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Moringa Oleifera Seed Extract: A Review on Its Environmental Applications

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Abstract

This review focus on the use of *Mornga oleifera* seed extract and it application in the environment. It is usually referred to as the miracle tree because of its vast usefulness of its various parts. It is a source of protein, calcium, iron, carotenoids and phytochemicals utilized for several usage in developing countries. The plant parts have been used in various application such as medicine, cosmetics, food supplements and water purification. This review presents the various application of *Moringa oleifera* seed extract as an adsorbent, coagulant, dewatering agent and as a disinfectant. This review also highlight the various methods used in processing the seed extracts, different phytochemical and chemical constituents present in the seed extract. Other aspects that require further investigation were also highlighted in this review.

Keywords: *Moringa oleifera*, extracts, adsorbent, dewatering agent, coagulant, disinfectant

INTRODUCTION

The use of natural materials in water treatment is not new as their use dates back to the ancient time. However, lack of knowledge on how they work has impeded their wide application. Recently, researchers have shown an increased interest in the use of plants materials as coagulants and disinfectants that could provide useful insight in water treatment. A number of plant materials studied are *Moringa oleifera*, *Magnifera indica* and *Prunus armeniaca* [1]; *Jatropha curcas, Hibiscus sabdarifa, Pleurotustuberregium* [2–4]; *Azardiratica indica, Solanum melongena, Cynodon dactylon, Alternanthera sessilis, Anisochilus carnosuss, Musa paradisiaca* [5]. Among these plant species, *moringa* species are well documented in terms of their extraordinary nutritional values and their excellent coagulation property. *Moringa oleifera* is the most widely cultivated species of a monogeneric family, the Moringaceae mostly found in the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan. This rapidly-growing tree (also known as the horseradish tree, drumstick tree, benzolive tree, *kelor, marango, mlonge, moonga, mulangay, nébéday, saijhan, sajna* or Ben oil tree), is now widely cultivated in many locations in the tropics [6–9]. It is commonly referred to as the miracle tree because of the multipurpose uses of the plant parts. *Moringa oleifera* seed kernels contain a significant amount of oil that is commercially known as Ben oil or Behen oil which is high in tocopherols [10-11].

Figure 1: *Moringa oleifera* tree [12]

The leaves are very rich in proteins, vitamins, minerals while the roots and other parts are used in traditional medicine [13]. Its husk can be used for making activated carbon. The defatted cake (seed residue after oil extraction) can be used as fertilizer or processed for animal feed [14]. *Moringa oleifera* seeds are round (1 cm in diameter) with a brownish semi-permeable seed hull, with 3 papery wings. The hulls of the seed are brownish to blackish but can be white if kernels are of low viability. The whitish wings of hull run from top to bottom at 120 intervals. Each tree can produce around 15000 to 25000 seeds/year. Average weight is 0.3 gm/seed. The kernel to hull ratio is 75:257 [14]. The most important part used for water treatment is the waste product of the seed i.e. the defatted cake which can be obtained at a very low cost. The crude extract of *Moringa oleifera* seed is commonly used in water treatment and purification [15–20]. Exhaustive literature reviews have shown the usefulness of the seed for water treatment. Earlier researches have revealed its ability to treat high, medium and low turbidity water. It can also be used as a softening agent as well as been as a dewatering agent hence its importance cannot be overemphasized in water treatment. When *Moringa oleifera* is compared with conventional chemical coagulants, it has the following advantages such as cost effectiveness, availability, biodegradable sludge, eco-friendly, low sludge volume, it does not produce harmful by-products, it is easily handled as it is not corrosive, and it does not affect pH of water. In the light of the above advantages, *Moringa oleifera* is environmentally friendly and available at low cost which can be good alternative to chemical coagulants with a potential application in water treatment in developing countries.

