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THE COAGULATION POTENTIAL OF WATERMELON SEED AS A SUSTAINABLE ALTERNATIVE FOR WATER TREATMENT

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ABSTRACT

Water quality conveys ecosystem health, the safety of human contact, the extent of water pollution, and the condition of drinking water. Thus, this research aimed at investigating the effectiveness of watermelon seeds as a potential water purifier in sustainable water treatment because of their adsorbent properties. The seeds treat water by acting as a coagulant, an antimicrobial agent, and enhance the filtration process during water treatment.

Introduction

The right to water entitles everyone to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic uses (CESCR, 2003). However, in Africa, one third of the population (over 780 million people) have no access to safe water, and almost two thirds have no access to sanitation, in spite of the wide recognition of the importance of improved water and sanitation and the heavy investment by international donors and governments in extending water supply systems, thus, leading to widespread of waterborne diseases that cause loss of productivity (UNICEF/WHO, 2012).

In addition, a large section of the population in the developing countries, are dependent on raw water without any treatment for drinking purposes (Enderlin, 1997) and this water source can be polluted by chemicals, agricultural runoff as well as human and animal feaces. Also, unhygienic handling of water during transport or within the home can contaminate previously safe water (WHO, 2007b). The world health organization has estimated that up to 80% of all diseases and sickness in the

An experimental laboratory-scale study using a jar test was conducted on medium turbid water from River Landzun in Bida, Nigeria to carry out coagulation and flocculation on six water samples. Six 1litre beakers with varying measures of ground watermelon seeds from 0.1 - 0.6g at 0.1g interval were filled with turbid water to determine the optimum watermelon seed dosage, pH, stirring time and speed of coagulation on the turbid water to be purified. The stirrers lowered into each jar and the stirring speed was set at 150 rpm for rapid mixing for 2 minutes and 80rpm for 8 minutes for slow mixing. The samples were then allowed to settle and the flocs were filtered using a filter paper and the above-listed parameters were measured on the filtrate. Results obtained showed that the greatest decrease was seen at the dose of 0.1g/L (100mg/l) of raw water, pH of 4.1, with optimal removal of turbidity as1.5 nephelometric turbidity unit (NTU) at optimum speed of 100rpm, and stirring time of 8 minutes were obtained. This result revealed that the coagulant was able to meet WHO recommended standards of drinking water quality valued at<5 NTU. This, therefore, implies that with further optimization, watermelon seed powder can be used as a natural coagulant, an alternative for household-level water treatment in low-income countries.

Keywords: Water treatment, Natural coagulant, Watermelon seed, Sustainable water purification

world is caused by inadequate sanitation, polluted water or unavailability of water nevertheless, 10% of these diseases can be prevented by improving on sanitation, drinking water, and water resource management (WHO, 2008).

However, to purify water that is fit for human consumption, coagulants are formulated to assist in the solids and liquid separation of suspended particles, these particles are characteristically very small and their suspended stability (colloidal complex) is due to both their small size and the electrical charge between them (Salem, et al. 2014). Thus, several techniques like filtration (ceramic and bio-sand), chemical disinfection, chlorination and solar water disinfection (SODIS) are frequently used household water treatment techniques in developing countries (Sobsey et al. 2008) and these have their attendant health effects. Filtration is one of the most important treatment processes used in water and waste-water treatment. It is used to purify the surface water for potable use, while in waste-water treatment, filtration is used to produce effluent of high quality and re-use it for various purposes (Deepika, Dipak, & Anjani, 2013).

