moringa leaves contain various phytochemical compounds which have potent anticancer and hypotensive activity and are considered highly therapeutic and are used in Siddha medicine (Premi *et al*., 2010). Moringa has properties for microbes and this explains why it is used extensively in the prevention of respiratory diseases in humans (Anwar *et al*., 2017). Okiki et al., (2015) indicate that the concentration of 100 mg L-1 for ethanol extract of leaves, flowers, and seeds was very active against Escherichia coli, Pseudomonas, and Staphylococcus aureus. (Okiki *et al*., 2015). It was shown that the methanolic extract of dried *Moringa oleifera* leaves possessed strong phytochemicals with strong inhibitory effects on bacteria that cause urinary tract infections. Liver tissue damage has been significantly improved by using the Moringa leaf extract. Histochemical tests have confirmed these results in addition to the DNA in liver cells, according to the research, the Moringa leaves extract had returned the amount of DNA in these cells to levels much better than those detected in animals treated with carbon tetrachloride alone. Scientists have found that the Moringa leaves extract stimulates the death of programmed cancer cells and arrests the cancer cell cycle of the colon and rectum. *Moringa olifera* leaf extract was assessed on the liver cancer cell line. It was found that the leaf extract has a significant anticancer effect on liver cancer cells compared to that of the plant bark extract. Thiocarbamate from the leaves was found to be a potent chemical preventive agent in chemo carcinogenesis, so the seed extracts have also been found to be effective on antioxidant parameters, hepatic carcinogen metabolizing enzymes, and skin papilloma genesis in mice (Uphadek *et al*. 2018). Khor *et al*. (2018) were findings identify a plant extract with an anticancerous effect on the lung cancer cell line A549, as well as an anti-cancer agent against breast and colorectal cancer cell lines. The roots of the Moringa contain some important alkaloids such as Morgenine, which raises the tension of the heart and blood vessels. More studies were needed in order to attain a certain level required for full biomedical endorsement of Moringa, and also to check and advise the suitable human daily uptake of distinct portions of the moringa tree (Reddy *et al*., 2012). Therefore, this paper aimed to proximately analyze and determine the nutritional content of *Moringa oleifera* leaves taken from a horticultural garden in Gwagawlada, Federal Capital Territory, Abuja, Nigeria,

MATERIALS AND METHODS

Plant Collection: Moringa oleifera leaves used in this research was obtained at horticultural garden in Gwagwalada and then brought to the university of Abuja herbarium by the botanist for identification.

Nutritional evaluation of Moringa oleifera: The freshly collected *M. oleifera* leaves were first sorted and cleaned, following analysis for nutritional value which includes moisture, Protein, Carbohydrate, Nitrogen, Fat, Fiber, and Ash. The proximate analysis of the sample for total ash, crude fiber, and ether extract was carried out using the methods described in the Association of Analytical Chemists (AOAC, 2010). The nitrogen was determined by Micro Kjeldahl's method described by Pearson (1976) and the nitrogen content was converted to protein by multiplying by 6.25. Carbohydrate was obtained by a method of difference described in AOAC (2010).

Determination of moisture content: Each sample weighed two grams (2 grams) and was placed in a dried and cleaned crucible dish. The dish was then placed in a Phoenix oven and heated to 70°–80° for two hours, then to 100° -105°c until the weight remained constant. After cooling in a desiccator, the samples were weighed. The weight loss was obtained as the moisture content.

Determination of fat content: The extraction flasks were washed with petroleum ether, dried, cooled, and weighed. Two grams (2 grams) of the sample were weighed into the extraction thimble. It is then placed back in the Soxhlet apparatus. The washed flask was filled to about three-quarters of its volume with petroleum ether (that has a boiling temperature range of 40-60^{0}C). The apparatus is then set up and extraction is carried out for a period of 4-6 hours after which complete extraction is made. The petroleum ether is recovered leaving only oil in the flask at the end of the extraction. The oil in the extraction flask is

dried in the oven, cooled, and finally weighed. The fat content is expressed as a percentage of raw material.

