African Journal of
Clinical Medicine and Pharmacy Research

ISSN : 0000-0000

Index: Harvard, Boston, Sydney University, Dimensions, Lens, ResearchGet Scilit, Semantic, Google Scholar, Base etc

https://doi.org/10.58578/AJCMPR.v1i1.3836

Evaluation of Water Purification Potentials of Moringa Seed (*Moringa oleifera*) In Jalingo Local Government Area of Taraba State

Obadiah Saveni Yusuf[1], Ajiduku Leyoa Abershi[2], Solomon Chuanu[3], Lipana Dorcas Bappa[4], Nasiru Audu Ngabea[5], Alice Njolke Mafe[6], David Christopher Bando[7], Danladi Mbosire Peter[8], Isaac John Umaru[9]

[1,2,3,4,5,6,8]Taraba State University, Jalingo, Nigeria; [7]National Biotechnology Research and Development Agency, Taraba, Nigeria; [9]Federal University Wukari, Nigeria

ajidukuleyoa@tsuniversity.edu.ng

Article Info:

Submitted:	Revised:	Accepted:	Published:
Aug 25, 2024	Sep 8, 2024	Sep 11, 2024	Sep 14, 2024

Abstract

Agricultural, Domestic and Industrial activities are all human activities that led to squalid of environment, mostly water pollution. Water is needed for every daily activities and conventional methods of treating wastewater such as the use of chlorine and other is detrimental to human health. Hence, there is need for a greener sustainable alternative of wastewater treatment such as biological method. This study focused on developing an efficient and cost-effective procedure for using *Moringa oleifera* seeds to produce natural coagulant for use in drinking water treatment. The study investigates processing *Moringa oleifera* seeds to concentrate the bio-active constituents which have coagulation activity. It is generally accepted that Moringa works as a coagulant due to positively charged, water-soluble proteins, which bind with negatively charged particles (silt, clay, bacteria, toxins, etc) thereby allowing the resulting "flocs" to settle to the bottom and then be removed by filtration. The turbidity removal was about 83-100% using two processed *Moringa oleifera* seeds to treat an undrinkable well water having 6 Nephelometric Turbidity Units (NTU). The product satisfies WHO standards for portable water and minimizes the cost of

water treatment and therefore it is recommended as an efficient and effective treatment for drinking water especially for the rural communities where there is poor access to potable water.

Keywords: Wastewater, Filtration, treatment, Moringa and Coagulant

INTRODUCTION

Water contamination has become a growing issue to the public and authorities since the industrial revolution. Due to the rise in industrialization and population growth, there is a significant increase in the need for fresh water. According to Boretti and Rosa (2019), the worldwide water requirement for agriculture, industry, and municipalities is projected to increase by 20-30% by the year 2050. As a result of this increase, there are more and different types of wastewater that are polluted with a wide range of chemicals. In addition to utilizing a considerable quantity of pesticides annually, the agricultural business produces substantial amounts of organic waste (Bockstaller *et al.*, 2009), making it a major contributor to water pollution. When introduced into ecosystems, these pollutants have the potential to cause serious harm to both the environment and the ecosystems. Some pollutants, especially those with an organic origin, usually biodegrade (either naturally or with the help of microbes), therefore they don't really constitute a threat to the environment. Nevertheless, many persistent organic pollutants (POPs), which are usually found in minimal quantity, have the ability to bioaccumilate in organisms and cause long term hazardous effects on animals (Schwarzenbach *et al.*, 2010). Chemical pollutants, including polycyclic aromatic hydrocarbons (PAHs), dyes, pharmaceuticals, hydrocarbons, hexachlorocyclohexanes, perfluorocarbons, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), bisphenols, and phthalic acid esters (PAEs), are widely recognised as persistent organic pollutants (POPs) that have significant effects on the overall health of ecosystems and humans (Dong *et al.*, 2018). Consequently, significant emphasis has been placed on the advancement of chemical removal methods; yet, their effectiveness diminishes when used on a big magnitude. Additional contaminants, such as heavy metals, might present issues since they are not easily broken down and can build up in the food chain. This accumulation poses significant risks to the health of both animals and humans (Arceivala & Asolekar, 2006). A greater comprehension of the magnitude of

the forthcoming issues has been developed due to the escalating production of wastewaters and the necessity to provide freshwater to an expanding population. Rout *et al.* (2020) discovered over 50 novel "emerging contaminants" (ECs), many of which originate from human activities and necessitate monitoring and focus. As our comprehension of the difficulties and necessity for managing wastewaters from various origins expands, innovative wastewater treatment technologies have emerged with the objectives of enhancing effectiveness, diminishing expenses, and minimising the carbon footprint of large-scale treatment facilities. Common treatment methods include coagulation/flocculation, precipitation, filtration, oxidation, ion-exchange, solvent extraction, electrochemical treatment, ozonation, adsorption, and membrane bioreactors (Crini, 2019; Rout *et al.*, 2020). An alternative and relatively new method involves utilising particular natural product and biomasses to eliminate contaminants.