Chlorination is also used for microbial water treatment because of effectiveness, affordability, and potential sustainability (WHO, 2002; Hutton & Haller, 2004) and

Lantagne et al. (2011) stated that 1.875 to 3.75 mg/l has been recommended for the treatment of low to high-turbidity water, although, there is no international standard for chlorine dosage in household water treatment. However, research shows that chlorine used in eliminating pathogens and to reduce the risk of infectious disease may account for a substantial portion of the cancer risk associated with drinking water by forming disinfection by-products (DBPs) and more than 250 different types of DBPs have been identified (Sadiq & Rodriguez, 2004). Similarly, aluminum sulfate (Alum), a widely used chemical for coagulation and flocculation, is also reported to affect the nervous system and skeletal problems, with possible connections to several diseases, such as Parkinson's, Alzheimer's (Flaten, 2001), and Lou Gehrig's diseases (Miu et al. 2003; Campbell et al, 2004). Alum also produces large sludge volume (Ndabigengesere, Narasiah & Talbot, 1995) and affects the natural alkalinity of water (Ndabigengesere & Narasiah, 1998). The people at greatest risk due to unsafe water are the elderly, children, and those living under unsanitary conditions (WHO, 2006).There is need for the provision of household water treatment techniques in order to reduce this risk (WHO, 2007a) and a lot of people can potentially benefit from this effective household water treatment. Household water treatment applications are any of a range of technologies, devices or methods employed for the purposes of treating water at the household level (WHO, 2011). It is therefore advantageous to look for cost-effective, safe, efficient, sustainable, and environmentally friendly natural coagulants as alternatives to these chemical coagulants to offset their side effects.

Natural coagulants are usually presumed safe for human health and one of the advantages of using natural plant-based coagulants for water treatment is that, they are cheaper to purchase, they do not produce treated water with extreme pH and they are highly biodegradable. Therefore, natural coagulants and disinfectants can play a vital role in alleviating the challenges facing the water sector on how more people can access clean drinking water in a cost-effective means, especially the rural poor who cannot afford any water treatment chemicals, without affecting their environment (Davy, 2001).

This research, therefore, aim at investigating the effectiveness of watermelon (*Citrullus lanatus*) as a potential water coagulant in water purification, this will be carried out by collecting samples of watermelon seed from different locations, examine their nutritional value, extract oil from the seed using the prescribed method and also examine the coagulation potentials of the crushed seed cake on the river samples.

Review of Literature

Historical accounts of traditionally used medicinal plants depict that different medicinal plants were in use as early as 5000 to 4000 BC in China, and 1600BC by Syrians, Babylonians, Hebrews and Egyptians (Dery, Ofsynia & Ngatigwa, 1999). Considerable indigenous knowledge system, from the earliest times, is found linked with the use of traditional medicine in different countries (Farnsworth, 1994), however, apart from their human health and livestock treatments, plants have been historically used for water treatment and there are evidences to suggest that communities in the developing world have used plant-based materials as one strategy for purifying drinking water (Sarah et al. 2008). Natural coagulants have been used for domestic household for traditional water treatment in tropical rural areas and they are usually presumed safe for human health, indigenous knowledge indicates that there are several plant species that can be used as coagulant and disinfectant (Gebremichael et al. 2005). A few studies have attempted to review the use of plants on water purification, but they focused either on particular plant species (Yongabi, 2010; Bichi, 2013), or on restricted plant parts e.g. the seeds of the plant species (Edogbanya, Ocholi & Apeji, 2013).

A number of effective coagulants of plant origin have currently been identified and have been used over the years, the coagulants include Narmali seeds, Okra, Cassava, Dutchus lablab, Broad beans, Flava beans, Watermelon, Moringa Oleiefera, Maize, *Solanum incunum or* thorn apple,*Ocimum sanctum*, *Azadirachtaindica, Triticumaestivum, Phyllanthus emblica*and *Strychnospotatorum,* Cactus latifaria (Megersa et al, 2014; Ugwu et al, 2017; Hussain & Haydar 2019. Some of the plants are coagulants because they are able to conduct the coagulation mechanisms which are neutralizing the charge in colloidal particles and perform polymer bridging (Amar, 2016; Kristianto, Kurniawan & Soetedjo, 2018). One of the most effective primary coagulants for water treatment, especially in rural communities is *Moringa oleifera* seeds (Gebremichael et al. 2005; Ndabigengesere & Narasiah, 1998; Ali et al, 2010; Sotheeswaran, Matakite, & Kanayathu, 2011; Yahya, Enemaduku, & Eru, 2011). Using natural plant-based coagulants for water treatment is cheaper, and they are highly biodegradable (Kukwa, Odumu, & Kukwa 2017).

