American Journal of Engineering Research (AJER) 2020
American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-9, Issue-9, pp-25-31
www.ajer.org
Research Paper Open Access

A Novel Procedure for Selecting Optimum Dosage and Coagulantactivity of Protein Extract from Stored *Moringa Oleifera* Seed

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ABSTRACT
New methods ofobtaining optimum dosage and coagulant activity of a natural coagulant used in clarification of turbid water were investigated. These were based on percentage turbidity removals achieved during the water clarification process.Turbid water samples were clarified by coagulation-flocculation and sedimentation, using the jar test approach. Proteins isolated from stored Moringa oleifera seed were used as coagulant. Results of the jar test showed that the protein extract from stored MO seed was effective in turbidity removal during water purification. Dosages of the coagulant used were 30mg/l, 40mg/l and 50mg/l. The different dosages used however, achieved varying turbidity removal efficiencies.It was observed that increase in coagulant dosage did not result in appreciable increase in percentage turbidity removals. Theturbidity removal efficiencies were used to identify optimum dosages using both an existing method by Al-sameraiy(2017) and the new method tagged economic coagulant optimization dosages (ECOD). The data was also used to compute coagulant activities using an existing method by Díaz et al, (2018) while introducing another approach.

KEY WORDS: *Coagulant, optimum, economic, dosage, activity, turbidity*

Date of Submission: 20-08-2020 Date of acceptance: 06-09-2020

I. INTRODUCTION

One vital essence of research is the development of the most appropriate, convenient, simple and effective method or procedure for executing a given task. Equally vital is the establishment of an optimal application, often in terms of economy, of valuable research materials, including chemicals and plant extracts. Extracts of *Moringa oleifera* (MO) seed used as natural coagulants in water purification are highly valuable and must be used in the most economical manner while achieving the desired results. American Water Works Association (AWWA, 2000) stated that it was crucial to determine the optimum dosage of a coagulant to minimize the dosing cost and obtain optimum performance in water treatment. It is therefore imperative that a method of identifyingan optimal dosage of MO seed protein extractto be used for water purification should be developed in order to eliminate or minimize waste.

Water treatment plant operations means decreasing the final price of the produced water in a way that achieves an optimum combination of efficiency and affectivity (Ng et al., 2016). Water turbidity is an important and significant parameter when water treatment plants obtain their input water from natural resources like rivers or lakes(Nahvi et al., 2018).Materials called coagulants are used to decrease water turbidity, the required amount of coagulant depending on the environmental conditions (Nordmark et al., 2016). Coagulation and flocculation constitute the backbone processes in most water and advanced wastewater treatment plants (Wang et al. 2005). According to Al-Sameraiy (2017), dosage is one of the most important parameters, which has been considered to determine the optimum conditions for the coagulation and flocculation in water treatment. Furthermore, in conventional water treatment practice, finding the optimum dose for each coagulant is a problem that must be solved and determined by empirical experiments (Al-Sameraiy, 2017). Al-Sameraiy, therefore developed an evaluating criterion that used second order coagulation rate constant (k_2) as an investigating parameter to identify optimum coagulant doses. This was based on the findings of extensive studies such as Ani et al. 2012;

Ifeanyi *et al*. 2012 andUgonabo*et al*, 2013, that second order reaction was more logical in representing primarily the aggregation rate of particles count on the basis of Brownian controlled and rapid coagulation process. The dosage at which the expression gave the highest value of second order reaction rate constant (K_2) was identified by Al-Sameraiy, 2017as the optimum dosage.

Proposing new models for estimating the optimum amount of coagulant seems an appropriate way to alleviate costs and generally improve the health of drinking water (Lamrini et al., 2005).Modeling is an important math-based tool typically performed in one of two ways, namely numeric or deterministic methods and data-driven methods (Haghiri*et al*, 2018). Data-driven techniqueshave been receiving considerable attention in the field of process monitoring due to their easy implementation and less requirements for the underlying model (Yin *et al*., 2016).