Moringa oleifera, commonly known as the drumstick tree or horseradish tree, is a plant that has gained significant attention due to its various bioactive compounds and potential health benefits (Leone *et al.*, 2015 Although it originated in India, this perennial tree is now grown in many tropical and subtropical areas of the world. Its appeal stems in part from its capacity to thrive in difficult environments, including poor soil and scarce water supplies (Ali *et al.*, 2022). Taxonomically, *Moringa oleifera* belongs to the family Moringaceae and the order Brassicales (Bhattacharya *et al.*, 2018). It is a versatile plant that has been used for centuries in traditional medicine for its therapeutic properties (Ali *et al.*, 2022). The leaves of *Moringa oleifera* are particularly rich in bioactive compounds such as vitamins, phenols, and antioxidants. These compounds contribute to its potential hypoglycemic and medicinal properties (Leone *et al.*, 2015).

Moreover the leaves, other parts of the *Moringa oleifera* plant also contain valuable compounds. The stem and bark has been described to contain alkaloids, namely Moringinine and Moringine (Sreelatha and Padma, 2009). The seeds of *Moringa oleifera* are known for their high nutritional content and are a rich source of edible oil (Barakat and Ghazal, 2016). The oil extracted from the seeds is rich in phytosterols, unsaponifiable matter, fatty acids, and tocopherols (Anwar and Bhanger, 2003).

The antioxidant activity and possible health advantages of the bioactive chemicals found in *Moringa oleifera* have been researched. It has been discovered that the leaves have a high total phenolic content and show antioxidant activity (Sreelatha and Padma, 2009). These

antioxidant properties contribute to the plant's potential as a food fortificant and its use in functional foods (Oyeyinka and Oyeyinka, 2018). Furthermore, *Moringa oleifera* leaves have been evaluated for their potential as a natural remedy for drug-induced hepatotoxicity (Thakare *et al.,* 202*2*).

Overall, Moringa oleifera is a plant with great promise in a variety of sectors, including medicine, nutrition, and agriculture. Its bioactive components, nutritional value, and ability to grow in adverse settings make it an important plant for future research and investigation. Research has shown that *Moringa oleifera* has potential anticancer properties (Khor *et al.*, 2018). Studies have demonstrated its in vitro and in vivo anticancer effects, suggesting its therapeutic potential in cancer treatment (Khor *et al.*, 2018). Additionally, *Moringa oleifera* has been found to have antistress, antioxidant, and scavenging potential (Luqman *et al.*, 2012). Its extracts have exhibit the ability to reduce oxidative stress markers and exhibit antioxidant properties (Luqman *et al.*, 2012).

Furthermore, *Moringa oleifera* has been investigated for its potential use as a food fortificant (Oyeyinka and Oyeyinka, 2018). The plant is considered a "miracle tree" due to its quality present of macro and micro nutrients that are important for human nutrition (Oyeyinka and Oyeyinka, 2018). Its leaves have been found to contain high concentrations of proteins and minerals, making them a valuable dietary source (Olson *et al.*, 2016). In addition to its nutritional value, *Moringa oleifera* has also been studied for its potential therapeutic effects in chronic hyperglycemia and dyslipidemia. The plant has been used historically in traditional medicine for its hypoglycemic properties (Anwar *et al.*, 2006). Research has shown that *Moringa oleifera* leaves can help regulate blood glucose levels and improve lipid profiles (Mbikay, 2012). *Moringa oleifera* seeds are of great importance due to their various characteristics and potential applications. The seeds of *Moringa oleifera* have been recognized as a promising resource for both food and non-food purposes. They are rich in monounsaturated fatty acids, sterols, tocopherols, and proteins, making them suitable for use in food preparations, biofuels, and other industrial applications (Leone *et al.*, 2016).

One of the key benefits of *Moringa oleifera* seeds is their nutritional value. They are rich sources of minerals such as potassium, phosphorus, sodium, zinc, magnesium, and calcium (Saa *et al.*, 2019). These minerals are vital for maintaining general well-being. Furthermore, *Moringa oleifera* seeds have been found to contain high levels of antioxidants, which can help

protect against oxidative damage and prevent the development of chronic diseases (Sreelatha and Padma, 2009).

In addition to their nutritional and medicinal properties, *Moringa oleifera* seeds also possess antimicrobial activity. Studies have shown that extracts of *Moringa oleifera* seeds exhibit antimicrobial activity against various food-borne microorganisms (Bukar *et al*., 2010). Moringa oleifera seeds' antibacterial action makes them a possible natural preservative for food products, lowering the risk of foodborne illness. Overall, *Moringa oleifera* seeds are extremely valuable due to their nutritional, therapeutic, and antibacterial characteristics. They can be used in a variety of applications, including food preparation, biofuel production, and the creation of natural preservatives. *Moringa oleifera* seeds are an important resource for boosting human health and well-being due to their high mineral, antioxidant, and bioactive chemical content.