PHYTOCHEMICAL CONSTITUENTS IN MORINGA OLEIFERA SEED

A careful examination of the phytochemical constituents present in the seed reveals vast abundant compounds rich in glucosinolates and isothiocyanates [21, 22]. Common phytochemicals found in the seed irrespective of the solvent used in the extraction includes alkaloids, resins, tannins, flavonoids, glycosides etc. An enormous literature has shown that the seeds have been extracted with various solvents, which has led to the presence of different phytochemicals and commonly used solvents are water, ethanol, methanol, etc. Water, being a universal solvent is commonly used in the extraction of phytochemicals from the seed because of its ease of handling of extracts and non-toxicity. Although extracts obtained by using water as solvent has shown to possess antibacterial activity but plant extracts from organic solvent have been found to possess more antimicrobial activity than water extract. Thus the use of other organic solvent such as ethanol, acetone, methanol increases more phytochemicals to be released because they are more effective against cell walls, penetrate cellular membrane to extract the intracellular ingredient, and degrade seeds [23]. Table 1 summarizes the various phytochemicals obtained from *Moringa oleifera* seed extracts from different solvents.

Table 1: Phytochemicals present in *Moringa oleifera* seed

Phytochemical	Extraction solvents			References
	Water	Ethanol	Methanol	
Alkaloids	+	+	+	[21, 24]
Tannins	+			[25]
Flavonoids		+	+	[26]
Saponin		+		[27]
Terpenoids			+	[21]
Glycosides			+	[22]
Steroidal rings			+	[21]
Cardiac glycosides			+	[21]
Crude proteins	+			[25]

where + means available

CHEMICAL CONSTITUENTS OF SEED

The seeds contains *4(alpha-L-Rhamnosyloxy) benzyl isothiocyanate, 4(-L-rhamnosyloxy) phenylacetonitrile, 4- hydroxyphenylacetonitrile*, and *4-hydroxyphenyl-acetamide, 4-(alpha-l-rhamnopyranosyloxy)-benzylglucosinolate Roridin E, Veridiflorol, 9-Octadecenoic acid, O-ethyl-4-(alpha-L- rhamnosyloxy) benzyl carbamate, niazimicin, niazirin, beta- sitosterol, glycerol-1-(9-octadecanoate), 3-O-(6′-O oleoyl- beta-D-glucopyranosyl)-beta-sitosterol and beta-sitosterol-3- O-beta-D-glucopyranoside* [28–31]. Out of these chemical constituent, An active antimicrobial agent ascribed to plant synthesized derivatives of benzyl isothiocyanates known as 4 *(α-L- rhamnosyloxy) benzyl isothiocyanate* was identified from earlier researches and about 8-10% of this compound is present in both defatted (after removing oil) seed and crude seed. This antimicrobial active agent has been reported to exert in vitro bactericidal activity against both gram positive and gram-negative bacteria in raw water. Their structure elucidation is shown in figure 2