Determination of crude protein: In a Kjeldahl flask, one gram (1.0 ml) of the sample was added. The flask is filled with one gram (1g) of hydrated copper sulphate (catalyst) and three grams (3g) of anhydrous sodium sulphate. To further break down the sample, 20 ml of concentrated tetraoxosulphate (IV) acid (H2S04) is added. Heat is applied to the digesting process until a solution is seen. After cooling the clear solution, 100 ml of distilled water was added, and a digest of roughly 5 ml was collected for distillation. Additionally, 5 milliliters of sodium hydroxide (NaOH) were added to the distillation flask, and the process was allowed to run for a few minutes. A boric acid indicator was used to absorb the ammonia that was distilled off, and 0.01M hydrochloric acid (HCl) was used to titrate this. The endpoint value of the titrate is taken and calculated when it changes from green to pink color.

Determination of ash content: A silica dish is heated to about 60^0C, cooled in a desiccator, and weighed. 5ml of powdered moringa sample is put into the silica dish and transferred to the furnace. The temperature of the furnace is allowed to reach about 525^0C after placing the dish in it. The temperature is maintained until a whitish-grey colour is obtained indicating that all the organic matter content of the sample has been destroyed. The dish is then brought out from the furnace, cooled in the desiccator and re-weighed.

Crude fibre: This technique determines the sample's crude fiber content after the material has been digested in solutions of sulfuric acid and sodium hydroxide and the residue has been calcined. The amount of fiber present is indicated by the weight difference following calcination.

Determination of carbohydrate: Carbohydrate was determined in accordance with the AOAC (2010) method and the formula below was used:

% Carbohydrate = 100 % - (protein + fat + fibre + ash + moisture).

Statistical Analysis: The results obtained were analyzed using one-way ANOVA and simple percentages and the F- test statistic at P = 0.05 level of significant from Microsoft excel statistics.

RESULTS AND DISCUSSION

Proximate Analysis: Table 1 shows the proximate composition of *Moringa oleifera* leaves. The moisture content recorded for the *Moringa oleifera* was 13.67 %, the protein content of the *Moringa oleifera* leaves was 28.50% while the fiber content of the three treatments recorded was 3.00 %. However, the ash content recorded was 9.33 % and the carbohydrate value was noticeably higher than other nutrient contents of the moringa leaves at 56.50 %.

Table 1: Proximate composition of Moringa oleifera leaves

Parameters	Proximate Values (%)
Moisture	13.67
Ash	9.33
Lipid	2.33
Fiber	3.00
Nitrogen	4.56
Protein	28.50
Carbohydrate	56.50

Each Value Represent Mean standard deviation of three replicate value

Study shows that there are people who suffer from malnutrition from around the world, particularly in Africa where by the Central African Republic is the top most ranked malnourished country worldwide. Consuming food items made from moringa is one crucial strategy to reduce malnutrition (Abbas *et al*., 2018).

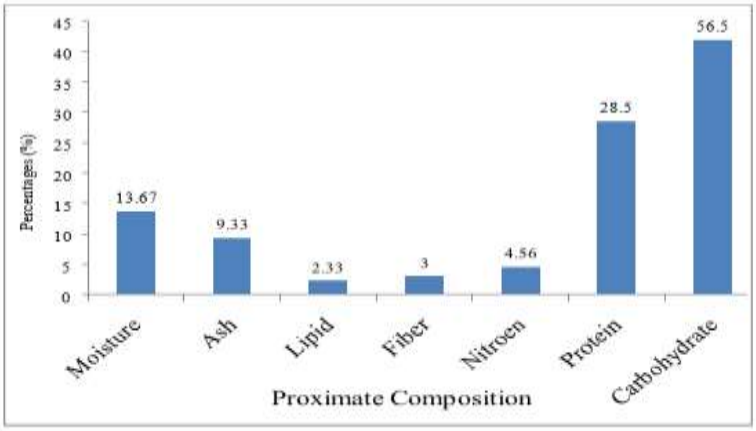

Fig 1: Nutritional composition of *M. oleifera* leaves

Moringa tree is versatile and can be used for food, natural medicine, feeds, natural stimulants for fertilizers and forage (Kumar *et al*., 2012). It contains powerful fungus and antibiotics that is used as a natural and inhibitory biomarker for many plant pathogens (Fahey *et al*., 2014). These leaves taken from plants are dried and used in form of medicinal capsules and are nutritious feed for cattle which aids the increase in meat production and milk yield increases by 45-65% (Gopalakrishnan *et al*., 2016).