Its common names include: *Moringa*, Drumstick tree (from the appearance of the long, slender, triangular seed-pods), Horseradish tree (from the taste of the roots, which resembles horseradish), Ben oil tree (from the oil which is derived from the seeds) or Benzoil tree (Duke *et al.,* 2002). *M. oleifera* is a fast-growing, deciduous, drought-resistant tree found in the southern foothills of the Himalayas in northern India. It is frequently planted in tropical and subtropical countries, where its young seed pods and leaves are utilized as vegetables. It can also be used to purify water and clean hands, and it is occasionally employed in herbal medicine (Parotta 1993). According to Reyes (2006), it can reach a height of 10-12m (32-40ft), with a trunk diameter of 45cm (1.5ft). The bark is white grey and ringed with thick cork. The bark of the young shoot is purplish or greenish-white, with hairy texture. The tree has an open crown with drooping, weak branches, and the leaves grow into fluffy foliage with tripinnate leaves.

The blooms are aromatic and bisexual, with five uneven petals that are thinly veined and yellowish-white. The flowers are approximately 1.0-1.5 cm long and 2.0 cm wide. They grow on slender, hairy stems in spreading or drooping later flower clusters ranging in length from 10 to 25cm (Marcu 2005). Flowering occurs within the first six months of sowing. Flowering occurs only once a year in seasonally chilly locations, between April and June. Flowering can occur twice or even all year long when seasonal temperatures and rainfall are consistent. The fruit is a hanging, three-sided brown capsule 20-45cm in size that contains dark brown, spherical seeds with a diameter of around 1cm. The seeds have

three whitish papery wings and are spread by wind and water. In cultivation, it is frequently chopped.

The majority of semiarid, tropical, and subtropical regions are where *Moringa oleifera* trees are produced, according to Palada (1996). Although it can withstand a broad variety of soil types, it favors well-drained, sandy or loamy soil that is neutral to slightly acidic (pH 6.3 to 7.0). It is common for roots to decay in soggy soil. Since moringa is a sun- and heat-loving plant, it cannot withstand frost or freezing temperatures. Because *M. oleifera* may be cultivated with rainwater without the need for costly irrigation methods, it is especially well suited for arid climates.

When it comes to water purification, powdered seeds work as a natural flocculent, making even the murkiest water clear. Using seed powder is an easy and quick way to purify unclean water. As the powder mixes with the water's sediments, it sinks to the bottom. Chemicals like aluminum sulphate, which are costly and harmful to both humans and the environment can be replaced by using Moringa to cleanse water. One cup of clean water put into a bottle and agitated for five minutes can be combined with two grams of powder to purify twenty liters of water (Gassenschmidt *et al.*, 1995).

MATERIALS AND METHODS

Study area

The study area for the project encompasses Jalingo Local Government Area (LGA) in Taraba State, Nigeria. Jalingo is the capital city of Taraba State and is situated in the northeastern region of Nigeria.

Water sample

The raw water that was used in this study was collected from any well within Jalingo metropolis at Taraba state water agency. The water treatment experiment was carried out in Taraba state water supply and sewerage corporation (TAWASCO) Laboratory, Jalingo. The physicochemical analysis of the samples of raw and treated water (samples A, B, C and D) was done at the TAWASCO Laboratory

Preparation of *Moringa oleifera* seed

Good quality dry seeds of *Moringa oleifera* were selected from the pods collected in Biotechnology center, Kona, Jalingo. Taraba State, Nigeria. The pods was allowed to

completely dry on the tree (the brown colored pods) because the green pods do not possess any coagulation activities (Leone *et al.*, 2015). The pods length will ranges between 40-60cm, and each will contain about 20-30seeds. The seed wings and coats were removed manually and the white kernel dried. Seed kernels and coats were finally crushed separately using a mortar and pestle.

Dosage

The dosage that was required to treat raw water depends on the turbidity of the water. However, to treat one liter of water, two seeds was used.

Methodology for water purification

The turbidity of the collected raw water sample was measured with a turbidity meter. Two seed kernels with their coats were crushed separately using mortar and pestle to obtain fine powder. The dosage of aluminum sulfate was added based on the degree of turbidity in the water. The seed kernel powder and the coat powder was mixed with small amount of clean water and aluminum salt in two bottles to form pastes separately and was shaken for one minute to activate the coagulant properties of the kernel, coat and the aluminum salt suspensions was poured into the raw water to be treated. One (1) liter of the turbid water (after determining the turbidity) was measured twice with a measuring cylinder into two big beakers and the seed kernel paste and the seed coat paste was added separately and stirred rapidly for one minute then slowly for ten minutes. The treated water was allowed to settle for two hours. When the particles and the contaminants have settled to the bottom, the purified water was carefully poured out. This clean water can then be filtered to make it completely safe for drinking. The turbidities of the water were measured before and after treatment (Folkard *et al.,* 1999). Other physicochemical analyses will also carryout for the water samples (samples A, B, C and D).

Determination of other physicochemical parameters

Colour

This was done by visual observation of the dirty (raw) water and treated water. And the colour of the raw water obtained from the well was brownish and treated water was slightly green due to the colouration of the leaf. Colour in water samples can results from the presence of natural metallic ions (Iron and Manganese), humus and peat materials, plankton, weeds and industrial wastes. Colour or true colour refers to the colour of water

upon removal of suspended solids (i.e. once the sample has been filtered). Gilvin is the name given to raw water collected from the well, due to the natural dissolved organic carbon compounds that give water a brown colouration. (Barakat, *et al., 2016*).