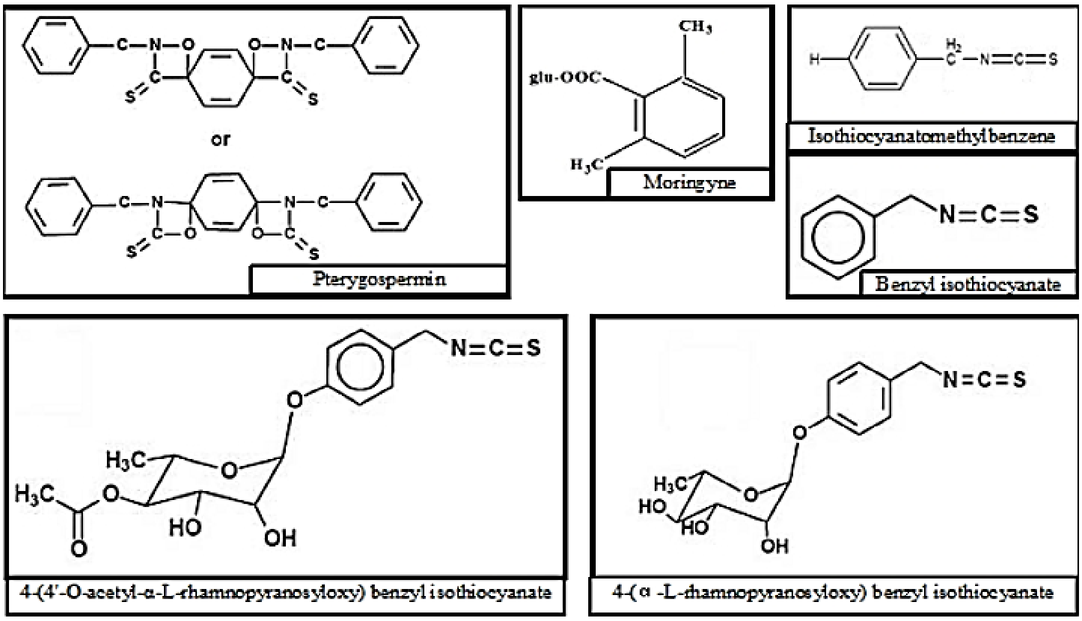

Figure 2: Chemical elucidation of isolated chemical constituent of the seed [14, 29]

PREPARATION OF THE SEED EXTRACTS

Traditionally, in Sudan, *Moringa oleifera* seed extracts are prepared by manually removing the dry seeds from their shells, grinding in mortal and pestle then soaking in water, and finally sieving the solution using a sieve of a particular mesh size or through a Mushin cloth [32] the resulting extract is then used in treating water. This is considered as a low technology of *Moringa oleifera* seed processing because it is suitable for households and the sludge produced can be used as a bio-compost. Over the time, the removal of the seed oil either by organic solvent extraction (by using normal hexane), cold pressing, or steam extraction gained popularity after which the defatted (removal of oil) seed cake extract is used in purifying water. This type of seed processing is considered as medium technology because it is suitable for medium to large communities and there are other by-product such as the oil which can be processed as edible oil, the seed shells can be processed to become activated carbon, and the sludge produced can be used as bio-fertilizer. Ali et al., (2010), introduced an innovative method of processing the seed by further treating the defatted seed cake extract with microfiltration to enhance more isolation of bioactive compounds from the extract before using it to treat water. This is regarded as high technology because extracts obtained from the defatted seeds can further be purified by using ion exchange, membrane system, etc. The solid by-products from these processes can used as animal feeds, the resulting permeate from membrane system can be freeze dried leading to longer shelf life for the seed (see figure 3 below). To date, most research focus on the use of the crude extract for treatment of water, while very few research have been done using the defatted seed extract and membrane processed seed extract for water treatment.

