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Potential of *Moringa Oleifera* Seed as a Natural Adsorbent for Wastewater Treatment

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Abstract

The present study deals with the appropriateness of the coagulation process using natural coagulant *Moringa oleifera* seed. Natural coagulants are useful for the treatment of wastewater because of its sustainability, cost-effectiveness, non-toxicity and lesser quantity of sludge formation. *M. oleifera* seed having a chemical composition of polypeptides having 6 amino acids like arginine acid, methionine acid, glutamic acid, phenylalanine, threonine, and histidine. *M. oleifera* is also known as a cationic polyelectrolyte and having molecular weight 6,000 to16,000 Dalton. The main objective of research work is the application of the *M. oleifera* seed as a natural adsorbent to treat synthetic dairy wastewater. The effects of pH, agitation time, the dose of sorbent and efficacy of *M. oleifera* seeds kernel for turbidity removal was assessed. *M. oleifera* seed eliminates turbidity 95 % and colour 94 % using 0.22 gm pod powder, and 0.2 L of 1.0 g/L synthetic dairy wastewater. Naturally dried *M. oleifera* seeds remove turbidity 95 %, sundried seeds remove turbidity 52 % and oven-dried seeds 45 %. As naturally dried *M. oleifera* pod having more surface area for adsorption and inter-particulate bridging which extract the extra active ingredients. pH range between 5 and 8 is more suitable to degrade the turbidity and colour. It is concluded that in the presence of an aqueous soluble cationic coagulant protein has great potential to remove the turbidity and colour of wastewater.

Keywords: *Moringa oleifera (M. oleifera)*, Bio-sorption, Chemical oxygen demand (COD), Turbidity, Coagulation

Introduction

M. oleifera is a tropical plant from the family of Moringaceae, that is cultivated rapidly in the arid zone and has an average height of 10 - 12 m, commonly known as moringa, drumstick [1]. Dry seeds of *M. oleifera* are water-soluble and is used as a natural coagulant to treat effluent and turbid water on a large scale [2]. *M. oleifera* is a medium size multipurpose tree found in northwest India and native to various parts of Asia, South America and Africa [3]. Pods of *M. oleifera* are non-hazardous and can be utilized as an economical and effective sorbent for the elimination of organics [4]. Application of alum and lime is a conventional coagulant used for water treatment worldwide. If other chemical such as sodium hydroxide is implemented to treat the water the total cost increases annually which is quite difficult for developing countries to cope with [2,5]. The natural coagulants are extremely efficient in degradation of Physico-chemical properties of wastewater like chemical oxygen demand, biochemical oxygen demand, turbidity, colour, etc [1,6]. Planted-based coagulants such as Moringa oleifera, Cactus and Strychnos potatoru are effective coagulants. **Table 1** illustrate that the efficiency of *M. Oleifera* seeds to treat turbidity of various wastewater.

Table 1 Efficiency of *M. Oleifera* seeds to treat turbidity [30].

Wastewater	Initial turbidity in (NTU)	Coagulant dosage	Turbidity removed (%)
Irrigation	< 50 - 50	MOC-DW 3 - 5 % w/v 20 - 120 mL/L	94 - 99.5
Dairy industry	85 - 145	0.75 - 1.24 g/L	98
Synthetic	10 - 1,000	MOC-SC 5 - 50 mg/L	50 - 99.4
Color water	47 - 48	MOC-DW 100 - 500 mg/L	92
Synthetic	200	MOC-SC 20 - 30 mg/L	93 - 96
Synthetic	105	500 mg/L	98
Raw wastewater	184 - 226	MOC-DW 4 mL/L	80
Synthetic	25	MOC-SC 20 - 200 mg/L	57.9
Synthetic	30	MOC-SC 50 - 1,000 mg/L	78.1
Tanning wastewater	121.9	10 - 50 mg/L	71 - 76
Dye industry	64.2 - 102	0 - 50 mg/L	45 - 95
Food industry	266.9	0 - 60 mg/L	40 - 90
Distillery industry	499 - 510	20 - 80 mL/L	99