Method of analysis of total suspended solids (TSS)

One hundred (100) ml of the water sample (dirty water collected from a well in Tanke-Bubu) was measured into four different beakers. The filter paper to be used will first be weighed and labeled Xg (initial weight of filter paper); a filtering apparatus was connected by inserting the folded filter paper into the funnel appropriately and filtered into a conical flask. The water sample was filtered differently through the filter paper. After proper filtering, some residues are left on the filter paper, the resulting residue was dried in an oven at about 60-70oc, after efficient drying, the weights of the dried filter papers containing residues was taken using a chemical balance and labeled Yg (final weight of filter paper) (Leone., *et al.* 2015).The total dissolved solids will then be calculated in mg/l using the formula below;

Weight of residue alone = [(Yg – Xg)x 10-3]mg

[(Yg – Xg) x 10-3]mg x 1000

TSS in mg/l = Volume (ml) of samples

Method of analysis of total dissolved solids (TDS)

The filtrates that was gotten from the above method (Total Suspended Solids) was placed in different beakers (about 100mls of these filtrates were measured). The beakers was pre-weighed separately before pouring the water samples into them and labeled Xg. Afterwards, the contents of the beakers was placed into the oven and the temperature of the oven was adjusted to between 103-105 o c in order to evaporate completely all the samples. Later, the beakers were weighed after evaporation and the weight of the beakers and the resulting residues was taken to be Yg. (Leone. *et al.* 2015).

The total dissolved solids for each water sample were determined using the formula below:

$$\text{Weight of residue in mg} = [\text{Y} - \text{X}]\ \text{x}\ 10 - 3]\ \text{mg}[Y - X]\ x\ 10 - 3]\ x\ 1000$$

Total dissolved solids = ml of sample

Analysis of electrical conductivity

The conductivity meter was switched on for at least 30minutes before the measurement, so as to stabilize the instrument and the calibrated using a standard solution (usually KCl or NaCl). The electrode that is clean with de-ionized water was rinsed with the water samples (raw and treated water), thereafter, water sample was measured into a beaker and then the electrode inserted for a few minutes until steady reading is obtained. The electrical conductivities for the water sample (both dirty and the treated water) was measured using a digital conductivity bridge. It was measured by inserting the tube into the water samples and the readings were taken.

Test for nitrate (NO_3^-) and nitrite (NO_2^-)

The test bottle was filled with the water samples (Raw water and the treated water). The test tube was rinsed and filled to the 2.5ml line with water from the sample bottle. It was diluted to the 5ml line with an already mixed acid reagent; it was mixed properly and left for 2minutes. Then the test tube was inserted into the Nitrate- Nitrogen Comparator and the result was taken. (Barakat *et al 2016)*

Total acidity and alkalinity

For analysis of total alkalinity, the method of Bukar *et al.,* 2010) was used. To determine total acidity, it requires titration of the water sample with a standard sodium hydroxide solution to an end-point pH 8.3 (i.e. the phenolphthalein end-point) and the readings was taken in mg/l.

pH Determination

pH was measured electrochemically using a combination electrode (glass plus reference electrode) and was calibrated against two or three commercially available buffer solutions of pH 4.7 and 9. The dirty water was stirred thoroughly with a glass rod to have a homogenous mixture. The glass electrode pH meter was inserted into the solution and the readings were taken. Same procedure was applied to the water treated with *Moringa oleifera* leaves and the readings will also be taken. (Mbikay, 2012).

Metal analysis

The water sample (dirty/raw water from well and the water treated with *Moringa oleifera* leaves) was digested using the Nitric acid-Hydrochloric acid digestion. 50ml of the water sample was transferred into a beaker; 3ml of concentrated HNO_3 was added. The beaker was placed on a hot plate and continuously evaporated at low heating to less than 10ml making sure that the sample did not boil and that no area of the bottom of the flask was allowed to go dry. It will then cool and 5ml of conc. HNO_3 acid was added and evaporated to less than 10ml and cooled. 10ml of HCl was added and 15ml of distilled water will also be added. It will then be heated for additional 15minutes to dissolve any remaining residue. It was cooled and made up to 100ml mark. The samples will then be ready for the analysis of Lead (Pb), Manganese (Mn), Chromium (Cr), Copper (Cu), and Iron (Fe) by atomic absorption spectrophotometry analysis. Atomic absorption spectrophotometer is an instrument calibrated for determination of metal ion in solution. Concentration is often recorded in ppm unit. The concentrations of the cations (Fe^{3+}, Mn, Cr, Mg, Cu, PO_4, and iodine) were determined by atomic absorption spectroscopy (ASS) using atomic absorption spectrophotometer and the readings were taken. (Oyeyinka *et al.,* 2018)

Determination of Total Hardness

Total hardness is due to the presence of both calcium and magnesium ion in the water samples (raw and treated water). The sum of calcium and magnesium is determined readily using Erichrome Black-T as indicator. Direct titration method was used in which 10ml of the water samples (raw and treated water) was buffered to pH 10 (5ml of ammoniacal buffer). It will then titrated against 0.01m EDTA, then the end point was noted when the solution changes from purple to pure blue. (Saini *et al*., 2016)

Data analysis

Data was analyzes for statistical significance by one-way ANOVA and students test was apply. Values at 0.05 were regard supplement in comparison with control. All data will express as mean SEM (Standard Error Mean).