Another important parameter, which has to be considered to determine the appropriateness of a coagulant in the coagulation and flocculation process in water treatment is the coagulation activity of that coagulant. The method used by Diaz et al (2018) to calculate coagulant activity made use of residual turbidities of both the blank sample and the treated water sample and expressed coagulant activity as a percentage. Rather than using residual turbidities, it may be more appropriate to express coagulant activity in terms of percentage turbidity removals from both the blank and the treated water samples.

II. MATERIALS AND METHODS

Dried pods of *Moringa oleifera* seeds were harvested from local growers located in Agulu, Anambra state and air-dried for 14days. The seeds were identified by Herbarium Curator, Dr. Mrs B. O. Aziagba, of the Department of Botany, Nnamdi Azikiwe University, Awka. A sample of the seed was kept in Cabinet Number 02, Shelf Number 29 of the Herbarium. Turbid water was collected from Ezu Riverin Amansea, Anambra State, Nigeria, at Longitude 6° 15′ and Latitude 7° 08′. Turbidity ranged between 65 NTU and 322 NTU, depending on the season the water sample was procured.

The air-dried seeds of *Moringa oleifera* (MO) seedwere stored at room temperature of about 30^{o}C for a period of 150days in different forms (winged seeds, shelled seeds and seeds in the pod), using different storage containers (covered baskets, corked glass bottles and cellophane bag).Winged seeds refer to seeds that were removed from the pod but the outer brown covering remained, which has some wing-like components. Shelled seeds are those removed from the pod and the outer covering also removed, exposing the inner white kernel. The *seeds* of MO were ground and defatted with n-hexane using the Soxhlet apparatus in accordance with Harwood *et al*, 1989 and Ali *et al*, 2010. This was followed by aqueous extraction of the coagulant. The coagulant active ingredient (seed protein) was isolated through acetone precipitation(TR 0049, 2009) and used in the purification of the water using the standard jar test apparatus(ASTM D2035-19). Coagulant dosages of 30 mg/l, 40 mg/l and 50 mg/l were used. The experimental procedure was repeated at 30days intervals throughout the period of seed storage until 150days.

Calculation of Optimum Coagulant Dosage and Coagulation Activity

The experimental data findings were used to calculate optimum coagulant dosage and coagulant activity for each storage mode at each 30-day interval. Existing methods of calculating these parameters were used and compared with the new approaches being adopted in this work.

Optimum coagulant dosage

Optimum coagulant dosage was calculated using the methodadopted byAl-Sameraiy, 2017 and also the method of percentage quotient being suggested in the present work.

(a) ***Method of Al-Sameraiy, 2017***

Al-Sameraiy, 2017 used coagulation second order rate constant(K_2) as an investigating parameter to identify optimum doses of coagulants. An expression for coagulation rate constant was obtained as equation 1.

$$K_2 = \frac{\left(\frac{1}{Ct} - \frac{1}{Co}\right)}{t} \qquad 1$$

Where

K_2 = coagulation second order rate constant
C_t = residual turbidity(NTU)
C_o = initial turbidity(NTU)
t = settling time(minutes)

The residual turbidity(C_t) and turbidity at time zero(C_o) from the experimental data findings were substituted into equation 1. In accordance with Al-Sameraiy (2017), the dosage at which the residual turbidity gave the highest value of second order reaction rate constant (K_2) was identified as the optimum dosage(Tables 1).

(b) Method of economic coagulant optimization dosage (ECOD)

This method being suggested in this work uses percentage quotients, expressed as equation 2, to determine optimal dosage.

$$\%Quotient = \frac{\%Turbidity\ \ Removal}{Coagulant\ \ Dosage} \qquad 2$$

The maximum percentage turbidity removals and the corresponding dosages from the experimental data findings were substituted into equation 2. Economic coagulant optimization dosage (ECOD) is the dosage that corresponds to the maximum percentage quotient. The computations were done using the data obtained at each 30-day interval through the storage period of 150days.

