



The characteristics and efficiency of *Strychnos potatorum* as a medicinal plant and water purification agent: a review

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Abstract

Strychnos potatorum (Clearing nut tree) is a deciduous tree with well-known pharmaceutical, medicinal and anthropological uses. Historically, the use of *Strychnos potatorum* as a medicinal plant is well documented in Asianic communities of Eastern India and Myanmar as well as some in Sub-Sahara Africa. Various parts of the plant from seeds to leaves are used to treat different conditions from gastropathy and bronchitis to diabetes, conjunctivitis, and even ulcers. The seeds of *Strychnos potatorum* are also known to be effective in water treatment and purification realms as an effective coagulant and an antimicrobial agent in the treatment of contaminated surface and underground waters. The ripe fruit pulp of *Strychnos potatorum* is also in some areas used as a washing detergent. This makes the plant an untapped vessel for sustainable use in regions where it is abundantly available especially in Sub-Sahara Africa. In this review, the focus is to bring to light the applications of this species and document its uses as well as look at the physicochemical characteristics that suit the plant to these various applications. This is an important natural wealth to the region where the plant is prevalent, in the Chobe and Ngamiland areas in Botswana and northern Limpopo in South Africa.

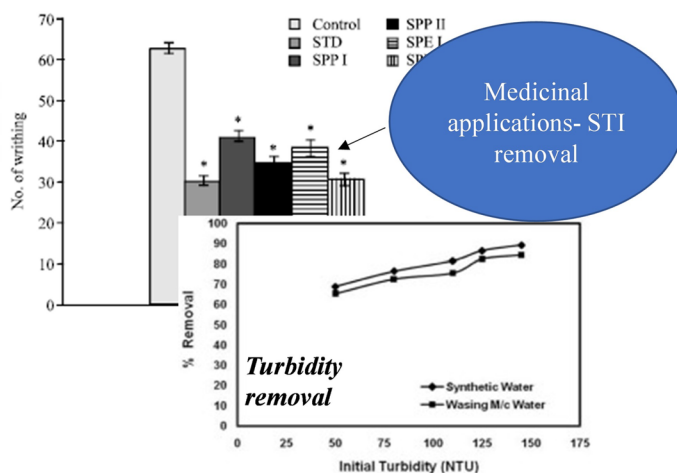
Graphical Abstract



STRYCHNOS POTATORUM



AREA PREVALENCE IN SA



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Introduction

Strychnos potatorum (*S. Potatorum*) Linn.F. is a therapeutic and deciduous tree species that belongs to the Loganiaceae family. It is the only *Strychnos* species endemic to both Africa and Asia. It is an endangered tree mostly found along the riverbanks and dense forests (Leeuwenberg 1963; Mwamba 2006). It is commonly known as clearing nut tree or Grape *Strychnos* and locally (in Botswana) it is known as Morumberumbe in the Subiya language (Mwamba 2006). In India, *S. potatorum* is commonly known as Nirmali and it was used as traditional medicine (Ayurvedic), as a remedy for eye disorders, dermatosis, loss of appetite, diarrhoea, and renal calculi (Kagithoju et al. 2013; Gangwar and Choubey 2017). In Southern Africa, Botswana in particular, the fruit pulps used as soap. The crushed fruit pulp is also used as a fish poison (Mwamba 2006). These exceptional uses of this plant are due to the existence of different secondary metabolites such as alkaloids, sterols, flavonoids, phenols, glycosides, saponins in the plant (Mallikharjuna et al. 2007; Yadav et al. 2014a, b; Vijay and Waman 2015; Sharma et al. 2023).

The ease of use, effectivity, and economic sustainability postulation as well as the physicochemical characteristics of *S. potatorum* like its possession of ethanolic groups makes it a considerable candidate as a medicinal plant. Inhabiting the developing world, exploring its various applications can help transition its traditional uses to large-scale commercial usage for it to be beneficial nationally and regionally. These notable uses include use in the pharmaceutical industries as well as in water treatment. It is duly noted that *S. potatorum* has natural polyelectrolytes which makes it an important coagulant as well as potentially a disinfectant (Babu and Chaudhuri 2005; Mohamed et al. 2014; Vishali and Karthikeyan 2014; Arunkumar et al. 2019; Rajalakshmi et al. 2021). Additional key metabolites found in the plant are strychnine, diaboline, isomotioli, sitosterol, stigmaterol, and compressterol, which are common in the Loganiaceae family (Sanmugapriya and Venkataraman 2006; Mallikharjuna et al. 2007; Chattopadhyay et al. 2022). These are significant in defining the effectiveness of the use of *S. potatorum* in intended applications.