RESULTS

Table 1: Summary of the physicochemical analysis for the water samples

S/N	PARAMETER	SAMPLE A	SAMPLE B	SAMPLE C	SAMPLE D
1.	Turbidity (NTU)	6.00	0.00	1.00	0.80
2.	Total suspended solids (mg/l)	5.38	4.92	5.18	4.38
3.	Total dissolved solids (mg/l)	8.42	6.98	7.84	6.84
4.	Electrical conductivity (Us/cm)	95.60	94.74	96.20	76.20
5.	Nitrate (mg/l)	14.20	8.40	11.40	10.40
6.	Nitrite (mg/l)	1.42	0.20	0.93	0.73
7.	pH value	8.09	8.02	8.05	6.05
8.	Iron (mg/l)	1.14	0.04	0.09	0.08
9.	Manganese (mg/l)	1.32	0.24	0.56	0.36
10.	Chromium (mg/l)	1.04	0.02	0.04	0.03
11.	Total hardness (mg/l)	12.28	10.04	11.22	10.12
12.	Total alkalinity (mg	63.80	38.70	44.30	40.30
13.	Copper (mg/l)	1.38	0.07	0.15	0.05
14.	Phosphate (mg/l)	10.90	2.14	6.80	4.80
15.	Total solid (mg/l)	13.80	11.90	13.02	11.02
16.	Iodine (mg/l)	4.20	0.60	0.98	0.58
17.	Colour	Brown	Colourless	Colourless	Colourless
18.	Odour	Unpleasant Smell	Odourless	Odourless	Odourless

Sample A is the raw water, sample B is the treated water using *Moringa* seed kernel, sample C is the treated water using *Moringa* seed coat and sample D (the treated water using aluminum salt).

DISCUSSION

Moringa oleifera seeds treat water on two levels, acting both as a coagulant and an antimicrobial agent. It is generally accepted that Moringa works as a coagulant due to positively charged, water-soluble proteins, which bind with negatively charged particles (silt, clay, bacteria, toxins, etc) allowing the resulting "flocs" to settle to the bottom or be removed by filtration. On the other hand, micro-organisms are removed by coagulation as well as acting directly as growth inhibitors of micro-organisms (Muyibi *et al*., 2002).

Turbidity is the measure of presence of fine negatively charge particulate matter suspended in water (cloudiness), usually reported as nephelometric turbidity units (NTU), determined by measurements of light scattering and reflection rather than from beams transmitted in straight lines. *Moringa oleifera* seed powder as a clarifying agent has an important limitation, i.e., unsuitability for low-turbidity waters <50 NTU (Dorea, 2006). "This may be due to the low molecular weight of the coagulant and the patch mechanism of charge neutralization and floc formation that forms smaller and light flocs" (Bratby, 2006). The seeds are highly effective in the removal of turbidity from surface waters with medium and high to extreme initial turbidities, i.e., >15 NTU to 10,000 NTU (Jahn, 1988). This fact is of paramount importance, especially in the highly turbid conditions experienced throughout the rainy season. It has been experienced that the "level of polyelectrolyte present in the kernels is substantially less during the wet season"; therefore, it is recommended that the seeds "should be harvested during the dry season only" which agrees with the findings of Fuglie, 2000.

The relatively higher turbidity suspended and dissolved solids, brownish colouration and unpleasant odour in Sample A (raw water) could be as a result of poor hygienic condition of the well from which the sample was taken. The turbidity of the water shows the presence of disease causing microorganisms, organic matter and dissolved salt (Shittu *et al*., 2004). *Moringa oleifera* seed kernel and seed coat reduced the turbidity of the raw water sample (with turbidity of 6 NTU) for about 83-100% efficiency, although the seed coat is not as effective as the seed kernel Sample (Table 1). Sample B shows no turbidity, while sample C has turbidity of 1 NTU. These confirm to the standard of drinking water (World Health Organization, 2004). The reduction of the microbial population in the water samples may be due to the presence of the active agent, 4-(4-O-acetyl-á-Lrhamnopyranosyloxy) benzyl isothiocyanate in *Moringa oleifera* seeds, which binds to

charged particulates in the water and settles at the bottom to form flocs (Folkard *et al.*, 1999).

CONCLUSION

Application of plant coagulants such as *Moringa oleifera* is highly recommended for domestic water purification in Nigeria, where people are used to drinking contaminated turbid water. The seed extract has more possessed antimicrobial activities against coliform and faecal coliform, and it can be used as natural coagulant agents in the reducing of suspended materials and microbial inhibition in water. This could be promising to apply these techniques as a household method, especially in rural areas to provide safe and potable drinking water.