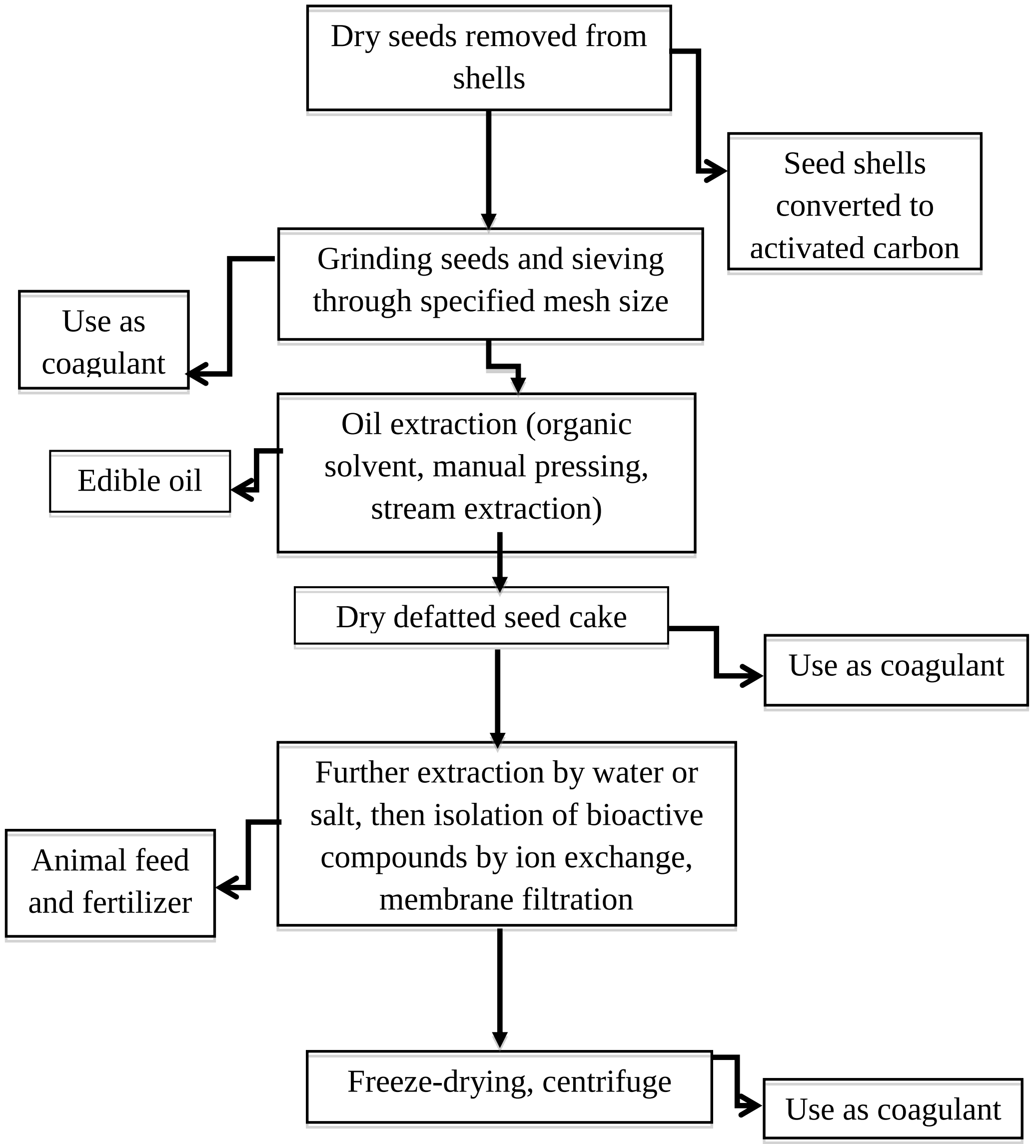

Figure 3: *Moringa oleifera* seed processing techniques

There are six different processing techniques are identified which are the crude water extraction (W), crude salt extraction (S), defatted seed cake with salt extraction (DS), defatted seed cake with water extraction (DW), membrane processed defatted seed cake with water extraction (MW) and membrane processed defatted seed cake with salt extraction (MS). The relevant literature on different processing techniques and their application in the environment reveals that most research focus more on the water extraction which is also called the crude extract as well as the salt extraction, while the other forms of extraction of the seed are yet to be explored. Hence, there are limited literature on techniques for processing of seed extract particularly the defatted seed cake with salt extraction and membrane processed defatted seed cake with salt extraction. These two methods of processing the seed extract have not been investigated and till date no literature are available.

APPLICATION OF SEED IN WATER TREATMENT

Exhaustive scientific literature has revealed the enormous usefulness of *Moringa oleifera* seed extracts for water and wastewater treatment. The use of the seed as a coagulant, disinfectant, adsorbent and dewatering agent are discussed in the following sections.