Precisely, this review is purposed to look in detail into these applications, especially in the context of Sub-Saharan Africa, and postulate ways in which efficiency can be improved. This is in lieu of the decreasing water treatment and purification bill for already ailing economies in the region.

Precisely, the review specifically discusses the main uses and biochemical explanations for these uses of *S.*

potatorum based on the physicochemical characteristics of the plant. Taking into account the abundance of plant in the developing world, this natural wealth forms an important research focus and product development for the populace. Mechanisms of both medicinal and water treatment uses are also discussed in this review to give possibilities for further research on possible industrial and traditional uses of *S. potatorum*.

Phytochemical and pharmacological significance

Phytochemistry of *S. potatorum*

The pharmacological significance of medicinal plants is determined by the existence of different secondary metabolites such as alkaloids, sterols, flavonoids, phenols, glycosides, saponins, etc. in the plant (Kamal and Ahmad 2014; Hussein and El-Anssary 2019; Kaushik et al. 2021; Agidew 2022; Rahim et al. 2023). Several investigations so far have revealed the presence of these secondary metabolites from the extracts of roots, stem bark, and seeds of *S. potatorum* (Mallikharjuna and Seetharam 2009; Sanmuga and Venkataraman 2010; Yadav et al. 2014a, b).

In a phytochemical study by Mallikharjuna et al. (2007), secondary metabolites from the extracts of roots, stem bark, and seeds of *S. potatorum* were studied and the presence of alkaloids, flavonoids, glycosides, lignins, phenols, saponins, sterols, and tannins was confirmed. Similarly, in a parallel study by Sanmuga and Venkataraman (2010), the presence of these metabolites was also confirmed. The metabolites play significant roles in treating different illnesses.

Additional phytochemical analysis on seeds using fractionation and High-Performance Thin Layer Chromatography (HPTLC) fingerprinting showed the presence of carbohydrates, alkaloids, steroids/triterpenes, polyphenolics, reducing sugars, saponins, and anthocyanins (Sanmuga and Venkataraman 2010). Phytochemical screening of fruit extracts of *S. potatorum* fruits showed the presence of glycosides, carbohydrates, flavonoids, phenolic compounds, and diterpenes (Gangwar and Choubey 2017). In addition, microscopic characterizations have revealed the presence of calcium oxalate, giving potential uses in ceramic glazes (Sanmuga and Venkataraman 2010). The endospermic tissue of the seeds of *S. potatorum* is also proven to contain large amounts of cuticles on the surface peripheries (Sanmuga and Venkataraman 2010).

The significant quantity of secondary metabolites documented are precursors to many drugs in the pharmaceutical industry and are used as therapeutic oils. They are safer, effective, and economic cost-effective. The increased global



demand for natural multiherbal formulations attests to the potential uses of *S. potatorum* (Kagithoju et al. 2013).

Pharmacological overview

Pharmacological uses demonstrated on *S. potatorum* and based on its chemical constituents include a varied range from antimicrobial, and antidiabetic to antipyretic uses.

Antimicrobial characteristics

Historically, seeds of *S. potatorum* have been employed in traditional and folk medicine in South East Asia owing to the presence of antimicrobial ethanolic elements (Marenga et al. 2022). Alkaloid fractions have been demonstrated to be responsible for the antimicrobial activities (Mallikharjuna and Seetharam 2009). The isolated alkaloid fractions from the seeds of *S. potatorum* are known to have significant antimicrobial activity against both bacteria and fungi (Mallikharjuna and Seetharam 2009). In a disk diffusion method study, the cold, hot and ethanol seed extracts showed antibacterial activity against common bacterial pathogenic strains like *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Enterococcus faecalis* (Thavaranjit 2016).

Compared to other natural antimicrobial herbs like *Ocimum sanctum*, *Triticum aestivum*, and *Phyllanthus emblica*, *S. potatorum*'s antipathogenic efficiency and effectiveness has been demonstrated to be superior (Sanmuga Priya and Venkataraman 2007). For instance, the rate of bacterial inhibition of *S. potatorum* is found to be twice that of *O. sanctum* (Sanmuga Priya and Venkataraman 2007). This is a clear indication that antibiotics and fungicides can be derived from the seeds of *S. potatorum*.

Antidiabetic activity

Several studies have demonstrated the anti-diabetic activity of *S. potatorum* (Raju et al. 2010; Dhasarathan and Theriappan 2011; Mishra et al. 2013; Biswas et al. 2014). Dhasarathan and Theriappan (2011) suggested that the active compounds from *S. potatorum* could be successfully employed in the treatment of diabetes. In their study, they induced the diabetic state of Wistar albino rats by injecting them with alloxan at a dose of 100mg/kg of body weight and the blood glucose levels were assessed (Dhasarathan and Theriappan 2011).