Coagulant activity

The activity of the coagulant in the removal of turbidity was determined using percentage coagulant activity adopted by Díaz et al, 2018(equation 3) and usingcoagulant activity index(equation 4).

$$\%\boldsymbol{Coagulant\ Activity} = \frac{\boldsymbol{Residual\ Turbidity_{blank}} - \boldsymbol{Residual\ Turbidity_{sample}}}{\boldsymbol{Residual\ Turbidity_{blank}}}\ x\ 100 \qquad 3$$

Coagulant Activity Index=

$$\frac{\%\mathbf{Turbidity\ Removed_{sample}} - \%\mathbf{Turbidity\ Removed_{blank}}}{\%\ \mathbf{Turbidity\ Removed_{sample}}} \qquad 4$$

III. RESULTS AND DISCUSSIONS

Table 1 shows the results of water clarification. The turbidity of the water before clarification(C_o) and the final residual turbidity of both the blank water sample (Br) and the experimental water sample after clarification (C_t) are shown in the table. Based on the initial and final turbidity values the percentage turbidity removals of boththe blank water(BPTR) and the experimental samples(SPTR) were calculated and also shown in the table.

Table 1. Determination ofpercentage turbidity removals, optimal dosages and coagulant activities.

Storage period	Storage mode	Dosage (mg/l)	C_0	Br	C_t	BPTR	SPTR	Optimal Dosages		Coagulant activities	
								Al-Sameraiy (2017) $K_2 = \frac{(\frac{1}{Ct} - \frac{1}{Co})}{60}$	% Quotient $(\frac{col.8}{col.3})$	Coagulant Activity (%) $\left[\frac{(5-6)}{5}\right] x\ 100$	Coagulant Activity Index $\left[\frac{(8-7)}{8}\right]$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)				
30		30	219	159	25	27	88.6	0.000591	**2.95333**	84	0.7
		40	219	159	14	27	93.6	0.001114	2.34	91	0.71
	Sbo	**50**	219	159	4	27	**98.2**	**0.004091**	1.964	**97**	**0.72**
		30	219	159	18	27	91.8	6.51E-05	**3.06**	89	0.71
		40	219	159	19	27	91.3	0.000801	2.2825	88	0.70
	Sba	50	219	159	11	27	**95**	**0.001439**	1.90	**93**	**0.72**
		30	219	159	78	27	64.4	0.000138	**2.14667**	51	0.58
		40	219	159	56	27	74.2	0.000222	1.855	65	0.64
	Wbo	50	219	159	31	27	**85.8**	**0.000462**	1.716	**81**	**0.69**
		30	219	159	125	27	42.9	5.72E-05	1.43	21	0.37
		40	219	159	74	27	66.2	0.000149	**1.655**	53	0.59
	Wba	50	219	159	64	27	**70.8**	**0.000184**	1.416	**60**	**0.62**
		30	219	159	17	27	**92.2**	**0.000904**	**3.22667**	**89**	**0.71**
		40	219	159	24	27	89.0	0.000618	2.455	85	0.70
	Wcb	50	219	159	25	27	88.6	0.000591	1.926	84	0.70
		30	219	159	7	27	96.8	0.002305	**3.22667**	96	0.72
		40	219	159	4	27	**98.2**	**0.004091**	2.455	**97**	**0.73**
	Pba	50	219	159	8	27	96.3	0.002007	1.926	95	0.72
60		30	321	211	108	34	66	0.000102	**2.2**	49	0.48
		40	321	211	101	34	69	0.000113	1.725	52	0.51
	Sbo	50	321	211	91	34	**72**	**0.000131**	1.44	**57**	**0.53**