The application of these natural coagulants reduces sludge volume by increasing the floc size, as they are having properties like long-chain polymer, high cationic charge density, high biodegradability, non-toxic, and eco-friendly [2,7]. To achieve this sustainable development, it is necessary to put into service the plant-based natural coagulant [3,8]. It is an eco-friendly and cheaper method for purification of industrial wastewater as compared to common coagulants like alum [2-4,9]. **Table 2** shows the comparison between chemical (common) coagulant and natural coagulants.

Table 2 Comparison between chemical (common coagulant) and natural coagulants.

Parameters	Chemical coagulant	Natural coagulant
Quantity	More coagulant dose is required	Less amount dose is required
Efficiency	More dose of coagulant leads to more dissolved solids	Natural coagulants are not leading to formation of dissolved solids
Toxicity	Extremely toxic	Non-toxic
Sludge	Sludge generated on a large scale	Small quantity sludge generated
Removal of heavy metals	Heavy metals cannot be eliminated	Heavy metals can be settled with coagulants
pH	Significant changes in the pH	No significant variations in the pH
Financial scheme	Costly	Economical, easily available

To eliminate colloidal particles from wastewater numerous conventional methods were used, such as coagulation, flocculation, flotation, solvent extraction, adsorption, ion exchange, membrane filtration, precipitation, and biological methods [10]. The coagulation/flocculation process draws attention for the elimination of dissolved, colloids, suspended and organic matter present in industrial effluent [4,6,10,11]. Extraction of *M. oleifera* was more efficient than $FeCl_3$ to degrade the *Clostridium perfringens* spores extensively [7,12]. Moringa oleifera seed and powder are competent to treat textile wastewater and also can be effectively used in purification of groundwater [8,13]. *M. oleifera* coagulant protein act as a coagulant to minimize the alkalinity and hardness of turbid water [9,14]. By the application of chemical coagulant, sludge is generated on a large scale and disposal of this toxic Sludge is a major problem in current circumstances. **Table 3** shows the basic advantages and limitations of chemical coagulants.

Table 3 Synthetic/inorganic coagulants advantages and disadvantages.

Sr. No	Coagulants	Advantages	Disadvantages
1	Aluminium sulphate (Alum) $Al_2 (SO4)_3 . 18H_2O$	Commonly practiced on a bulky scale, easy to operate and handle. Generates a lesser quantity of sludge than lime. Competent for pH 6.5 and 7.5	Competent for limited pH range. Dissolved solids salts were enhanced in water.
2	Sodium Aluminate $Na_2Al_2O_4$	It requires normally small dosage. More effective to eliminate the hardness of water.	Costly, ineffective for soft water.
3	Polyaluminium Chloride (PAC) $Al_{13}(OH)_{20}(SO)_4 . Cl_{15}$	Rapid floc formation and faster settling than alum.	Unusually utilized, little full-scale data compared to other aluminium derivatives
4	Ferric Sulphate $Fe_2(SO_4)_3$	Effective when pH 4 - 6 and 8.8 - 9.2	Generally, need to add alkalinity
5	Ferric Chloride $FeCl_3 .6H_2O$	Effective when pH 4 -11	Consumes more alkalinity as alum
6	Ferrous Sufate (Copperas) $FeSO_4 .7H_2O$	Moderate effect of pH	Percentage of dissolved solids salts enhanced in water.
7	Lime Ca $(OH)_2$	Commonly utilized, effective, may not add dissolved solids salts to effluent.	Depend on pH, produces huge amounts of sludge, excess dose is not effective.