Histopathological investigations in this realm also suggested that ethanolic extracts can reduce serum glucose levels over 21 days at an increased dose (Mishra et al. 2013). From their results, it was clear that the ethanolic extracts from *S. potatorum* play a significant role in combating non-insulin-dependent diabetes mellitus (NIDDM), proving its

importance and possible multi-applications. For instance, 7 days after a 200 mg/ml dose of *S. potatorum* 50% ethanolic extracts caused a reduction of about 20 mg/ml of serum glucose level presence. An increase in dosage amount increases the rate of reduction of the serum glucose level. With diabetes, especially NIDDM) being among the leading cause of mortalities globally (Mishra et al. 2013), it is of high importance to tap into one of the natural wealth in Botswana to try and combat this. It is predicted that by the year 2030, up to 366 million could be affected (Nolte et al. 2008).

Contraceptive and nephroprotective potential

A growing potential use of *S. potatorum* pharmacologically is as a male contraceptive. Gupta et al., (2006) investigated the contraceptive effectiveness of *S. potatorum* seeds' methanolic extracts. Their study was done on male rats of proven fertility. These rats were given a 70% aqueous solution of the methanolic extract from *S. potatorum* orally for 60 days. Parameters such as sperm motility, sperm density, serum testosterone level, biochemical analysis, and testicular cell population were studied. The treatment resulted in a fertility suppression of up to 92% in the rats over three months, owing to a reduction in Sertoli and spermatogonia cells. Ultimately, the study concluded that the plant is capable of suppressing male fertility without altering general metabolism and could be employed in the establishment of male contraceptive agents (Gupta et al. 2006). This is indeed a promising result in family planning, especially for the male population which is by far lagging in terms of having effective family planning means. Nonetheless, regardless of promising initial studies in this realm, further research ought to be carried out to generate a product that can be tested on humans and ultimately bring it forth to the market.

S. potatorum is also known to have some nephroprotective potential. From a study done by Varghese et al. (2011), a dose level of 200 mg/kg/body of ethanolic extract of *S. potatorum* seeds normalized raised blood urea, blood protein, and serum creatinine in rats. The study concluded that the plant possesses significant nephroprotective activity. Again, this highlights the potential significance of *S. potatorum* in curbing acute renal injury resulting from nephrotoxins.

Anti-inflammatory and antiarthritic activity

The versatility of *S. potatorum* in medicine extends to it being a strong potential treatment for inflammation and arthritis. Sanmuga Priya and Venkataraman (2007) evaluated the anti-inflammatory impacts of *S. potatorum* seeds on acute rat models. The study successfully demonstrated that both aqueous extract and seed powder of the plant was able to normalize the augmentation of the base, acid phosphatases as well as lipid peroxide levels. This pointed



to stabilization and free radical searching characteristics. This henceforth leads to the conclusion that the plant can be used as an anti-inflammation remedy.

Antiarthritic activity has also been noticed for *S. potatorum* in several preliminary studies to date. Ekambaram et al. (2010) investigated the antiarthritic activity of Freud's adjuvant-induced arthritic rat model. Their investigation proved that the seeds of *S. potatorum* exhibit antiarthritic activity. Dose levels of 200 mg/kg of both seed powder and aqueous extract were found to normalize the haematological and biochemical aberrations in adjuvant-induced arthritic rats (Ekambaram et al. 2010). However, secondary and tertiary studies still need to be undertaken.

Antinociceptive and antipyretic effects

In Indian and Sub-Sahara African communities, antinociceptive effects of *S. potatorum* have been noted. Traditionally, powdered forms of the seeds have been deployed as pain relief remedies. Experimental investigations of both aqueous and seed powder extracts of *S. potatorum* seeds revealed antinociceptive and antipyretic effects on experimental rats (Sanmugapriya and Venkataraman 2010). Dose levels of 200 mg/kg resulted in significant antinociceptive activity. The drugs also exhibited antipyretic activity in the Typhoid vaccine-induced pyrexia model (Sanmugapriya and Venkataraman 2010).

Hepatoprotective and anthelmintic potential

Sanmugapriya and Venkataraman (2006) investigated the hepatoprotective and antioxidant activities of seed powder and aqueous extract of the seeds of *S. potatorum* against CCL₄-induced acute hepatic and liver injury. Dose levels of 100 and 200 mg /kg of both seed powder and aqueous extract showed significant action by reducing the serum marker enzymes, serum glutamate oxaloacetate transaminase, and serum glutamate pyruvate transaminase specifically. This gives the seeds of *S. potatorum* the capability of being a precursor to the creation of Acetylcysteine.