REFERENCES

Adedapo, A. A., Mogbojuri, O. M., & Emikpe, B. O. (2009). Safety evaluations of aqueous extract of the leaves of Moringa Oleifera. *Journal of Medicinal Plants Research*, 3(8), 586-591.

Adejumo, B. A. (2014). Annuals. *Food Science and Technology, 15*(2), 246-249.

Ademoroti, C. A. M. (1996). *Environmental Chemistry and Toxicology*. Foludex Press Ltd.

Adeyeye, E. I., & Otokiti, M. K. O. (1999). Proximate composition and some nutritionally valuable minerals of two varieties of Capsicum annum (Bell and cherry peppers). *Discovery and Innovation, 11*, 75-81.

Agarwal, M., Rajani, S., & Mishra, A. (2001). Study on flocculating efficiency of Okro mucilage in sewage wastewater. *Macromolecular Materials and Engineering, 286*(9), 560-563.

Ahmad, J., Khor, B. C., & Suleyman, A. M. (2005). Effects of storage conditions of Moringa Oleifera seeds on its performance in coagulation. *Bioresource Technology, 8*, 35-41.

Ali, M., Khalil, M., Jahan, F., Hossain, M., & Samanta, A. (2022). Moringa Oleifera: A review on nutritional attributes, therapeutic applications, and value-added product generation. *SAARC Journal of Agriculture, 20*(2), 1-15.

Amedorme, S. K., Apodi, J., & Gbezudor, K. A. (2013). Design and construction of forced convection indirect solar dryer for drying Moringa leaves. *Scholars Journal of Engineering and Technology, 1*(3), 91-97.

Anjorin, T. S., Ikokoh, P., & Okolo, S. (2010). Mineral composition of Moringa Oleifera leaves, pods, and seeds from two regions in Abuja, Nigeria. *International Journal of Agriculture and Biology, 12*, 431-434.

Anti-bacterial Evaluation of Moringa Oleifera leaf extracts on Selected Bacterial pathogens. *Journal of Microbial Resistance, 2*(2), 1-4.

Anwar, F., & Bhanger, M. I. (2003). Analytical characterization of Moringa Oleifera seed oil grown in temperate regions of Pakistan. *Journal of Agricultural and Food Chemistry, 51*, 6558-6563.

Anwar, F., Hussain, A. I., Ashraf, M., Jamil, A., & Iqbal, S. (2006). Effect of salinity on yield and quality of Moringa Oleifera seed oil. *Grasas y Aceites, 57*(4), 394-401.

Anwar, F., Latif, S., Ashraf, M., & Gilani, A. H. (2007). Moringa Oleifera: A food plant with multiple medicinal uses. *Phytotherapy Research, 21*, 17-25.

Anwar, F., Sajid, L., Muhammad, A., & Anwarul, H. G. (2007). Moringa Oleifera: A food plant with multiple medicinal uses. *Phytotherapy Research, 21*, 17-25.

AOAC. (1990). *Official Methods of Analysis* (15th ed.). Association of Analytical Chemists.

Arceivala, S. J., & Asolekar, S. R. (2006). Wastewater treatment for pollution control and reuse. Tata McGraw-Hill Education.

Bockstaller, C., Guichard, L., Keichinger, O., Girardin, P., Galan, M. B., & Gaillard, G. (2009). Comparison of methods to assess the sustainability of agricultural systems. A review. Agronomy for sustainable development, 29, 223-235.

Boretti, A., & Rosa, L. (2019). Reassessing the projections of the world water development report. NPJ Clean Water, 2(1), 15.

Crini, G., & Lichtfouse, E. (2019). Advantages and disadvantages of techniques used for wastewater treatment. Environmental chemistry letters, 17, 145-155.

Dong, W., Xie, W., Su, X., Wen, C., Cao, Z., & Wan, Y. (2018). Micro-organic contaminants in groundwater in China. Hydrogeology journal, 26(5).

KhaIafalla, E., Dafata, H. M., Nasaratab, A. A., Abou, H., Tnein, K. M., Lightfoot, D. A., El-Deeb, F. E., & El-Shemy, H. A. (2010). Active principle from Moringa Oleifera Lam leaves effective against two eukaryotes and a hepatocarcinoma. *African Journal of Biotechnology, 9*(49), 8467-8471.

Khor, K., Lim, V., Moses, E., & Samad, N. (2018). The in vitro and in vivo anticancer properties of Moringa Oleifera. *Evidence-Based Complementary and Alternative Medicine, 2018*, 1-14.

Kuang, A., Blasiak, J. S., Chen, S., Bingham, G., & Mary, E. (2006). Modification of reserve deposition in wheat and brassica seeds by synthetic atmospheres and microgravity. *Gravitational and Space Biology Bulletin, 19*, 161-162.

Ladan, M. J., Abubakar, M. G., & Lawal, M. (1997). Effect of solar drying on the nutrient composition of tomatoes. *Nigerian Journal of Renewable Energy, 5*, 67-69.

Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J., & Bertoli, S. (2015). Moringa Oleifera seeds and oil: characteristics and uses for human health. *International Journal of Molecular Sciences, 17*(12), 2141.

Lisa, L. P. (1997). Wild plant food in agricultural environment: A study of occurrence, management, and gathering rights in Northeast Thailand. *Human Organization, 56*, 209-221.

Luqman, S., Srivastava, S., Kumar, R., Maurya, A., & Chanda, D. (2012). Experimental assessment of Moringa Oleifera leaf and fruit for its antistress, antioxidant, and

scavenging potential using in vitro and in vivo assays. *Evidence-Based Complementary and Alternative Medicine, 2012*, 1-12.

Makkar, H. P. S., & Becker, K. (1996). Nutrients and antiquality factors in different morphological parts of the Moringa Oleifera tree. *Journal of Agricultural Science, 311-322*.

Managing water in the home: Accelerated health gains from improved water resources. World Health Organization. Retrieved from www.who.int on June 19, 2016.

Marcu, M. G. (2005). *Miracle tree*. KOS Health Publications.

Matawal, D. S., & Kulack, P. A. (2004). Alternative to chlorination as a water disinfectant: Case study of ultraviolet (UV) radiation. *NJTE, 93-103*.

Mbah, B. O., Eme, P. E., & Paul, A. E. (2012). Effect of drying techniques on the proximate and other nutrient composition of Moringa Oleifera leaves from two areas in Eastern Nigeria. *Pakistan Journal of Nutrition, 11*(11), 1044-1048.

Mbikay, M. (2012). Therapeutic potential of Moringa Oleifera leaves in chronic hyperglycemia and dyslipidemia: A review. *Frontiers in Pharmacology, 3*.

Mepba, H. D., Eboh, L., & Banigbo, D. (2007). Antioxidant activity and total phenolic content of Moringa Oleifera leaves in two stages of maturity. *Plant Foods for Human Nutrition, 64*(4), 303-311.

Monica, G. M. (2005). *Miracle tree*. KOS Health Publications.

Morris, A., Barnett, A., & Burrows, O. (2004). Effect of processing on nutrient content of foods. *Cast Journals and Articles, 37*, 160-164.

Morton, J. F. (1991). The horseradish tree, Moringa Oleifera (Moringaceae) - A boon to arid lands. *Economic Botany, 45*, 318-333.

Moyo, B., Masika, P. J., Hugo, A., & Muchenje, V. (2011). Nutritional characterization of Moringa Oleifera. *African Journal of Biotechnology, 10*(60), 12925-12933.

Muhl, Q. E. (2014). Flowering, fruit growth, and intracellular storage component formation in developing Moringa Oleifera Lam. seed as influenced by irrigation. PhD Thesis, University of Pretoria, Pretoria.

Muller, L. L., Hensarling, T. P., & Jacks, T. J. (1975). Cellular ultrastructure of jojoba seed. *Journal of the American Oil Chemists' Society, 52*, 164-165.

Mutiara, T., Harijono, K., Estiasih, T., & Sriwahyuni, E. (2012). Nutrient content of Kelor (Moringa Oleifera Lam.) leaves powder under different blanching methods. *Food and Public Health, 2*(6), 296-300.

Narasiah, K. S., Vogel, A., & Kramadhati, N. N. (2002). Coagulation of turbid waters using Moringa Oleifera seeds from two distinct sources. *Water Science and Technology, 2*(5-6), 83-88.

NRC (National Research Council). (2006). *Lost crops of Africa: Volume II: Vegetables*. The National Academies Press.

Oduro, I., Ellis, W. O., & Owusu, D. (2008). Nutritional potential of two leafy vegetables: Moringa Oleifera and Ipomoea batatas leaves. *Scientific Research and Essays, 3*(2), 57-60.

Ogunsina, B. S., Koya, O. A., & Omoniyi, T. E. (2011). Characteristics and oil extraction of Moringa Oleifera seed using hydraulic press. *International Journal of Applied Agricultural and Apicultural Research, 7*, 173-181.

Ogunsina, B. S., Radha, C., & Singh, A. K. (2010). Physicochemical and functional properties of full-fat and defatted Moringa Oleifera kernel flour. *International Journal of Food Science and Technology, 45*(11), 2433-2439.

Okunlola, A., Olateju, S. A., & Kumoye, S. A. (2007). The potential of processed Moringa Oleifera seeds as a coagulant in water treatment. *Proceedings of the Water Environmental Federation, 4*, 342-350.

Olayemi, A. B., & Alabi, R. O. (1994). Studies on traditional water purification using Moringa Oleifera seed. *African Study Monographs, 15*(3), 135-142.

Oliveira, J. T. A., Silveira, S. B., Vasconcelos, I. M., Cavada, B. S., & Moreira, R. A. (1999). Compositional and nutritional attributes of seeds from the multipurpose tree Moringa Oleifera Lamarck. *Journal of the Science of Food and Agriculture, 79*(6), 815-820.