AS ADSORBENT

Heavy metals are one of the most important pollutants affecting water quality. They have significant toxic effect on human and the aquatic species hence their removal is very essential. A lot of heavy heavy metal find their way in the water bodies due to industrial activities such as electroplating, mining, tanneries, fossil fuel combustiion etc. Several studies have shown that moringa oleifera seeds have excellent adsorbent property which have been utilized for the removal of concomitants such as metals, organic matter and even pesticides. The seed can be modified into various forms either grinded as a dry powder, defatted seed cake (after oil extraction) or the seed husk coverted to activated carbon. These various forms have been evaluated for their adsorption property in removing metals and other organic chemicals. Earlier studies conducted revealed that shelled and non-shelled *Moringa oleifera* seed contains about 37% and 27% of protein [33]. The adsorptive capacity of the seed is due to the presence of proteins, some fatty acids, carbohydrate with contains cellulosic interlinked lignin in their structure. Lignin is a complex bipolymeric heterogenous molecule with different functional groups such as methoxyl, hydroxyl-aliphatic, carboxyl and phenolic groups. It also has aromatic-three dimensional polymer structure with an infinite apparent molecular weight thus favouring biosrption as a promising technique for removal of heavy metal [33]. Metal bisorption occurs using various mechanisms such as chemisorption, complexation, ion exchange, microprecipitation, adsorption-complexation on surface etc. Metal adsorption unto agro-based adsorbents surface occur due to functional groups present in the cell walls of plant. Cellulose, present in the secondary cell wall sorb metals from solution and the metal ions bind either as a result of two hydroxyl groups present in the cellouse/lignin unit or as a results of hydrogen bonds of the metal [34].

According to Sharma et al., 2006, the seed's ability to remove heavy metals were investigated using Fourier Transform Intrared (FTIR) spectrometry that highlighted an amino acids-metal bonding interactions responsible for the sorption phenomenon.

Metals removed from water by using *Moringa oleifera* seed include arsenic, cadmium, zinc, nickel [35–39]. *Moringa oleifera* seed has been shown to remove arsenic from water according to study carried out by [37] in the research, sorption studies in the batch experiment showed that the optimum condition for the removal of arsenic (III) and arsenic (V) was 60.21% and 85.06% respectively. For cadmium removal, 85.10% removal was achieved, for the removal of nickel, 90% removal was achieved .
Selected revelant literature on the use of *Moringa oleifera* as an adsorbent for the removal of heavy metals and organic concominants are presented in table 2 below. The role of moringa oleifera seed in the removal of heavy metal as well as organic pollulant from water cannot be over emphasized.

Table 2 : Selected relevant literature on the use of *Moringa oleifera* seed as adsorbent

Form of *moringa oleifera* seeds	Heavy metals	Outcome	References
Shelled *Moringa oleifera* seed	Arsenic (Ar) (III &V)	60.21%, 85.06% removal of As (III) and As (V) was achieved respectively at dosage of 2g, metal concentration of 25 mg/l, contact time 60 min, volume of test 200ml and pH 7.5 for As (III), pH 2.5 for As (V)	[37]
Shelled *Moringa oleifera* seed	Cadmim (Cd)	85.01% removal was achieved at dosage of 4g, contac time of 40 minutes, metal concetration of 25µg/ml, test solution of 200ml at pH of 6.5	[40]
Seed powder	Silver (Ag)	Optimum conditions obtained were 2g of adsobent dosage, contact time of 20 minutes, pH of 6.5metal concentration of 25 mg/l, test volume of 100ml	[41]
Seed powder	Nickel (Ni)	About 90% removal was achieved.	[42]
Seed powder	Copper (Cu)	Kinetics study was dsecribed to be pseudo-second order mode, optimum removal not discussed	[39]
Seed powder	Lead (Pb)	68.43% removal was achieved	[43]
Seed powder, Residue after coagulant extraction, Activated carbon from seed husk	Chromium (Cr) (III)	97%, 94%, and 99.9% removal was achieved using the whole seed, residue after coagulant extraction and activated carbon from husk respectively	[44]
Seed Biomass	Zinc (Zn)	Over 90% removal was achieved within 40 minutes of contact	[38]
Seed	Manganese (Mn)	Over 95% removal was achieved	[45]