Anthelmintic potential of the plant has also been explored by Mallikharjuna et al. (2010), who evaluated the anthelmintic activity of crude extracts from root, stem bark, and seeds and alkaloid fractions of *S. potatorum* against a nematode hepatoprotective pathogen. From their findings, all the extracts especially the ethanol extracts resulted in significant anthelmintic activity causing the death and/or paralysis of the parasite. Overall, pharmacologically, the ethanolic extracts are the most efficient extracts in the treatment of various ailments.

Use as a water purification agent

Poor water quality and sanitation are major challenges worldwide (du Plessis 2022). Most preventable morbidity and mortality is a result of water- and food-borne infections (Bodlund et al. 2014). The quality of water is generally defined by its physical, chemical, and microbiological characteristics (Arora 2017; Arunkumar et al. 2019; Omer 2019; Shah et al. 2023). Water that is regarded safe to drink must not contain any chemicals or micro-organisms that could be dangerous to human health (Shatat 2008). Water with finely dispersed and suspended impurities is not easily clarified, resulting in high turbidity and colour (Sharma and Bhattacharya 2017). The coagulation process is one of the most important steps to employ to obtain safe drinking water (Jiang 2015) and the conventional coagulants that are employed in water treatment processes can be subdivided into inorganic and organic coagulants (El-taweel et al. 2023). Inorganic chemical coagulants such as aluminium sulphate and ferric chloride are currently being utilized in the water purification process (Justina et al. 2018). However, the process of obtaining them involves non-sustainable mining and conversion of raw materials and their production is associated with sludge disposal which is not eco-friendly. The use of chemical coagulants in water treatment often results in high metal concentrations in treated water which may be very harmful for consumption (Arunkumar et al. 2019; Ahmad et al. 2022). Natural coagulants like *S. potatorum* have several distinct advantages over chemical coagulants, including the fact that they produce significantly less sludge and are human-safe (Pritchard et al. 2009; Koul et al. 2022; Nimesha et al. 2022; Diver et al. 2023). Noting that the use of chemical coagulants is not sustainable and environmentally friendly, it is therefore of great importance to substitute them with natural coagulants in the face of global sustainable initiatives hence the consideration of *S. potatorum* as a potential coagulant. In most cases, natural or organic coagulants are extracted from bacteria, fungi, plants, and animals (Saleem and Bachmann 2019b). The most promising plant-based coagulants that have been investigated so far are *S. potatorum* and *Moringa oleifera*, with the latter being the most intensively studied among the two (Arunkumar et al. 2019).

S. potatorum seeds have been reported to function as an effective coagulant to clarify turbid waters (Folkard and Sutherland 2002; Deshmukh et al. 2013; Sheeba et al. 2023). According to Ancient Sanskrit from India, the seeds of *S. potatorum* have been employed to clarify muddy surface water over a period of 4000 years (Deshmukh et al. 2013). Thus, this evidence proves that the plant was the first reported plant-based coagulant to be utilized in water



treatment. However, the studies that are concerned about its use as a plant-based coagulant appear to be very limited in the Indian sub-continent (Vijayaraghavan et al. 2011). Recently, natural and surface-modified *S. potatorum* has been widely utilized in the coagulation of suspended matter in water and wastewater treatment (Deshmukh et al. 2013).

Mechanisms of purification

The seed extracts of *S. potatorum* are anionic polyelectrolytes that use inter bridging mechanism to destabilize particles in water (Raghuwanshi et al. 2002; Madhavan and Karpagam 2019; Nimesha et al. 2021; Koul et al. 2022). The presence of macromolecules such as lipids, alkaloids, and polysaccharides in the seeds of *S. potatorum* is believed to be responsible for the seeds' enhanced coagulation efficiency. This is attributed to the existence of $-\text{COOH}$ and free $-\text{OH}$ radicals in the polysaccharides (Sharmila and Subramanian 2019; Yin 2010; Theodoro et al. 2013; Arunkumar et al. 2019). According to Adinolfi et al. (1994), the seed extracts of *S. potatorum* containing polysaccharides moiety of galactan and galactomannan successfully reduced the residual turbidity of artificial turbid water prepared using kaolin clay in distilled water up to 80%. The galactomannan contains 1,4 linked -D-mannopyranosol residues that include many free $-\text{OH}$ groups along the mannose backbone, resulting in inter-particle bridging. Notwithstanding the fact that the exact coagulation mechanism that is associated with the seeds of *S. potatorum* has not been intensively studied, it is logical to deduce that the presence of numerous $-\text{OH}$ groups along galactomannan and galactan chains are responsible for the availability of adsorption sites that are weak but plentiful, eventually leading to the coagulant interparticle bridging effect (Yin 2010; Koul et al. 2022; Panwar et al. 2022).