Oleifera is a cost-effective, environment-friendly, simple, flexible, reliable water to treat low and high turbid water [10,11]. Aluminum sulphate is extensively utilized globally as a common coagulant, however, the application of aluminum sulphate as coagulant leads to Alzheimer's disease which is integrated with aluminum in the water intended for human consumption. By the application of aluminum as a coagulant generates sludge on a large scale and it required supplementary treatment to dispose of the sludge [12,13]. **Figure 1**, shows the Efficiency (%) of *Moringa oleifera* and Aluminum Sulphate. Water treatment cost will be increased to adjust the pH of the water. This can be achieved by using high concentration of alum dose. [14,15]. The shelled *M. oleifera* seeds reveal an ample potential for being exploited as an inexpensively feasible and native pre-treatment approach in the present technology of wastewater treatment [14,16]. In order to sort out issues related to chemical coagulant like formation of fog, adverse reaction etc, numerous studies were made. It is found that the natural coagulants are more beneficial, effective. These natural coagulants are extracted from microorganisms, animals or plants [17]. *M. oleifera* pods are indigenous, economical and are easily available in huge quantities as raw material that can be used for various industrial appliances to lower the cost of effluent treatment [18]. The seeds of ~~a~~ variety of species restrain cationic polyelectrolytes which proved to be efficient in the treatment of water, as a substitute for aluminum sulphate [19]. Parts of *M. oleifera* tree is rich in nutrients (protein, vitamins and minerals) and has numerous applications in medical sector. So, the tree is known as miracle tree [20]. The application of chemical coagulants exhibited the main disadvantages of pH adjustment and high operating cost [21]. *M. oleifera* is eco-friendly, biodegradable, non-corrosive, and there is no toxic effect once the dose of coagulant is used for wastewater treatment [22-26].

The objective of the study was to minimize different parameters of wastewater quality such as turbidity, colour, COD using the varied doses of *M. oleifera.*

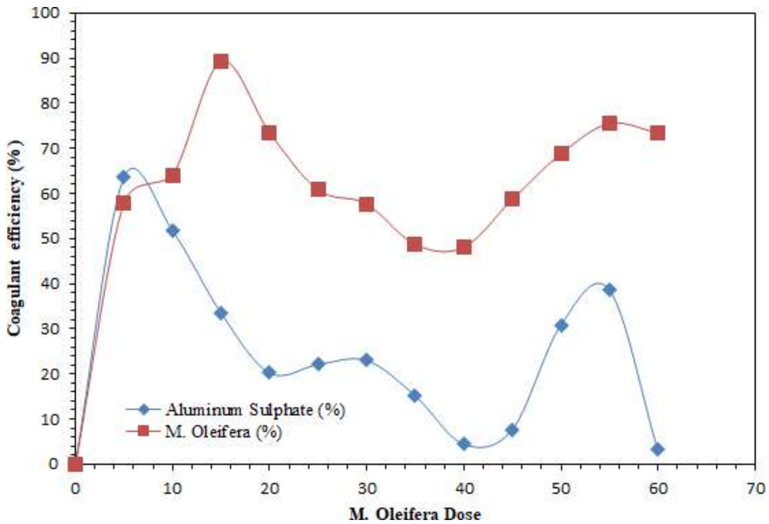

Figure 1 Efficiency (%) of *M. oleifera* and aluminum sulphate.

Material and methods

M. oleifera seeds were collected locally from Ahmednagar, Maharashtra, India. Best quality dry brown seeds were selected and the seed was crushed to ~~a~~ fine powder using a regular electric blender. Powder is then sieved using 250 µm sieve and weighted using an analytical balance. There are 3 main processes involved in preparation of *M. oleifera* seed coagulants are flour (seed powder), extraction of protein and purification [30,35]. Steps involved in preparation of seed powder enhances the performance rate [30]. **Figures 2** and **3** shows the main process involved in the preparation of seed powder. For extraction of coagulant of about 2 gm *M. oleifera* seeds powder was added to various salts NaCl, KCl, $NaNO_3$, and KNO_3 in several concentrations. Magnetic stirrer (REMI (Model, 2MLB)) was used to mix the mixture for 0.5 h at room temperature. The supernatant was filtered by using Whatman paper 42, and the residual was dried at room temperature for 24 h [21,27].