The focus of this research work is on *Citrullus lanatus,* which is popularly known as watermelon. Watermelon is a flowering plant that originated from Africa, though there is conflicting research about whether its source is West Africa (Guillaume & Susanne, 2014) or Northeast Africa (Stauss, 2015). Evidence of the cultivation of both *C. lanatus* and *C. colocynthis*in the Nile Valley has been found from the second millennium BC onward, and seeds of both species have been found at Twelfth Dynasty sites and in the tomb of Pharaoh Tutankhamu. Watermelons were cultivated for their high-water content and stored to be eaten during dry seasons, not only as a food source, but as a method of storing water (Stauss, 2015). Watermelon seeds were also found in the Dead Sea region at the ancient settlements of Bab edh-Dhra and Tel Arad (Amar, 2016).

Watermelons (Citrullus Lanatus) are popular seasonal plants in the sub-Sahara and it is a member of the cucurbit family (Cucurbitaceae) which has four distinct parts that include the rind/peel, the seed, the fleshy white and the fleshy red/pink/yellow parts. The seeds can be brown, white green, or yellow and a few varieties are actually seedless (Muhammad et al, 2015).

Figures 1 and 2 shows the collection of watermelons at one of the stalls at St John's schools junction, and the watermelon seeds are shown in figure 3.

Figure 1: Watermelons in the sales stall

Fig 2: Watermelon showing the seeds

The composition of the watermelon seed kernel was determined by (Jesteena & Anitha, 2018) to be 35.7% crude protein, 50.1% crude oil, 4.83% crude fiber, 3.60% total ash, and 5.81% nitrogen free extract approximately, 4.36% of the rind is peel and the other is the inside whitish portion. A study by (Banerjee et al, 2012) revealed that the rind contains 93.8% moisture, 0.49% ash, 0.1% nitrogen, and 2.1% sugars, and that the skin of fully ripe watermelon contains approximately 20% cellulose, 23% hemicelluloses, 10% lignin, 13% pectin, 7mg/g silica, and 12% silica free minerals. Watermelon seed can be used as effective water purifier because of their adsorbent properties and they treat water by acting as coagulants and antimicrobial agents as well as enhancing the filtration process during water treatment (Malunjkar, & Ambekar, 2015; Sciban, Antov & Wasnja, 2006; Banerjee et al, 2012; Muhammad et al, 2015).

Fig 3: Watermelon seeds

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Water Quality

Water quality refers to the chemical, physical, and biological characteristics of water, based on the standards of its usage (Johnson & Ernest, 2011). It is most frequently used by reference to a set of standards against which compliance can be assessed and generally achieved through treatment of the water. The most common standards used to monitor and assess water quality convey the health of the ecosystems, safety of human contact; extend of water pollution and condition of drinking water.

Coagulation

Coagulation flocculation involves the addition of compounds that promote the clumping of fines into larger floc so that they can be more easily separated from the water in water treatment. Coagulation is a chemical process that involves neutralization of charge whereas flocculation is a physical process and does not involve neutralization of charge. The coagulation-flocculation process can be used as a preliminary or intermediary step between other water or wastewater treatment processes like filtration and sedimentation. Iron and aluminum salts are the most widely used coagulants but salts of other metals such as titanium and zirconium have also been found to be highly effective (Chekli et al, 2017). Natural plant extracts for water purification are mostly derived from the seeds, leaves, pieces of bark or sap, roots and fruit extracts of trees Pritchard et al, (2009).

Natural and Synthetic Coagulants

Natural coagulants from plant extracts such as *Moringa oleifera* seeds, Cactus latifaria and *Prosopisjuliflora* are used in water treatment for human consumption. It is verified that active coagulant agents in plant extracts are proteins because of their ability to tightly bind with other molecules and recent study confirms that watermelon (*citrulluslanatus*) seed is a potential natural coagulant for water treatment because of its high protein content, B vitamins, minerals (such as magnesium, potassium, phosphorous, sodium, iron, zinc, manganese and copper) and fat among others (Muhammad et al, 2015).
In contrast, the synthetic coagulants such as aluminum-based coagulants have shown negative effect on humans such as the development of Alzheimer's disease resulting from high amount of aluminum remaining in treated water; monomers of some synthetic organic polymers are neurotoxic and pose strong carcinogenic properties which are peripheral nerve toxins that affect humans and animals. Synthetic coagulants are known to produce large amount of sludge and altering the chemistry of the treated water, thereby changing its pH value. Hence, this study is aimed at the characterization of watermelon seed as a potential coagulant for water treatment Rajasree et al, 2016).