The polymer bridging mechanism occurs when a long-chain polymer or polyelectrolyte coagulant destabilizes colloidal particles by forming a bridge between them (Morrissey et al. 2020). The polymer coagulant adsorbs numerous particles to the surface of the polymer molecule resulting in the production of strong clusters of macro flocs which are then tied together by bridges (Maćczak et al. 2020; Alazaiza et al. 2022). Figure 1 shows the bridging mechanism.

Comparison of *S. potatorum* seeds' efficacy to other natural coagulants

The list of some of the plant-based natural coagulants that has been studied so far is summarized in Table 1, highlighting the source of wastewater used, optimal conditions and the performance of different coagulants. As aforementioned, *M. oleifera* is the most intensive studied coagulant amongst all other plant-based natural coagulants, it has so far shown to generate soft water which has allowable limits standard levels of minerals and salts as per World Health Organisation (WHO) standards. This can be attributed to its effectiveness in reducing total coliforms, turbidity, hardness, Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), etc. in treated waters. *M. oleifera* successfully removed turbidity, COD, BOD, TSS, TDS and hardness, with removal efficiencies of 61%, 65%, 55%, 69%, 68%, and 25% respectively from municipal water with a dose of 5_g/L (Kumar Kaushal and Goyal 2019). High performance of *M. oleifera* is noticed on high turbidity (100_NTU) (Nephelometric Turbidity Units) with a removal efficiency of 95% as compared to lower (31_NTU)- and- medium turbidity (100_NTU) where the removal efficiencies were 61% and 69% respectively on synthetic artificial water. Furthermore, 96% of total coliforms were removed from the same source of water denoting the seeds not only as a clarifying agent