AS COAGULANT

Moringa oleifera seed in different extracted and purified forms has proven to be effective at removing suspended material, soften hard waters, removal of turbidity, chemical oxygen demand (COD), colour and other organic pollutant [46–52]. The proposed mechanism of the active coagulation components in *Moringa oleifera* seed protein is assumed that positively charged proteins attach to parts of surfaces of negatively charged particles through electrostatic interactions. This leads to formation of negatively and positively charged areas of the particle surface. Due to particle collision and neutralization, enmeshment of suspended particles which form flocs with a net-like structure take place [53–56].

The coagulation active agent of moringa oleifera seeds have been established to be protein with cationic peptides of relatively low molecular weight ranged from 6–16 kDa with isoelectric point above pI 10 [57]. Analysis and sequencing of amino acids present in *Moringa oleifera* seed revealed high contents of glutamine, arginine and proline with a total of other 60 residues. The protein peptide has eight positively charged amino acids (7 arginines and 1 histidine) and 15 glutamine residues [58]. Some researches have reported that coagulation efficiency of *Moringa oleifera* seeds can be greatly enhanced by extraction of its active agents with salt solution having one valence electron such as NaCl, KCl etc [59].

In the research conducted by [16], the coagulaton capacity was greatly ehanced to about 7.4 times higher when the coagulative agent was extracted with 1M NaCl than that extracted by distilled water. This improvement was suggested to be apparently due to salting-in mechanism in proteins wherein a salt increases protein- protein dissociations, leading to increasing protein solubility as the salt ionic strength increases [16].

Several studies have reported on the performance of *Moringa oleifera* seeds as an alternative coagulant or coagulant aid for various treatment of water such as turbidity, alkalinity, dissolved organic carbon (DOC), humic acid and hardness removal in raw water [50, 51, 60–64]. Earlier studies have also recommended the use of MO seed extracts as coagulant for water treatment for the removal of various pollutants such as orange 7 dye, alizarin violet dye in water [65, 66]. Recent study [17] carried out colour reduction studies on distillery spent wash using *Moringa oleifera* seeds and optimum colour reduction was found to 56% and 67% using NaCl and KCl salt respectively. It has also been used to treat palm oil mill effluent waste (POME) and dairy industry waste (DIW)[67–69]. Selected application using *Moringa oleifera* seed is shown in Table 3.

Table 3: Selected relevant literature review on *Moringa oleifera* seed as effective coagulant

Pollutant removed	Outcome	References
Sodium lauryl sulphate from aqueous solution	Sodium lauryl sulphate was removed from aqueous solutions up to 80% through coagulation/flocculation process	[47]
Humic acid	Total organic carbon (TOC) and dissolved organic carbon (DOC) were greatly reduced in the water samples containing 9mg/L carbon as humic acid when treated with 1mg/L of the extract	[63]
Dyes (anthraquinonic, indigoid,azoic)	Polynomial regression of the surface plot using the response surface methodology were carried out and the adjusted R^2 was found to be 0.99, 0.94 and 0.74 for anthraquinonic dye, indigoid dye and azoic dye respectively	[70]
Colour removal from distillery spent wash	Optimum conditions for maximum 56% and 67% colour removal using sodium chloride (NaCl) and potassium chloride (KCl) salts respectively.	[17]
Treatment of dairy industry waste	Removal efficiencies of up to 98%, for both color and turbidity, were reached using 0.2 g MO and 0.2 L of 1.0 g/L sorbate solution (DIW	[15]
Removal of water hardness	Water hardness removal efficiency achieved was about 80%	[61]
Removal of suspended solid and turbidity from palm oil mill effluent waste	The pretreatment using *moringa oleifera* seed resulted in 99.2% suspended solids removal and 52.5% COD reduction.	[67]
Removal of low turbidity from water	The turbidity removal was up to 96.23 % using 0.4 mg/L of processed Moringa oleifera seeds to treat low initial turbidity river water between 34-36 Nephelometric Turbidity Units (NTU)	[51]