Advantages of Plant Coagulants and Disinfectants

Natural coagulants and disinfectants have enormous advantages in water treatment because they produce less sludge volume compared with Alum (Ndabigengesere, Narasiah & Talbot, 1995; Blix, 2011) and require no pH adjustment (Ndabigengesere, Narasiah & Talbot, 1995). They are low cost water treatment technique (Gebremichael et al, 2005) and a number of useful products may be extracted from the seed. In particular, edible and other useful oils may be extracted before the coagulant is fractionated, residual solids may be used as animal feed and fertilizer, while the shell of the seed may be activated and used as an adsorbent. The coagulant is thus obtained at extremely low or zero net cost (Gebremichael et al, 2005). Usage of natural products also reduces the formation of disinfectants that deteriorate human health and their by-products are organic and biodegradable and reduced risk of handling (Ndabigengesere, Narasiah, & Talbot, 1995; Ozacar & Ayhan, 2002; Yongabi, Lewis & Harris, 2011a).

Performance of Plant Species on Turbidity

Various literatures reported that plant species have capability of turbidity reduction, although their performance varies. The quantity of the plant required depends on turbidity ranges mean, that is, as initial turbidity of water sample increases; the required optimum dosage of coagulant also increases (Katayon et al, 2006). All the reported natural coagulants were more efficient in higher turbidity ranges than lower and medium turbidity waters either in artificially prepared or natural turbid raw water from surface and ground water (Nkurunziza, Nduwayezu, Banadda & Nhapi, 2009; Asrafuzzaman, Fakhruddin & Alamgir, 2011; Yongabi, Lewis & Harris 2011b; Mangale, Chonde & Raut 2012a; Mangale, Chonde & Raut 2012b). The residual turbidity decreases to a certain dosage of natural coagulants, which is referred to as the optimized dose and above the optimum, it results in increased turbidity (Blix, 2011). For example, the result of (Kihampa, Mwegoha, Kaseva, & Marobhe, N. 2011) shows that the extracted dose of *Solanum incanum*displayed an optimal dose of 2 ml (2 × 10-5 g/ml) for treating turbid water samples of initial turbidities of 450, 300 and 105 nephelometric turbidity unit (NTU). The corresponding average percentage removals were 99.78, 99.11 and 97.14 at residue turbidities of 1, 2.67 and 3 NTU, respectively and (Shilpa, Akanksha, & Girish, 2012) reported the optimum dosage of *Opuntia ficusindica*and *Dolichos lablab* as 20mg/L, removal efficiency was found to be 89.03% and 77.10% respectively. Increasing dosage of coagulants beyond certain limit does not improve the removal of turbidity; but rather this significantly increases the residual turbidity of the coagulated sample (Katayon et al, 2006). Researches indicated that plant coagulants even showed a better coagulation effect than synthetic coagulant counterpart like Alum (Kihampa, Mwegoha, Kaseva, & Marobhe, N. 2011; Yongabi, Lewis & Harris, 2011b).

Materials and Methods

The data for this study were obtained from primary and secondary sources. The primary source was from Collection and Preparation of Coagulants while the secondary data were obtained from related literatures.

Materials

Materials used include watermelon seeds, watermelon seed cake (coagulant), N- hexane, Landzun river water in Bida, Niger State, Nigeria, distilled water, Soxhlet extraction apparatus, digital Ph meter, electronic weighing balance, thermometer, drying oven, beakers, turbidimeter, conductivity meter and stop watch (timer). All reagents used are of analytical grades.