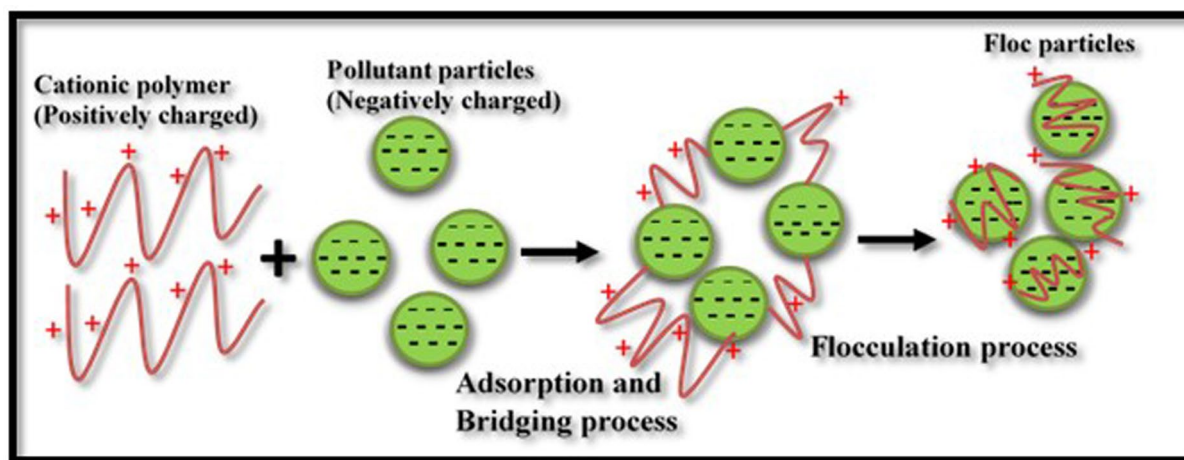


Fig. 1 Bridging adsorption mechanism schematic



Table 1 Comparison of *S. potatorum* seeds' efficacy to other natural coagulants

Type of coagulant	Type of water	Form of Coagulant	Optimised parameters		Parameters studied	Removal Efficiency %	References
			Dosage (mg/L)	pH			
<i>Moringa oleifera</i>	Municipal wastewater	Seeds	5000	–	Turbidity	61.2	Kumar Kaushal and Goyal (2019)
					COD	65.3	
					BOD	55	
					Hardness	69	
					TSS	68	
					TDS	25	
<i>Moringa oleifera</i>	Synthetic artificial turbidity water	Crude extracts of seeds	100	–	Turbidity (low)	61.3	Choubey et al. (2012)
					Turbidity (medium)	69.2	
					Turbidity (high)	95.2	
					Total coliform counts (cfu/100 mL)	96	
<i>Cicer afrietinum</i>	Synthetic artificial turbidity water	Crude extracts of seeds	100	–	Turbidity (low)	71.5	
					Turbidity (medium)	81.5	
					Turbidity (high)	95.5	
					Total coliform counts (cfu/100 mL)	90	
<i>Dolicos lablab</i>	Synthetic artificial turbidity water	Crude extracts of seeds	100	–	Turbidity (low)	60.8	
					Turbidity (medium)	68.9	
					Turbidity (high)	89.4	
					Total coliform counts (cfu/100 mL)	89	
<i>Strychnos potatorum</i>	Synthetic artificial turbidity water	Seeds	40	7	Turbidity	93	Alenazi et al. (2020)
<i>Strychnos potatorum</i>	Ground water	Seeds	20	7	Fluoride content	86	Jayanthi and Akshaya (2022)
<i>Cicer arietinum</i>	Dairy wastewater	Seeds	400	9	Turbidity	74.23	
					BOD	63.2	
					Total Solids (TS)	92.65	Deepa et al. (2022)
<i>Strychnos potatorum</i>	Dairy wastewater	Seeds	800	7	Turbidity	75.62	
					BOD	72.1	
					(TS)	94.7	
<i>Moringa oleifera</i>	Dairy wastewater	Seeds	400	10	Turbidity	65.6	
					BOD	70.9	
					TS	9.35	Ramamurthy et al. (2012)
<i>Strychnos potatorum</i>	Turbid pond water	Seeds	10 ml/L	7	Turbidity	90	
					Total coliform	87	
<i>Tamarindus indica</i>	Industrial waste water	Seeds	400	7.25	Turbidity	97.72	Ayangunna et al. (2016)
					COD	39.55	
<i>Moringa oleifera</i>	Carwash wastewater	Seeds	–	–	Turbidity	94	
					COD	60	
					Phosphorus	81	



Table 1 (continued)

Type of coagu- lant	Type of water	Form of Coagulant	Optimised param- eters		Parameters studied	Removal Efficiency %			References
			Dosage (mg/L)	pH					
<i>Strychnos pota- torum</i>	Carwash waste- water	Seeds	–	–	Turbidity	97			Mohamed et al. (2014)
					COD	60			
					Phosphorus	82			
<i>Moringa oleifera</i>	River water	Kernel of seeds	50			90.46			Gaikwad and Munavalli (2019)
			100	–	Turbidity	88.57			
<i>Strychnos pota- torum</i>	River water	Kernel of seeds	0.2			71.42			
			0.6	–	Turbidity	64.28			
			0.8			57.4			
<i>Moringa oleifera</i>	Synthetic turbid- ity water	Seeds			Turbidity	Low	Medium	High	
			250			82.5	91.2	96.7	
			500	7.4		80.7	88.4	94.2	
			750			76.3	92.1	95.2	
			1000			80.1	93.2	96.3	
<i>Strychnos pota- torum</i>	Synthetic turbid- ity water	Seeds		7.4	Turbidity	Low	Medium	High	Muthuraman and Sasikala (2014)
			250			80.2	90.3	86.5	
			500			85.2	86.8	84.4	
			750			82.3	88.9	88.6	
			1000			84.2	86.7	90.6	

but also as a disinfectant (Choubey et al. 2012). Carwash wastewater was used to investigate the efficacy of *M. oleifera* seeds on the removal of turbidity, COD and phosphorus and the removal efficiencies were 94%, 60% and 81% respectively (Mohamed et al. 2014).

On a comparison done by Choubey et al. (2012) using the seed crude extracts of three different plant-based coagulants namely; *Cicer afrietium*, *Dolicus lablab* and *M. oleifera* using synthetic turbid water. All the coagulants showed a significance performance on high turbidity waters as compared to lower and medium turbid waters. A significant decrease in turbidity from 100 NTU to 3.9, 11.9 and 5.9 NTU was noticed for *C. afrietium*, *D. lablab* and *M. oleifera* respectively and a further reduction to 3.3, 9.5 and 5 NTU after dosing and filtration. Additionally, it was discovered that these natural coagulants decreased 89%–96% of total coliforms (Choubey et al. 2012).