Omotesho, O. A., Oyewole, S. O., & Muhammad, R. (2013). The potentials of Moringa tree for poverty alleviation and rural development: Review of evidences on usage and efficacy. *International Journal of Development and Sustainability, 2*(4), 1633-1643.

Onwualu, A. P., Pawa, N. I., & Okoh, E. S. (2006). Postharvest technology generation, dissemination, and utilization in Nigeria. In J. F. Morton, *Economic Botany* (pp. 289-312).

Oseni, T. O., & Sidibé, A. (2002). Traditional leafy vegetables in Senegal: Production, nutrition, and medicinal values. *African Development Perspectives Yearbook, 8*, 39-51.

Osman, M. A. (2004). Changes in nutrient composition, trypsin inhibitor, phytate, tannins, and protein solubility of Dolichos Lablab seeds occurring during germination. *Journal of Food Technology, 2*, 62-68.

Patel, B. R., & Chhibba, I. M. (2009). Performance of Moringa Oleifera under semi-arid condition of North West Rajasthan. *Indian Journal of Horticulture, 66*(3), 403-407.

Quattrocchi, U. (2012). *CRC World Dictionary of Medicinal and Poisonous Plants*. CRC Press.

Raja, W. D. (2001). *Vegetables for human nutrition*. ICAR.

Rajasekaran, A., & Maheswari, E. (2010). Antioxidant effect of Moringa Oleifera along with anticancer drugs in enhancing their therapeutic effect. *Journal of Medicinal Plant Research, 4*(25), 2502-2514.

Ramachandran, C., Peter, K. V., & Gopalakrishnan, P. K. (1980). Drumstick (Moringa Oleifera): A multipurpose Indian vegetable. *Economic Botany, 34*, 276-283.

Randriamananjo, J. M., Rakotonirina, S. V., & Rakotonirina, A. (2007). Screening for antifungal activities of forty-two ethnobotanically selected Madagascan plants. *African Journal of Traditional, Complementary, and Alternative Medicines, 4*(4), 424-432.

Rashid, U., Anwar, F., Ashraf, M., Saleem, M., & Yusup, S. (2008). Moringa Oleifera oil: A possible source of biodiesel. *Bioresource Technology, 99*(17), 8175-8179.

Rout, P.R., Zhang, T.C., Bhunia, P. & Surampalli, R.Y. (2020) Treatment technologies for emerging contaminants in wastewater treatment plants: a review. Science Total Environment, 753, 141990.

Sajfr, R. (2000). Structure, pharmacokinetics, and therapeutic effects of the leaf extract of Moringa Oleifera. *Journal of Pharmacology and Toxicology, 5*(2), 77-85.

Sanchez-Machado, D. I., Nunez-Gastelum, J. A., Reyes-Moreno, C., Ramirez-Wong, B., & Lopez-Cervantes, J. (2009). Nutritional quality of edible parts of Moringa Oleifera. *Food Analytical Methods, 3*(3), 175-180.

Schmidt, R. H. (1988). Basic elements of sanitation in food plants. *Dairy Food Environmental Sanitation, 8*(9), 22-25.

Sharma, P., & Suthar, M. (2012). Plant parts and seeds of Moringa Oleifera: A review on phytopharmacological properties. *International Journal of Pharmaceutical Sciences and Research, 3*(4), 1210-1218.

Sharma, V., Paliwal, R., & Sharma, S. (2011). Phytochemical analysis and evaluation of antioxidant activities of hydro-ethanolic leaf extract of Moringa Oleifera Lam. *Journal of Pharmacy Research, 4*(2), 554-557.

Sidibe, M., & Williams, J. T. (2002). *Moringa*. International Science Publisher.

Sreelatha, S., & Padma, P. R. (2009). Antioxidant activity and total phenolic content of Moringa Oleifera leaves in two stages of maturity. *Plant Foods for Human Nutrition, 64*(4), 303-311.

Talalay, P., & Talalay, P. (2001). The importance of using scientific principles in the development of medicinal agents from plants. *Academic Medicine, 76*, 238-247.

Thurber, M. D., & Fahey, J. W. (2009). Adoption of Moringa Oleifera to combat under-nutrition viewed through the lens of the diffusion of innovations theory. *Ecology of Food and Nutrition, 48*(3), 212-225.

Tona, L., Kambu, K., Ngimbi, N., Cimanga, K., & Vlietinck, A. J. (1998). Antiamoebic and phytochemical screening of some Congolese medicinal plants. *Journal of Ethnopharmacology, 61*, 57-65.

Uhegbu, F. O., Elekwa, I., & Ugbogu, A. E. (2005). Comparative efficacy of crude aqueous extract of Mangifera indica, Carica papaya, and sulphadoxine pyrimethamine on the mice infested with malaria parasite in vivo. *Global Journal of Pure and Applied Science, 10*, 203-208.

Verma, A. R., Vijayakumar, M., Mathela, C. S., & Rao, C. V. (2009). In vitro and in vivo antioxidant properties of different fractions of Moringa Oleifera leaves. *Food and Chemical Toxicology, 47*(9), 2196-2201.