AS DEWATERING OR SLUDGE CONDITIONER

Treatment of sludge generates water of about 97.5% hence, handling become a difficult task [71]. As a result of the high water content, sludge is usually dewatered before they are disposed finally. Dewatering can be done by mechanical systems such as centrifuge, belt filter presses and gravity drainage or chemical conditioning by using chemicals like alum, ferric chloride and polyacrylamides [72]. In sludge treatment and management, dewatering is one of the important steps in reducing sludge volume which has a corresponding impact on the costs of treatment. Chemical conditioning improves drainage property of sludge but due to their high costs as well as effects on environment, they are fast becoming unpopular. *Moringa oleifera* seeds have been reported to produce sludge that is more compact [52, 72] hence reducing sludge volume. The sludge produced is very biodegradable and can be used as a bio-fertilizer to increase the yield of sample food [12, 72]. Research also revealed that *Moringa oleifera* seed extracts can be used singly in the dewatering process of sludge or can be used together with alum to dewater sludge [77]. Their results revealed that *Moringa oleifera* showed comparable conditioning effect as alum and sludge conditioned with *Moringa oleifera* and alum, in a dual chemical conditioning process, showed better results than *Moringa oleifera* alone. Optimization process conditions using the box-behnken design of response surface methods for the use of *Moringa oleifera* as a sludge conditioner was carried out in a study by Tat et al., [52]. Their result showed that the optimum process conditions were obtained at mixing speed of 100 rpm, mixing duration of 1 min and *Moringa oleifera* dosage of 4695 mg/L.

AS DISINFECTANT

The use of *Moringa oleifera* seed as a disinfectant for drinking water is an emerging yet useful aspect. Although, a lot of literature reviews have revealed its antibacterial property against both gram-negative and gram-positive microbes [4, 26, 73–79], yet its application is channelled into traditional medicine and food. Limited relevant literature reviews are available using *Moringa oleifera* seed as disinfectant for drinking water purposes. However, the research on *Moringa oleifera* seed as disinfectant in water till date was conducted by Bichi et al., [80] which revealed that the seed extracts has a great potential usage as disinfectant. The optimization study using the cube model of the response surface methodology was carried out by Bichi et al., [80] where defatted *Moringa oleifera* crude extract was used as disinfectant in water. The result from the study showed that the optimal conditions were determined as 31 min mixing time, 85 rpm mixing speed and 3.25 mg/mL *Moringa oleifera* dosage. The water kinetics using the seed extracts was also carried out by Bichi et al., [81] in another study that revealed that the kinetic followed a pseudo first order kinetics hence the disinfection of water using *Moringa* seed extract obeyed the Chicks-Watson disinfection kinetics model. The coefficient of specific lethality (Λcw) obtained from the study was determined as 3.76 L mg-1 min-1 for *E.coli* inactivation using *Moringa oleifera* seeds extracts. This is the only study conducted till date on the use of the seed extract as a disinfectant for water treatment, which open up opportunities for various research to be conducted in this aspect.

CONCLUSION

A general overview of *Moringa oleifera* plant, its various uses, different preparation methods as well as the chemical constituents of its seed were elaborated. Also, the advantageous uses of *Moringa oleifera* seed extract as an excellent coagulant, adsorbent, dewatering agent as well as a disinfectant were broadly discussed. However, other aspect worth considering is the study of the effects of the seed shelf life, investigation of the active compounds responsible for the anti-microbial activities and extensive study of the mode of attack of the seed extract on microbes should be assessed.

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