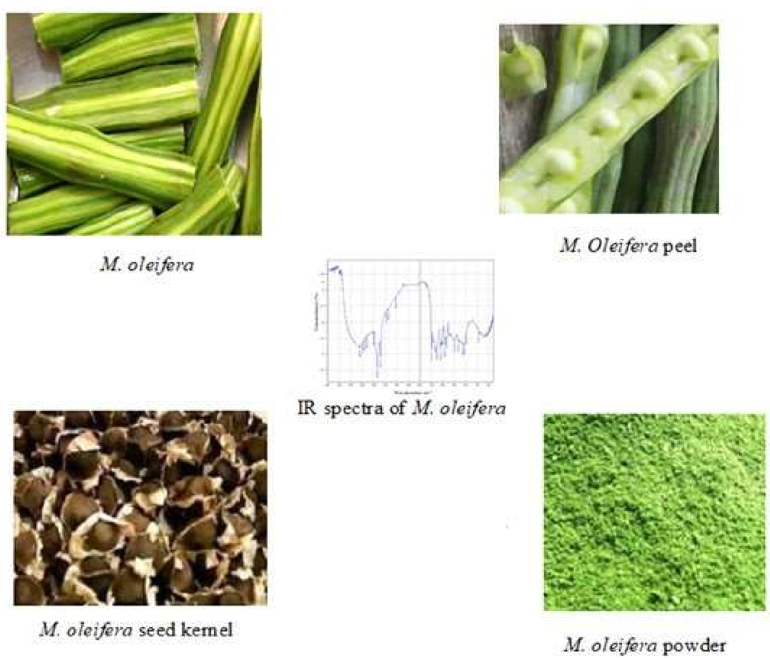

Figure 2 Main process involved in *M. oleifera* seeds processing.

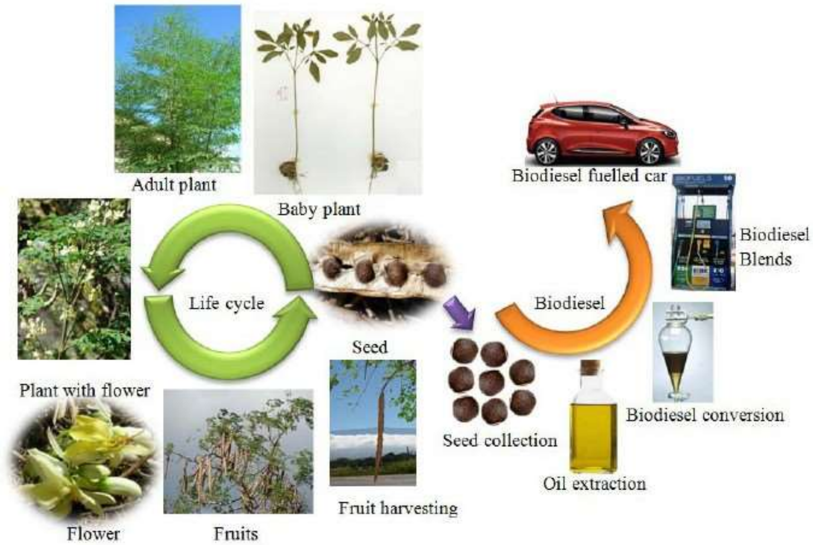

Figure 3 *Moringa oliefera* life cycle and extraction of oil from seed [36].

Preparation of synthetic wastewater

Synthetic wastewater was prepared by adding 0.1 to 2 gm of milk powder/L of tap water [28]. For complete dispersion, the suspension was stirred for 10 min. To monitor the coagulation activity of *M. oleifera* seed, the Jar test was performed and turbidity removal efficacy was measured. NaOH and 0.1 N HCL solutions were used to regulate the pH of the solution for jar test.