	Sba	30	321	211	61	34	70	0.000221	**2.3333**	71	0.51
		40	321	211	23	34	**93**	**0.000673**	2.325	**89**	**0.63**
		50	321	211	41	34	92	0.000355	1.84	81	0.63
	Wbo	30	321	211	168	34	48	4.73E-05	**1.6**	20	0.29
		40	321	211	138	34	57	6.89E-05	1.425	35	0.40
		50	321	211	121	34	**62**	**8.58E-05**	1.24	**43**	**0.45**
	Wba	30	321	211	111	34	46	9.82E-05	1.5333	47	0.26
		40	321	211	76	34	44	0.000167	**1.6**	64	0.23
		50	321	211	58	34	**72**	**0.000235**	1.44	**73**	**0.53**
	Wcb	30	321	211	172	34	46	4.5E-05	**1.5333**	18	0.26
		40	321	211	166	34	**48**	**4.85E-05**	1.2	**21**	**0.29**
		50	321	211	167	34	48	4.79E-05	0.96	21	0.29
	Pba	30	321	211	33	34	90	0.000453	**3.0**	84	0.62
		40	321	211	28	34	**91**	**0.000543**	2.275	**87**	**0.63**
		50	321	211	29	34	91	0.000523	1.82	86	0.63
90	Sbo	30	280	168	69	40	75	0.000182	**2.5**	59	0.47
		40	280	168	68	40	76	0.000186	1.9	60	0.47
		50	280	168	55	40	**80**	**0.000244**	1.6	**67**	**0.5**
	Sba	30	280	168	61	40	78	0.000214	**2.6**	64	0.49
		40	280	168	23	40	**92**	**0.000665**	2.3	**86**	**0.56**
		50	280	168	41	40	85	0.000347	1.7	76	0.53
	Wbo	30	280	168	127	40	55	7.17E-05	**1.83333**	24	0.27
		40	280	168	97	40	65	0.000112	1.625	42	0.38
		50	280	168	80	40	**71**	**0.000149**	1.42	**52**	**0.44**
	Wba	30	280	168	111	40	60	9.06E-05	**2.0**	34	0.33
		40	280	168	76	40	73	0.00016	1.825	55	0.45
		50	280	168	58	40	**79**	**0.000228**	1.58	**65**	**0.49**
	Wcb	30	280	168	125	40	**55**	**7.38E-05**	**1.83333**	**26**	**0.27**
		40	280	168	130	40	54	6.87E-05	1.35	23	0.26
		50	280	168	126	40	55	7.28E-05	1.1	25	0.27
	Pba	30	280	168	71	40	**75**	**0.000175**	**2.5**	**58**	**0.47**
		40	280	168	86	40	69	0.000134	1.725	49	0.42
		50	280	168	97	40	65	0.000112	1.3	42	0.38
120	Sbo	30	65	48	7	26	**89**	**0.002125**	**2.96667**	**85**	**0.71**
		40	65	48	8	26	88	0.001827	2.2	83	0.70
		50	65	48	29	26	69	0.000318	1.38	40	0.62
	Sba	30	65	48	13	26	80	0.001026	**2.66667**	73	0.68
		40	65	48	4	26	**94**	**0.00391**	2.35	**92**	**0.72**
		50	65	48	7	26	89	0.002125	1.78	85	0.71
	Wbo	30	65	48	11	26	83	**0.001259**	**2.76667**	**77**	**0.69**
		40	65	48	13	26	80	0.001026	2	73	0.68
		50	65	48	18	26	72	0.00067	1.44	63	0.64
	Wba	30	65	48	15	26	**77**	**0.000855**	**2.56667**	**69**	**0.66**
		40	65	48	17	26	74	0.000724	1.85	65	0.65
		50	65	48	16	26	75	0.000785	1.5	67	0.65
	Wcb	30	65	48	9	26	**86**	**0.001595**	**2.86667**	**81**	**0.7**
		40	65	48	25	26	62	0.00041	1.55	48	0.58
		50	65	48	21	26	68	0.000537	1.36	56	0.62
	Pba	30	65	48	18	26	**72**	**0.00067**	**2.4**	**63**	**0.64**
		40	65	48	23	26	65	0.000468	1.625	52	0.60
		50	65	48	19	26	71	0.000621	1.42	60	0.63
150	Sbo	30	134	85	61	36	55	0.000149	**1.83333**	28	0.35
		40	134	85	63	36	53	0.00014	1.325	26	0.32
		50	134	85	54	36	**60**	**0.000184**	1.2	**36**	0.40
	Sba	30	134	85	14	36	90	0.001066	**3.0**	84	0.60
		40	134	85	13	36	90	0.001158	2.25	85	0.60
		50	134	85	7	36	**95**	**0.002257**	1.9	**92**	**0.62**
	Wbo	30	134	85	80	36	40	8.4E-05	1.33333	5.9	0.10
		40	134	85	52	36	61	0.000196	**1.525**	39	0.41
		50	134	85	51	36	**62**	**0.000202**	1.24	**40**	**0.42**
	Wba	30	134	85	24	36	82	0.00057	**2.7**	72	0.56
		40	134	85	12	36	91	0.001265	2.275	86	0.60
		50	134	85	8	36	**94**	**0.001959**	1.84	**91**	**0.62**
	Wcb	30	134	85	26	36	81	0.000517	**2.7**	69	0.56
		40	134	85	12	36	91	0.001265	2.275	85	0.60
		50	134	85	11	36	**92**	**0.001391**	1.84	**87**	**0.61**
	Pba	30	134	85	27	26	80	0.000493	**2.66667**	68	0.68
		40	134	85	13	26	**90**	**0.001158**	2.25	**85**	**0.71**
		50	134	85	16	26	88	0.000917	1.76	81	0.70