Method

The research method used for this study is experimental research design; this was conducted in laboratory to assess the potentials of natural coagulants and disinfectants in turbidity and microbial load reduction for drinking water. Fresh seed of watermelon (*citrulluslanatus)* of the cucurbitaceae family as shown in Fig.2 were obtained from fruit depot at the front of St John's Schools, Esso in Bida, Niger State, Nigeria. The seeds were washed severally with distilled water, sun-dried for a week, sorted and shelled. 150g of watermelon seed were ground with a high-speed laboratory electric blender. The crushed seeds were then packed in a thimble and placed in a soxhlet extraction apparatus, 500ml of the n-Hexane was used to extract oil from the crushed seed in the column. The apparatus was left running for about six hours and stopped when the extraction was complete. The cake was later washed with distilled water to remove n-Hexane residual, dried in an oven and sieved. The finer particles were then used as the coagulant.

Collection of water Sample

The water sample was collected with a plastic container from the post office market side of river Landzun in Bida, Niger State, Nigeria. The water was then treated using the prepared coagulant.

Determinants of Physical and Chemical Parameters of the water sample

a. Turbidity

Turbidity of the water sample was measured before and after treatment using a turbidimeter in accordance with the international standard of water quality measurement and the results recorded.

b. Total Solid

Six samples of the raw water were taken in 1litre beaker each. A clean and dry empty crucible was weighted and the samples were then poured into it and re-weighed. The respective weights were recorded and the crucible with the sample water was then placed on a hot plate at 104^oC to evaporate the water. When all the water evaporated, the crucible was allowed to cool down and reweighed together with the residue.

The total solid present was then calculated using the equation:

TS = 100(A – B)/200ml Where:

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A = weight of (crucible + water) - weight of crucible empty
B = weight of (crucible + residue)

c. Total Suspended Solid (TSS)

Sample of the raw water was put in a sample bottle. The weight of a dry filter paper was taken empty and the sampled water was then filtered and the residue dried at 35-40°C in an oven. The new weight of the filter paper plus residue is then taken. The difference in the weight of the empty filter paper and with residue after drying was calculated and divided by total volume of sample.

d. Total Dissolved Solid (TDS)

This was obtained by taking the difference between TSS and TS or two-thirds of the conductivity using the conductivity meter. It is a measured as a volume of water with the unit as milligrams per litre(mg/l) or also as parts per million (ppm).

e. pH

The pH of the samples was taken using an electronic pH meter.

f. Colour

The colour of the water sample was observed before and after treatment using a turbidity meter.

g. Jar test

The jar test apparatus was used to carry out coagulation and flocculation on the water samples. Six 1litre beakers were used to study the effect of coagulant dosage on coagulation, the effect of pH on coagulation and the effect of stirring time and speed on coagulation.

The following parameters were then measured on the filtrate after the coagulation was completed: Turbidity, Colour, Flocs weight, TDS and Conductivity. Six different weights of the coagulant were placed in six beakers of I litre each, the first having 0.1g or 100mg, and the remaining five varying from 0.1g to 0.6g at 0.1g interval in order to determine the optimum dosage. The jars were placed in the jar test kit with stirrers lowered into each. The stirring speed was set at 150rpm of rapid mixing for 2 minutes and 80rpm for 8minutes of slow mixing. After this was completed, the samples were allowed to settle and the flocs filtered using a filter paper and these parameters (Turbidity, Colour, Flocs weight, TDS and Conductivity) were measured on the filtrate. From the results obtained the dosage with the best results in colour and turbidity removal was taken as the optimum.

Results and Discussion

Table 1 shows the initial figures of different testing parameters of the sampled water before the ground melon seed was added, the temperature was 36°c, pH was 4.84, conductivity in µS/cm was 140, total dissolved solids in mg/L was 3, turbidity in NTU was 5 while the colour in TCU was 50.