Bio-sorbent characterization

Characteristics of *M. oleifera* seeds were investigated by using the infrared spectra analysis at New Arts Science, Commerce College Ahmednagar, Maharashtra, India, in the range 4,000 - 500 per cm. O-H stretching at frequency 3,420 per cm comprising of fatty acids, protein, carbohydrates, and the lignin components. The peak frequency of 2923 and 2852 per cm represents C-H–CH_2 group. Stretching frequency 1,750 - 1,640 per cm represents the carbonyl group (C=O), fatty acids, lipid, protein and amides [29]. **Figure 4** illustrates the *M. oleifera* seeds infrared spectrum. Analysis of *M. oleifera* seeds contain protein 36.90 %, Fat 37.25 %, carbohydrates 16.38 %, Crude fibre 12.85 %, moisture 6.41 % and ash 3.06 % [34]. **Table 4** shows the characteristics of *M. oleifera* seeds after extraction [30].

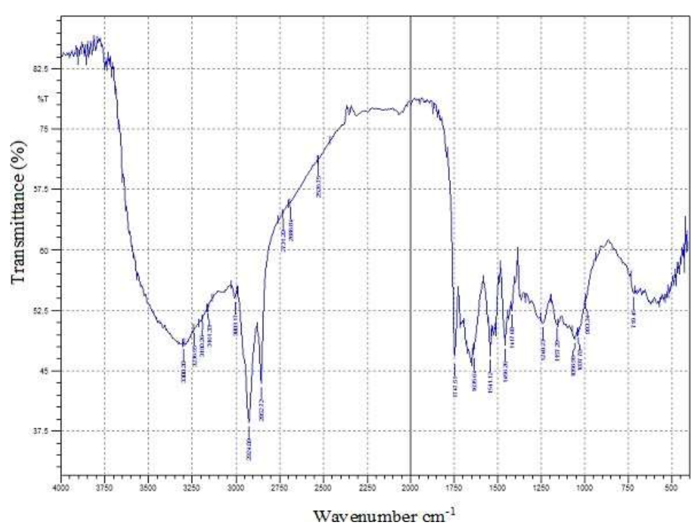

Figure 4 FTIR spectra of *M. oleifera* seeds powder.

Table 4 Characteristics of *M. Oleifera* seeds after extraction [30].

Sr. No	Parameters	value	Units	Fatty acids	Value (%)
1	Dry residue (without NaCl)	3.29	g/L	Lauric acid (C12:0)	0.1
2	Nitrite ($NO2^-$)	3.96	N mg/L	Myristic acid (C14:0)	0.1
3	Ammonium (NH_4^+)	0.06	N mg/L	Palmitic acid (C16:0)	7.8
4	Phosphate (PO^{3-})	0.05	P g/L	Palmitoleic acid (C16:1)	2.2
5	Phosphorous (P_4)	0.07	P g/L	Stearic acid (C18:0)	7.6
6	Isoelectric points	10 - 11	unitless	Oleic acid (C18:1)	67.9
7	Molecular weight	6.5 - 14	kDa	Linoleic acid (C18:2)	1.1
8	Oxidability, $KMnO_4$	1.08	O_2 g/L	Linolenic acid (C18:3)	0.2
9	Protein content [b]	1,832	mg/L	Archidic acid (C20:0)	4.0
10	Protein content 0.01M[a]	1,290	mg/L	Eicosenoic acid (C20:1)	1.5
11	Protein content 0.1M[a]	4,388	mg/L	Behenic acid (C22:0)	6.2
12	Protein content 1M[a]	4,499	mg/L	Lignoceric acid (C24:0)	1.3

a: NaCl extract, b: Water extract

Coagulation test

To reduce the turbidity of synthetic dairy wastewater the effective dose of coagulant was determined by performing Jar test. Tests were performed using 1 L circular jar. 60 s rapid mixing (125 rpm) followed by 15 min slow mixing (40 rpm) for flocculation and 30 min for settling the solution. The supernatant sample was collected and turbidity of sample was determined. The turbidity of supernatant sample was then compared with residual sample turbidity. Initial turbidity of residual sample was 87 NTU. To validate the results all the tests were performed carefully in a triplicate. The experimentations were carried out as per IS 3025 (Part 50):2001.