S. potatorum is a crucial promising natural coagulant that has drawn much attention from researchers recently (Arunkumar et al. 2019). In several studies, it has shown similar coagulation properties to that of *M. oleifera* (Mohamed et al. 2014; Muthuraman and Sasikala 2014) and at some instances it performed way much better than *M. oleifera* (Mohamed et al. 2014; Deepa et al. 2022). The eco-friendly

natural coagulants were derived from *S. potatorum* seeds by treating the seeds with 0.5M of NaCl. The filtrate of the solvent-seeds suspension was then used as a coagulant to treat synthetic turbidity water prepared using kaolinite. The research validated the use of *S. potatorum* seeds in water treatment as they successfully reduced kaolinite turbidity water by 93% at optimal conditions of a pH of 7 and a dosage of 40 mg/L after the unit was run for 70 min (Alenazi et al. 2020). Furthermore, the powdered seeds of *S. potatorum* reduced the fluoride content in ground water at a rate of 86%. Also, a reduction in the concentrations of phosphides, sulphides, nitrates, chlorides and sulphates from very high concentrations to very low permissible concentrations in portable water was noted. The study concluded that the seeds could be employed as a potential coagulant in defluoridation of ground water (Jayanathi and Akshaya 2022). In dairy wastewater, the reduction efficiencies of *S. potatorum* seeds were found to be 75.62, 72.1 and 94.7% for turbidity, BOD and total solids. It is noteworthy to mention that the seeds of *S. potatorum* outperformed the seeds of *M. oleifera* and *C. arietinum* which had the removal efficiencies of 65.6, 70.9, 92.35% and 74.23, 63.2, 92.65% for turbidity, BOD, and total solids respectively. However, at a higher dosage of



800_mg/L than that of *M. oleifera* and *C. arietinum* which was 400_mg/L (Deepa et al. 2022).

The disinfectant property of the seeds of *S. potatorum* was proven by treating turbid pond water, a total removal of 87% of total coliform was noticed at a pH of 7 and a dosage of 10 g/L (Muthuraman and Sasikala 2014). In carwash wastewater treatment, the seeds of *S. potatorum* outperformed the seeds of *M. oleifera* with removal efficiencies of 97, 60 and 82% for turbidity, COD, Phosphorus respectively while the removal efficiencies of *M. oleifera* were 94, 60 and 81% for turbidity, COD, Phosphorus respectively.

According to literature, *M. oleifera* is the only plant-based natural coagulant that has been tested on both semi-and full process scale coagulation. Those trials have also demonstrated that water treatment plants using *M. oleifera* as a coagulant are very easy to construct and operate as well as economic viable. In addition, the outcomes of the trials have shown that *M. oleifera* is effective in removing both turbidity and microbial counts (Saleem and Bachmann 2019a). Turbidity removal efficiency of a full-scale trial conducted in Malawi was equivalent to that of alum (Sutherland et al. 1994). Noting that the seeds of *S. potatorum* has demonstrated similar coagulation properties to that of *M. oleifera* on a lab-scale, this is a clear indication that the plant can also be successfully utilized in water treatment on a full-scale. Also, a composite of these two materials has a great potential as *M. oleifera* works best as a disinfectant while *S. potatorum* is a good coagulant and flocculant.

Limitations and relevant modifications to improve efficiency

Although the use of *S. potatorum* as a coagulant in water purification offers numerous advantages as compared to chemical coagulants, its utilization like any other bio-coagulant is still very limited (Vijayaraghavan et al. 2011; Kurniawan et al. 2020). Unlike the chemical coagulants which are easy to acquire, the extraction of active compounds from the plant needs to go through many processes before their application in water treatment. These processes include washing, drying, pulverizing, sieving, dialysis, and the removal of insoluble substances (Arunkumar et al. 2019). These sequential processes that are involved in obtaining the extracts of active compounds that potentially act as coagulants need to be properly carried out. Thus, it is very imperative to simplify these sequential processes in quest of making the utilization of the extracts applicable and readily available. Further research should look into ways to get active compounds into pellets for easier handling and storage, as well as

ways to maintain them for long-term properties (Kurniawan et al. 2020).

There is a high demand for *S. potatorum* as it is therapeutically and economically important (Kagithoju et al. 2013). Overuse and overharvesting of these species led to the drastic reduction of their population and they were declared endangered by Indian Forestry Department (Kagithoju et al. 2013). The reduction of the population of *S. potatorum* was addressed through the use of embryonic culture that improved their viability and germination percentage (Kagithoju et al. 2013). The germination period of *S. potatorum* was 7–11 days. Therefore, it is necessary to perform the embryonic culture of *S. potatorum* in the local environment. Embryo culture produces sterile seedlings that can be used for rapid multiplication of plants that possess the same genetic makeup and are free from diseases and pests (Cobrado and Fernandez 2016). There is a need for propagation techniques that produce multiple plants per explants (seeds, embryos, and buds).