The following nomenclature are adopted in the table:

C_o	=	Initial concentration (turbidity of raw water)
Br	=	Residual turbidity of blank water sample
C_t	=	Residual turbidity of experimental water sample
BPTR	=	Blank percentage turbidity removal
SPTR	=	Sample percentage turbidity removal

Turbidity Removals

Proteins extracted from MO seed stored in the different forms and containers were found to retain their coagulation and flocculation properties.The different coagulant dosages used in the purification of the turbid water, 30mg/l, 40mg/l and 50mg/l, achieved varying percentage turbidity removal efficiencies. Maximum percentage turbidity removals ranged between 48 and 95%. It was observed that increment in the coagulant dosage did not result in appreciable increase in percentage turbidity removal achieved. After 30days of storage, for example, shelled seed in bottle achieved 88.6% turbidity removal with a dosage of 30mg/l, that is, an average of 29.5%turbidity removed per 10mg of coagulant or 2.95% per gram of coagulant. Increasing the dosage to 40mg/l and 50mg/l, turbidity removals achieved were 93.6 and 98.2% respectively, that is, additional 5% turbidity removal per each 10mg of coagulant added or 0.5% per gram of coagulant added. This shows that increasing the concentration of the coagulantbeyond a certain dosage achieved relatively less efficiency.It is important therefore, to determine an optimal coagulant dosage that will meet the requirement of a given regulation;thus, the additional quantity of coagulant can be saved, especially in times of scarcity of MO seed.*Moringa oleifera*seed is more abundant during certain periods of the year and less available at other times. Furthermore, the determination of optimal dosage of MO seed extract is important because increase in concentration of MO seed extract in water purification results in increase in the organic load in the treated water (Ndabigengesere and Narasiah, 1998, Okuda *et al*, 2001).

Optimal Dosages

Optimal dosages computed using both the method of Al-Sameraiy (2017) and the ECOD method are presented in Table 1. The highest values of K_2 obtained in the method of Al-Sameraiy (2017) and the highest values of percentage quotient obtained in the ECOD method are written in bold forms. These are values corresponding to optimum dosages in each method.