Results and discussion

Influence of initial pH

M. oleifera seeds consist of crude fiber, lignin, hemicellulose, and cellulose. It also contains amino functional groups ($R-NH_3$), carboxyl group (C=O), and fiber carbonaceous. The functional group present in *M. Oleifera* seeds is dissociated during the adsorption process at various pH. **Figure 5** shows influence of pH in the removal of turbidity, COD, and colour. Turbidity is removed around 95 % at pH 5, decolourization is achieved at 94 % at pH 5. COD reduction is enhanced with an increase in pH (from 36 % at pH 5 to 46 % at pH 8) as more hydrogen ions are present at lower pH. No any significant changes were observed in colour and turbidity in pH range 5 - 8. *M. oleifera* seeds curtail the adsorption efficiency above pH 8, as the solubility of the proteins decreases present in *M. oleifera* seeds. **Figure 5**. Also illustrate that the efficiency of turbidity, colour and COD removal depends upon the pH. Acidic pH is highly influencing the rate of degradation of parameters reason may be more H^+ ions are present.

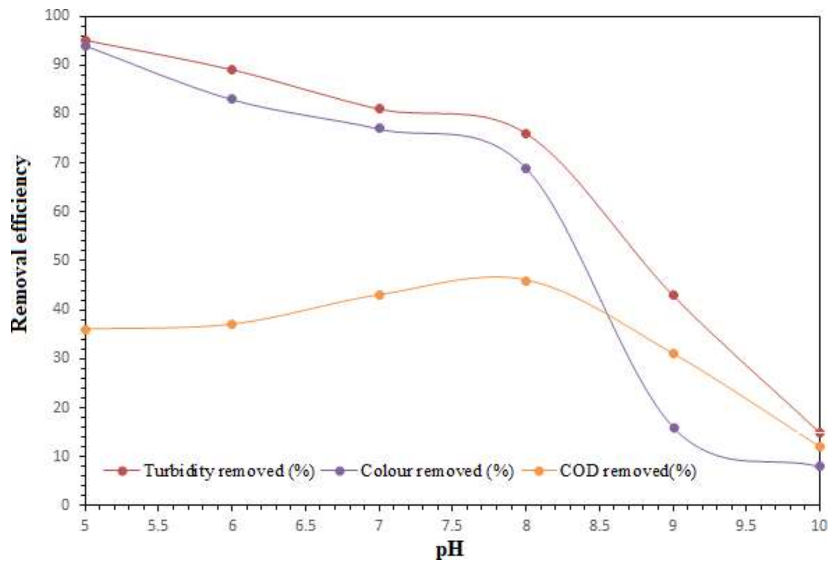

Figure 5 Influence of pH in removal of turbidity, colour, COD.

Effect of agitation time

Adsorption process was evaluated by using the Physico-chemical aspect. Agitation time plays a significant role in the removal of turbidity. Agitation time causes the variation in equilibrium adsorption as well as the kinetics of the adsorption process. Agitation time for experimentation was varied from 0 - 120 minutes. The dose of the adsorbent varied from 0.1 - 0.28 gm/L. **Figure 6** presents the efficiency of removal increases with an increase in agitation time. Reduction of turbidity and colour reached 95 and 94 % respectively with agitation time of 100 min. Beyond 100 min rate of degradation will be retarded reason may be desorption process will be taking place at the equilibrium time.