In contrast to chemical coagulants such as iron and aluminium where their coagulation mechanisms are well understood, the respective coagulation mechanism that is associated with *S. potatorum* has not been thoroughly investigated. Thus, further research needs to be conducted in order to understand the respective coagulation mechanisms of the plant (Vijayaraghavan et al. 2011). Another limiting factor is the availability of the plant in larger quantities, unlike the chemical coagulants which are abundant on earth (Kurniawan et al. 2020), *S. potatorum* plant can only be found in few areas around the world (Fern 1997). The application of *S. potatorum* as a coagulant in water purification requires paying attention to the availability of the plant (Kurniawan et al. 2020). This can be alleviated by the cultivation of different varieties of plant in various areas of the world. Cross planting and pollination with related varieties can be instigated to improve acclimatization to different parts of the world. The different characteristics of water also limit the successful utilization of the plant as a coagulant since it affects its working conditions. For instance, the seed extracts of *S. potatorum* have been proved to perform better on high-turbid water than on low-turbid water (Deshmukh et al. 2013; Warriar et al. 2014; Kumar et al. 2016).

To improve the performance of *S. potatorum* in water purification, coupling with large surface area nanomaterials such as graphene and graphene oxide can be undertaken. Owing to the presence of the methanolic, ethanolic, and phenolic functional groups in the seeds of *S. potatorum*, these can be utilized to cojoin the oxygenated functional groups in graphene oxide and also through π - π interactions to form



mechanically strong nanocomposites with improved performance in water purification (Kandjou et al. 2019). Coupling with other naturally occurring herbal plants such as *M. oleifera* is also a possibility. A composite of these two materials has a great potential as *M. oleifera* works best as a disinfectant while *S. potatorum* is a good coagulant and flocculant (Tsie et al. 2020). Most importantly, these plants are also indigenous to Sub-Sahara Africa, Botswana in particular, and therefore pave a way towards harnessing this natural wealth in the Sub-continent. Furthermore, further research should look into advanced technologies for the extraction of active compounds from the plant into powder form for easier handling and storage, as well as ways to preserve them for long-term shelf life. Incorporating into other nano-materials is also a possibility to form enhanced nano-composites.

Modern uses of *S. potatorum*

Medicinal uses

The pulverized seeds of *S. potatorum* are used to treat watering and aching eyes (Saif et al. 2012; Behera et al. 2018). The vapour that is produced by decocting the roots of the strychnos potatorum is used to treat colds and venereal disorders (Gangwar and Chowbey 2017). Epilepsy is also treated with a decoction. The roots of *S. potatorum* have aphrodisiac properties, as a result, they are used to increase sexual desire in humans. The seeds are used to cure a variety of ailments that affect the liver, kidneys, and stomach, as well as gonorrhea, leucorrhoea, bronchitis, chronic diarrhoea, strangury, kidney and bladder stones, diabetes, and eye problems (Fern 1997; Yadav et al. 2014a, b). There is thus a need for industrializing the production and manufacturing of these potential remedies and moving them from solely traditional uses.

Miscellaneous applications

The fruits of the plant are used for consumption as food and can also be preserved for further use (Fern 1997). Then the fruit pulp is used as a soap in Southern Africa and, bark of the plant is used as a fish poison. Further, they can also be used as an ingredient in coffee (Mwamba 2006). However, the wood of *S. potatorum* is used to make carts, shafts, agricultural implements, and tool handles (Fern 1997).

Conclusion

In summation, the article analyses the phytochemical and pharmacological significance of *S. potatorum* plant and its varied parts from the seeds to the seeds, outlining the pharmacological significance of *S. potatorum* plant which are due to the existence of different secondary metabolites such as alkaloids, and sterols, flavonoids, phenols, glycosides, saponins, etc. in the plant. Further it has also highlighted, the use of *S. potatorum* in wastewater treatment and purification, its coagulation mechanisms, limitations associated with the plant and modern uses of *S. potatorum*. The significance of strychnos potatorum has been well explored in this work, henceforth, its research and improved usage can be of benefit to the Sub continent of Sub Sahara Africa. Although the plant has the potential to be successfully used as a medicinal and water purification agent, further research should look into advanced technologies for extraction of active compounds from the plant into powder form for easier handling and storage, as well as how to maintain them for long-term shelf life. For enhanced nanocomposites, it can be incorporated into other nanomaterials.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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