Al-Sameraiy (2017) noted that the highest values of (K_2) obtained always identified optimum coagulant dosages which only coincided with the dosages that achieved maximum percentage turbidity removals. Maximum percentage turbidity removals could be termed optimal if all that is considered is only the total amount of turbidity removed, or if it is the dosage which turbidity removal meets certain regulatory requirement such as World Health Organisation (WHO) maximum limit of 5NTU. It may not, however, always be the optimum dosage, especially if turbidity removal by two or more other dosages complies with the given regulation. An addition to the methods of determination of optimum coagulant dosage is suggested, which uses percentage quotients to obtain economic coagulant optimization dosages (ECOD).

(i) ***30day storage period optimal dosages***

Table 1 shows that on the 30th day of storage, the highest K_2 value for the shield seed in bottle (Sbo), shield seed in basket (Sba), winged seed in bottle (Wbo) and winged seed in basket (Wba) identified 50mg/l as their optimum dosage. The highest K_2 values for winged seed in cellophane bag (Wcb) and Pod seed in basket (Pba) identified 30mg/l and 40mg/l respectively as their optimum dosages. These identified optimum dosages corresponded with the various dosages of MO protein that achieved the maximum percentage turbidity removals(Table 1). On the other hand, the method of ECOD identified 30mg/l as optimum dosage for protein obtained from the various storage forms, except the winged seed in basket for which the optimal dosage was identified as 40mg/l.The optimal dosages identified, based on ECOD, did not correspond to dosages that achieved maximum percentage turbidity removals except for the winged seed in cellophane bag (Wcb). Furthermore, optimal dosages corresponded to the minimum percentage turbidity removals(30mg/l), apart from the winged seed in cellophane bag that corresponded to the dosage with maximum percentage turbidity removal and the winged seed in basket (Wba) which corresponded to the dosage with the second highest percentage turbidity removal (Table 1). Such dosages that are both optimal and also achieved maximum percentage turbidity removal shall be termed “super dosage (SD)” and the one with the second highest percentage turbidity removal as “semi super dosage (SSD)”.

(ii) 60day storage period optimal dosages

Table 1 shows that on the 60th day of storage, optimum dosages obtained using the method ofAl-Sameraiy 2017 were 50mg/l for protein from shelled seed in bottle, winged seed in bottle and winged seed in basket. Optimum dosages of protein from shelled seed in basket, winged seed in cellophane bag and pod seed in basket were 40mg/l each. All the optimum dosages obtained merely corresponded to dosages that exerted maximum percentage turbidity removals. Optimal dosages obtained using ECOD followed the same trend as in 30day storage period results, mostly corresponding to dosages that exerted minimum percentage removals. An exception was the winged seed in basket which was observed to be a semi super dosage (SSD) as defined in (i).

(iii) 90day storage period optimal dosages

Table 1 shows the same observations as in the 30day and 60day storage period results. Optimal dosages obtained using method of Al-Sameraiy(2017) simply corresponded to the observed dosages with maximum percentage turbidity removals. Optimal dosages obtained using the method of ECOD did not correspond to the dosages with maximum percentage turbidity removals. The dosage of 30mg/l was observed to be the optimum dosage of the protein extract from all the modes of storage. It is the most economical dosage.

(iv) 120day storage period optimal dosages

Table 1 shows that optimal dosages at the 120th day of storage corresponded to the dosages that achieved maximum turbidity removals in the method of Al-Sameraiy, 2017. Table 1 further shows in the ECOD method,optimal dosages were 30mg/l in all the modes of storage. These did not necessarily correspond to the dosages that achieved the maximum percentage turbidity removals. They were dosages that achieved the maximum percentage turbidity removal per unit of coagulant. It is of note that the raw water turbidity on this day was very low(65NTU). Contrary to previous reports in literature that *Moringa olifera* seed extract may not be an efficient coagulant for low turbidity water (Muyibi and Evison 1995), the turbidity removal efficiency was not affected by the low level of initial turbidity, probably because this research made use of protein isolate, rather than crude extract of *Moringa oleifera*seed. It is also observed that the optimum dosages identified were mostly super dosages (SD) except for shelled seed in basket for which the optimum dosage achieved the minimum percentage turbidity removal.