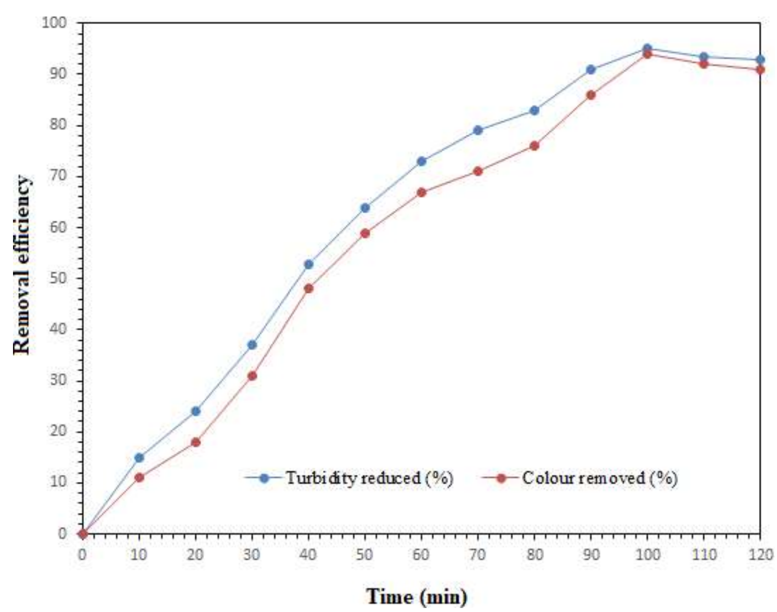

Figure 6 Effect of agitation time in removal of turbidity and colour.

Effect of MO amount

M. oleifera has good property of coagulation-flocculation (C-F). The effect of *M. oleifera* seed amount was investigated to check the result of the adsorption process on dairy wastewater. 120-min agitation was carried out at pH 7.2 and temperature 31 °C. **Figure 7**, elucidate the efficacy of turbidity and colour removal increased continuously as sorbent has potential and positively charged proteins which act as an effective coagulant. The rate of degradation of the turbidity and decolourization will directly proportional to sorbent dose up to 0.22 gm/L. After achieving the optimum dose of sorbent, the rate of removal of turbidity and colour were retarded. As excess dose of sorbet stabilizes the dairy wastewater adversely.

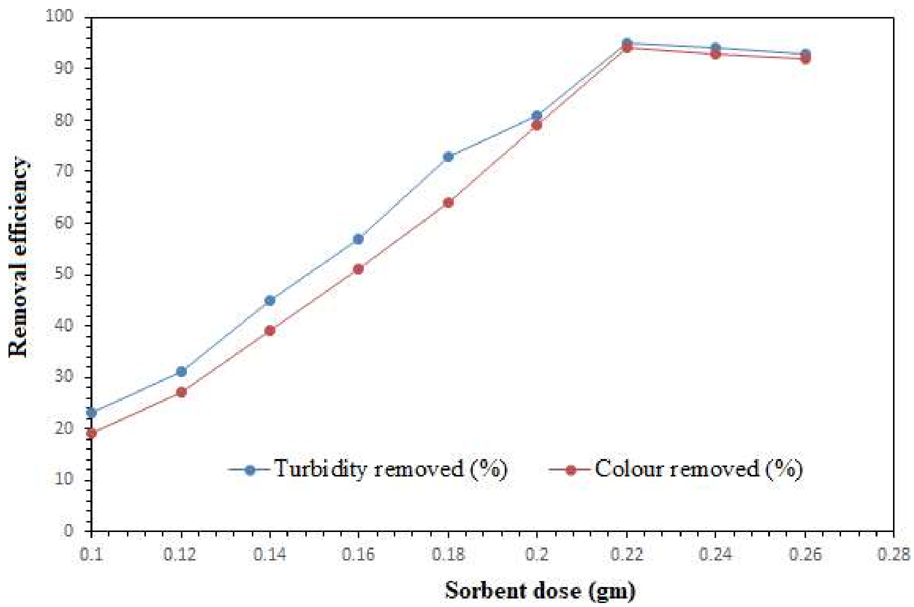

Figure 7 Effect of sorbent dose to remove the turbidity and colour.