Based on the findings obtained from this research, the moisture content recorded for the *Moringa oleifera* was 13.67 %, the protein content of the *Moringa oleifera* leaves was 28.50% while the fiber content of the three treatments recorded was 3.00 %. However, the ash content recorded was 9.33 % while carbohydrate content was noticeably greater than other nutrient contents of the *Moringa oleifera* leaves at 56.50 %. The value obtained may noted to be higher than the value (6.35%) reported by Maina *et al*. (2016). Removal of moisture by heat generally improves the digestibility of foods, increases the concentration of nutrients, and can make some nutrients more available (Makkar and Becker, 2016).

Conclusion: Based on the acquired results, it can be said that *M. oleifera* leaves typically have a high nutritional content. *M. oleifera* leaves are easily obtained and useful for both nutrition and medical purposes. Since. *oleifera* is a cheap source of nutrients, It should be used in food supplementation, fortification, and complementation (especially in infant feed). It should be used for medicinal purposes.

REFERENCES

Abbas, RK; Elsharbasy, FS; Fadlelmula, AA (2018). Nutritional value of *moringa oleifera*, total protein, amino acid, vitamins, minerals, carbohydrate, total fat, and crude fiber, under the semi-arid conditions of Sudan. *J. Microb. Biochem. Technol.* 10:56-58. Doi:10.4172/1948-5948.1000396.

Abd El-Hack, ME; Alagawany, M; Elrys, AS; Desoky, EM; Tolba, HMN; Elnahal, ASM; Elnesr, SS; Swelum, AA (2018). Effect of Forage *Moringa oleifera* L. (moringa) on Animal Health and Nutrition and Its Beneficial Applications in Soil, Plants and Water Purification. *Agric.* 8: 145: 1-22. Doi: 10.33390/agriculture 8090145.

Anwar, F; Latif, S; Ashraf, M; Gilani, AH (2017). *Moringa oleifera*: A food plant with multiple medicinal uses. *Phytother. Res.* 21:17–25. Doi: 10.1002/ptr 2023.

Aregheore, EM (2012). Intake and digestibility of *Moringa oleifera*-batiki grass mixtures for growing goats. *Small Rumi. Res.* 46:23–28. Doi: 10.1016/50921-4488(02)0017-5.

Dahot, MU (2018). Vitamin contents of the flowers and seeds of *Moringa oleifera*. *Pakist. J. Biochem.* 21: 1–2.

Drumstick tree' (*Moringa leifera* Lam.): a multipurpose potential species in India. *Gene. Resour. Crop. Evo.* 58 (3): 453–460. https://doi.org/10.1007/s10722-010-9629-6

Fahey, JW (2015). *Moringa oleifera*: A Review of the Medical Evidence for Its Nutritional, Therapeutic and Prophylactic Properties. *Tre. Lif. J.* 1: 1–15.

Fahey, JW; Zalcmann, AT and Talalay, P (2014). The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. *Phytochem.* 56: 5–51.

Fuglie, LJ (2011). *The Miracle Tree*: *Moringa oleifera*, *Natural Nutrition for the Tropics*; Church World Service: Elkhart, IN, USA,: p. 172.

Gopalakrishnan, L; Doriya, K; Kumar, DS (2016). *Moringa oleifera*: A review on nutritive importance and its medicinal application. *Food Sci. Human Wellnes.* 5: 49–56.

Grubben, G; Denton, yyjkO (2014). *Plant Resources of Tropical Africa*; Earthprint Limited: Stevenage, UK, 2004; pp. 56–60.32.

Islam, Z; Islam, RSM; Hossen, F; Mahtab-ul-islam, K; Hasan, RMd Karim, R (2021). Moringa oleifera is a prominent source of nutrients with potential health benefits. *Inter. J. food sci.* doi: 10.1155/2021/6627265.