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Table 1: Initial Raw Water Properties

No	Parameter	Initial Result
1	Temperature (oC)	36.0
2	pH	4.84
3	Conductivity (µS/cm)	140
4	Total dissolved solids (mg/L)	3.00
5	Turbidity (NTU)	5.0
6	Colour (TCU)	50.0

Source: Authors' Fieldwork, 2021

When the sampled water was treated with varied quantities of watermelon seeds in order to test for the potency of coagulation properties, the result derived is shown in table 2. The dosages were varied from 0.1g/L to 0.6g/L for each sample treated. The settling time of 15 minutes was used and the samples filtered as longer time periods were observed for complete settling to take place. At varying dosage, changes were observed on the pH value, at 0.1g/L, the pH value was 4.1, while it changes to 5 in the beaker with 0.6g/L of melon seed, this shows that coagulation is better in an acidic medium. There was a notable decrease in the temperature, conductivity, TDS and turbidity of the water sample after treatment. The observation on pH and conductivity made in this present study were in accordance with other previous studies on coagulation and flocculation ability of some seeds. The greatest decrease in turbidity was seen at the dose of 0.1g/L of raw water, which reduced the turbidity from 5.0 NTU to 1.5 NTU. This value is still above the WHO recommended level of 5.0 NTU, however, according to Arnoldsson, Bergman, Matsinhe, & Persson, (2008), the optimal dosage for a specific water is defined as the dosage which gives the lowest turbidity in the treated water, therefore, the optimum dosage of watermelon seed for water purification in this research is 0.1g/L.

Table 2: Result of the Effect of Coagulant Dosage on Water Samples

S/No	Dosage (g/L)	Temperature (oC)	pH	Conductivity (µS/cm)	TDS (mg/L)	Turbidity (NTU)	Colour (TCU)
1	0.1	28	4.1	13.1	11.2	1.5	63
2	0.2	29	4.3	13.3	12.5	1.8	70
3	0.3	30	4.4	13.5	12.9	2.4	75
4	0.4	31	4.6	13.6	13.2	2.9	76
5	0.5	33	4.7	13.7	13.8	3.3	77
6	0.6	35	5.0	13.8	14.5	3.5	78

Source: Authors' Fieldwork, 2021

Table 3 shows the result of the optimum dosage of watermelon seed for water purification in the experimental research in comparison with the WHO standard. The result show that all the parameters are within WHO limits.

Table 3. Comparison of the experimental data with the WHO recommended limits for potable water

Parameter	Before treatment	After treatment	WHO standards
pH	4.84	4.1	6.5-8.5
Temperature (°c)	36	28	<10.0
Colour (TCU)	50	63	0.3
NTU	5	1.5	5
Conductivity(µS/cm)	140	13.1	<400

Sources: Authors' Fieldwork 2021 and WHO Standard

Conclusion

From the study, the result of watermelon seeds as a coagulant to treat the raw water from Landzun river were obtained on pH, dosage, stirring speed and time on six samples respectively. However, the optimum result was the sample with coagulant dosage of 0.1g/L, optimum speed at 100rpm, and stirring time of 8 minute. A significant reduction in turbidity and, temperature pH was observed after treating the water. Turbidity reduced from 5 NTU to 1.5 and temperature from 36°c to 28°C pH. The coagulation of water melon seed revealed a minimal change on the pH of the river water samples from 4.84 to 4.1 after treatment. From the results obtained, watermelon seed has been found to be very useful for water purification. Since it is a potential natural coagulant, watermelon seeds can thus, be used for surface water treatment. It is affordable for both the people in the urban areas who make use of surface water for their domestic chores and especially for people in the rural communities. This is because the seeds are readily available and the process of the alternative water treatment is sustainable and does not involve high-cost technology.

Recommendations

It is therefore recommended that:

- Watermelon seeds should be used for sustainable water purification since it is natural.
- The masses especially in the rural settlements should be enlightenment on the water purification potentials of watermelon seeds; this can be done in town hall meetings.

- There should be wide education on the proper processing and handling of the seeds for water purification.
- Interested people should also invest in improved method of mass extraction to reduce the rigour of individual constant processing of the watermelon seeds. This will ensure continuous availability of hygienic seed powder rather than relying on crude extraction.
- Other natural coagulants of plant sources should moreover, be investigated for their active components to ascertain their potential coagulation abilities.

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