Efficacy of *M. oleifera* seeds kernel for turbidity removal

M. oleifera seed kernel (sun-dried, oven-dried and naturally dried) were employed to find the efficacy of turbidity removal. **Figure 8** shows that the effectiveness of naturally dried seed kernel is more effective than other seed kernels. A similar result was reported by author Gaikwad and Munavalli [31]. The comparison of naturally dried seed, sun-dried seeds and oven-dried seeds shows that naturally dried seeds remove turbidity upto 95 %, sundried seeds remove turbidity upto 52 % and oven-dried seeds upto 45 % at sorbent dose of 0.22 gm/L.

This shows that naturally dried *M. oleifera* pod having more surface area for adsorption and inter-particulate bridging which extracts the extra active ingredients [32]. The efficacy of the adsorption process depends up on various parameters such as functional group (s) contain in the sorbent, pod morphology, adsorbent contact area, polarity and pore size dispersion [33].

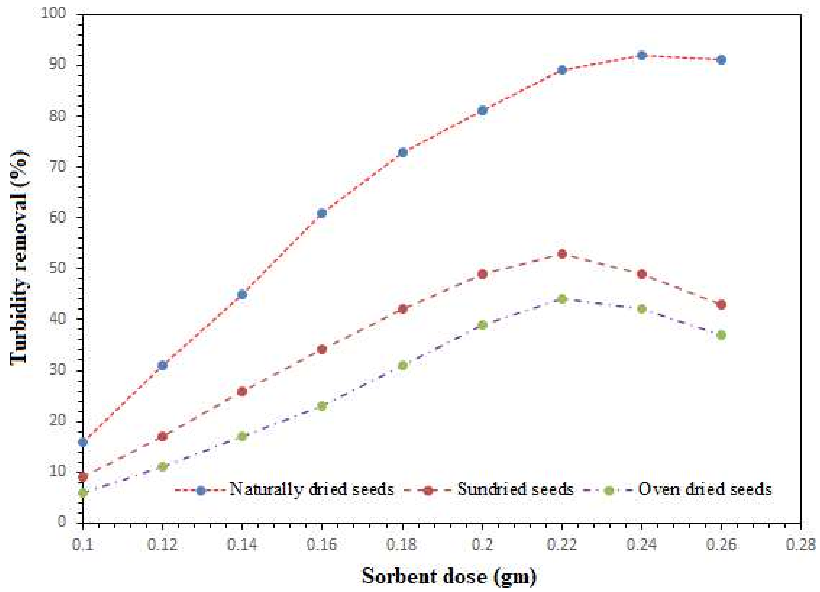

Figure 8 Efficacy of *M. oleifera* seeds kernel for turbidity removal.

Conclusions

M. oleifera seed is effectively used to eliminate turbidity and colour. *M. oleifera* seeds are natural, low-cost, appropriate, effective and readily available in large quantities. Fourier-transform infrared spectroscopy of *M. oleifera* seeds illustrate that it contains fatty acids, protein, carbohydrates, and the lignin components which are having more coagulation and flocculation properties. They have a robust ability to eliminate the various components of dairy wastewater as M. oleifera seed possesses superfluous coagulant property. Sorbent dose of 0.22 gm/L removes the turbidity 95 %, colour 94 % and COD 46 %. Experimental results concluded that the sorption process enhances among pH 5 to 8. The naturally dried *M. oleifera* seeds have more efficacy than sun-dried and oven-dried seeds. The turbidity removed by naturally dried seeds is 95 %. Sundried seeds remove turbidity 52 % and oven dried seeds 45 %. *M. oleifera* seeds act as a polyelectrolyte which removes the turbidity through sorption and inter-particle bridging.

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