Khor, KZ; Lim, V; Moses, EJ; Samad, NA (2018). The In Vitro and In Vivo Anticancer Properties of *Moringa oleifera. Evide-Base. Comple. Alter. Med*. 2: 7-14.

Kumar, VK; Rubha, MN; Manivasagan, M; Babu, R; Balaji, P (2012). *Moringa oleifera—The Nature's Gift. Univer. J. Environ. Res. Tech.* 2: 203–209.

Levasseur, V (2016). *Nutritional and Functional Properties of Moringa Leaves- from Germplasm, to Plant, to Food, to Health, Accra, Ghana, November* 16-18.

Maina, IW; Obuseng, V; Nareetsile, F (2016). Use of *Moringa oleifera* (Moringa) seed pods and Sclerocarya birrea (Morula) nut shells for removal of heavy metals from wastewater and borehole water. *J. Chem.* 1: 6-11

Makkar, HPS; Becker, K (2016). Nutritional value and antinutritional components of whole and ethanol extracted of *Moringa oleifera* leaves. *Anml. Fed. Sci. Tech.*63: 211–228.

Nielsen, L (2022). Growing moringa:The majestic drumstick tree. Epic Gardening. https://www.epicgardening.com/growing moringa.

Nouman, W; Siddiqui, MT; Basra, SMA; Farooq, H; Zubair, M; Gull, T (2013). Biomass production and nutritional quality of *Moringa oleifera* as field crop. *Turk. J. Agric. Fores.* 37: 410–419. Doi:10.3906/tar-1206-29

Okiki, PA; Osibote, I.A; Balogun, O; Oyinloye, BE; Idris, O; Olufunke, A; Asoso, SO; Olagbemide, PT (2015). Evaluation of Proximate, Minerals, Vitamins and Phytochemical Composition of *Moringa oleifera* Lam. Cultivated in Ado Ekiti, Nigeria. *Advan. Bio. Res.* 9 (6): 436-443.

Pandey, A; Pradheep, K; Gupta, R.; Nayar, ER; Bhandari, DC (2019).

Premi, M; Sharma, HK Sarkar, BC and Singh, C (2010). Kinetics of drumstick leaves (*Moringa oleifera*) during convective drying. *Afri. J. Plant. Sci.* 4 (10):391-400

Reddy, DHK; Seshaiaha, K; Reddy, AVR; Leec, SM (2012). Optimization of Cd (II), Cu (II) and Ni (II) biosorption by chemically modified *Moringa oleifera* leaves powder. *Carb. Poly.* 88: 1077–1086. DOI: 10.1016/j.carbpol.2012.01.073

Sultana, B; Anwar, F (2018). Flavonols (kaempeferol, quercetin, myricetin) contents of selected fruits, vegetables and medicinal plants. *Food. Chem.* 108: 879–884.

Sultana, N; Alimon, AR; Haque, KS; Sazili, AQ; Yaakub, H; Hossain, SMJ (2014). The effect of cutting interval on yield and nutrient composition of different plant fractions of *Moringa oleifera* tree. *J. Food. Agric. Environ.* 12: 599–604.

Uphadek, B; Shinkar, DM Patil, PB; Saudagar, RB (2018). *Moringa oleifera* as a pharmaceutical excipient. *Inter. J. Curr. Pharm. Res.* 10(2): 13-16. Doi: http://dx.doi.org/10.22159/ijcpr.2018v10i2.25883.

Waris, ID; Yanti, IS; Okzelia, DS; Amirulah, F (2023). Formulasi sabun cair cuci tangan dan uji aktivitas bakteri staphylococcus aureus dari ekstrakdaun kelor (*Moringa oleifera* lam). Sinteza. *J. farmasi. Klinis. Dan. Sains. Bahan. Alan*. 3 (1). https://doi.org/10.29408/sinteza.v3i1.7890.

Wiginton, K (2023). Health benefit of moringa. www.webmd.com. Yang, RY; Chang, LC; Hsu, J; Weng, BBC; Palada, MC; Chadha, ML;