(v) 150day storage period optimal dosages

At the 150th day of MO seed storage, optimum dosages obtained using method of Al-Sameraiy (2017) were 50mg/l in all but the protein from pod seed stored in basket, which showed optimum dosage of 40mg/l. All the observed optimum dosages corresponded to dosages that achieved maximum percentage turbidity removals,the same as shown in the 30, 60, 90 and 120th days of storage.The method of ECOD gave 30mg/l as the optimal protein dosage in all the modes of storage, except the winged seed stored in bottle for which 40mg/l was the optimal dosage (Table 1). These were not the dosages that achieved maximum turbidity removals. They were dosages that achieved the maximum percentage turbidity removals per unit of coagulant used and hence the most economical dosages.

Coagulant Activity

Table 1 shows the coagulant activities of *Moringa oleifera* seed protein, computed using the method of Díaz et al, 2018 and a new method using percentage turbidity removals. The maximum activity by the protein from each mode of storage is written in bold form in Table 1.

The method of Díaz et al, 2018 calculated coagulant activity based on turbidity residuals of the blank water sample (Br) and the coagulant-treated water (Ct), and expressed it as a percentage. However, coagulation activity does not seem to be percentage of anything. Coagulant activity derived using percentage turbidity removals compares the percentage of turbidity removed by the coagulant with that removed without the coagulant and expresses it as anindex. The closer the index is to one (1), the better the activity of the coagulant. The advantage of the new method is that it provides a moderate value for the activity of the coagulant. The new method subtracts the component of turbidity removal that would have been achieved if the water was left under a quiescent condition without the coagulant.

The two methods however,have in common that the maximum coagulant activity observed for protein from each storage mode coincided with the dosage that achieved the highest turbidity removal. It is also observed that in both methods, the most appropriate mode of storage, based on the activity of its protein, is the shelled seed stored in basket. Themaximum coagulant activities of the protein obtained from the seed stored in this mode is between 86 and 93% in the first method or 0.6 and 0.7 in the second method. This agrees with the findings of Golestenbagh*et al* (2011) that the coagulation property of shelled *Moringa oleifera* seed is not affected by storage time. The next appropriate mode of storage is the seed pod stored in basket with coagulant activity ranging between 58 and 97% in the first method or 0.5 and 0.7 in the second method.

IV. CONCLUSION

An existing method of deducing optimal dosages as adopted by Al-Sameraiy(2017) was used to deduce optimal dosagesof protein extract from stored MO seed used for clarification of turbid water. The method identified dosages that yielded maximum percentage turbidity removals as the optimal dosages. Such dosages might indeed be termed optimal if all that is considered is the total percentage turbidity removals achieved and/ or if it is the dosage that meets the requirement of a given regulation. In terms of economy of coagulant however, the dosage that has the highest percentage turbidity removal may not necessarily be the optimum dosage. Hence a new method of deducing optimal dosages, using percentage quotients,has been introduced, which identifies optimum dosage as the dosage with which the percentage removal per unit of coagulant is the maximum. These are termed economic coagulant optimization dosages (ECOD).Furthermore,coagulant activities of *Moringa oleifera* seed protein were computed using the method of Díaz et al, 2018. This method is based on residual turbidity of both the raw water and the sample, and expresses coagulant activity as a percentage. Coagulant activity was also derived using percentage removals. This method compares the percentage of turbidity removed by the coagulant with that removed without the coagulant and expresses coagulant activity as anindex. The closer the index is to one (1), the better the activity of the coagulant. The advantage of the new method is that it provides moderate values of coagulant activities.

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