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Tesis

Analysis of the effectiveness of Lepidium meyenii, Solanum tuberosum and Musa paradisiaca species as natural coagulants in the treatment of the Cunas River - Peru

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Analysis of the effectiveness of *Lepidium meyenii, Solanum tuberosum and Musa paradisiaca* species as natural coagulants in the treatment of the Cunas River – Peru

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Abstract. The research aimed to analyze the effectiveness of the skins of *Solanum tuberosum* (Potato), *Musa paradisiaca* (Banana) and *Lepidium meyenni* (Maca) as natural coagulants in the removal of physical and chemical parameters: Total suspended solids (TSS), turbidity, pH and color, in the water sample obtained from the lower basin of the Cunas River. This study presents a level of explanatory research with experimental design, using the inductive method due to the analysis of samples, pre and posttest. In addition, for the elaboration of natural coagulants from skins of *S. tuberosum*, *M. paradisiaca* and *L. meyenni*, these skins were obtained from restaurants and street commerce, to later perform the Jar-Test at different doses (25, 50, 75, and 100 ppm) using 4 water samples of 1000 mL for each coagulant. The results were: M. paradisiaca had a total average removal effectiveness of 69.39% with 75 ppm, *S. tuberosum* had a removal effectiveness of 55.86% with 75 ppm, and finally, L. meyenni had a lower removal effectiveness with a total average of 52.62% with 100 ppm. It is concluded that the natural coagulant of *M. paradisiaca* has a higher average effectiveness compared to S. tuberosum and *L. meyenni*.

1. Introduction

The increase in demand for water has led to a considerable decrease in the availability of this resource [1]. In 2030 the land will have a water decrease of 40% [2], and by 2050 there will be an increase in water use worldwide of 20% to 30%. 46% of the variation in the flow of a river is due to climatic effects, whereas 54% is due to the impacts caused by man; Of this percentage, 24.7% is given by wastewater [3]. These anthropogenic activities generate effluents, polluting water bodies such as lakes or rivers [4]. The pollution of rivers and the environment is reaching a critical level due to the lack of treatment plants [5] . In Latin America, 3/4 of wastewater is returned to rivers and other water sources [6]. This pollution will be driven by the increase in waste generation by 70%, due to population growth and urban expansion by 2050 [7] . In Peru, during the year 2020, a total of 92 822.84 tons of solid waste were recovered, of which 68 399.63 tons were municipal organic waste (remains of vegetables and / or fruits that come from markets, homes and others) [8] . In many parts of the country, the proximity of urban areas to rivers is one of the main causes of water pollution. Pollution is not only produced by the dumping of solid waste into rivers, but also by washing clothes, vehicles, the dumping of fat, fuel, among others [9]. The waters of natural origin that do not have any treatment are called raw waters, these are found in rivers, streams, lakes [10]. Water treatment plants present equitable processes; the most important are the coagulation and flocculation process [11]. In the coagulation process, small particles are formed by the addition of a coagulant to the water or also by applying mixing energy. The suspended particles are destabilized by the neutralization of the charges of negative colloids, where they use mostly inorganic coagulants and these alter the physicochemical properties of water [12]. The use of plant resources as natural coagulants in the various water clarification processes turns out to be an appropriate technology in vulnerable sectors, in the face of scarce economic conditions. These plant resources are available to everyone, since the main source of production is nature [13]. When using natural coagulants, it can be observed that it minimizes and avoids the use of chemical coagulants, significantly reducing treatment costs; if the use of these natural coagulants is available [14], the delimitation of the dosage of natural coagulants is the most important part because it determines the efficiency of the measurable parameters in the sample [15]; therefore, the stock solutions obtained from plant residues are used as primary coagulants in treatment plants, which allows to have an effluent that meets the acceptable physical parameters of color and turbidity [16]. That is why the need arises to investigate about these natural coagulants, taking into account that the Junín region presents multiple tributary rivers to the Mantaro River. A main tributary river is the Cunas River; this represents a great economic importance because it is the main source for various activities such as agricultural, fishing, recreational, industrial, hydro electrical and human consumption [17] Through the visits made to the body being studied, it was possible to verify the presence of various effluents of discharge of wastewater directly to the Cunas River, which cause the contamination of its waters [18] [19]. Numerous studies have evaluated the use of natural coagulants to replace chemical coagulants [20]. It is necessary to evaluate coagulants and flocculants more effectively, less harmful to the environment. In this sense, natural coagulants are a viable alternative due to their safety for health [21]. The coagulants of the skins of *L. meyenii*, *S. tuberosum* and *M. paradisiaca* were collected from the waste of restaurants and street commerce. The present research focuses on analyzing the effectiveness of the skins of *S. tuberosum*, *M. paradisiaca* and *L. meyenni* as natural coagulants in the decrease of total suspended solids, turbidity, pH, and color in the lower basin of the Cunas River. The Cunas River was taken as an object of study because it is a main source of development of multiple economic activities for the Mantaro Valley, and in the lower basin is where there is a greater presence of urban area, 67% of this sector has poor quality water [22]. It should be noted that there are currently no studies on the use of the skin or pulp of *L. meyenni* as a natural coagulant.

2. Material and Methods

The study presents a level of explanatory research with experimental design [23], and employs the inductive method due to the analysis of pre and posttest samples [24]. The water samples were extracted from 3 points of the lower basin of the Cunas River [25]; subsequently, the sample was separated into 13 beakers of 1000 mL each. Having 3 kinds of natural coagulants, it was decided to allocate 4 beakers, with a sample for each natural coagulant, and a control sample. To obtain the coagulant, skins were collected from restaurants and street commerce. Processing was carried out to obtain natural coagulants so that they could be used in the samples and thus know the optimal dose of the different coagulants from the skin of *S. tuberosum*, *L. meyenii,* and *M. paradisiaca*. Doses of 25, 50, 75 and 100 ppm were applied to each of the beakers [26]; At the same time, no alteration was made to the control group.

2.1. Water sampling

Following the National Protocol for monitoring the Quality of Surface Water Resources, it was considered to take 3 samples in the lower basin, this due to studies that mentioned that the quality of the Cunas River is affected by wastewater discharges [17]. For the collection of samples, 3 plastic containers (drums) with a capacity of 22.71 L were used. The analysis of the physicochemical parameters (turbidity, pH, color, and TSS), were performed in a laboratory certified by INACAL (National Institute of Quality).

2.2. Obtaining natural coagulants

The procedure for obtaining natural coagulants was as follows: Initially, 2Kg of skin residues of S. tuberosum, *L. meyenii* and *M. paradisiaca* were collected from the restaurants and markets located in the city of Huancayo-Peru [27]. Subsequently, the processes were carried out separately for each species where a first washing with drinking water was carried out, then in a container 5 liters of water with 5 drops of NaClO (sodium hypochlorite) were placed, where the skins were immersed; after that, a third wash was carried out using distilled water for the elimination of impurities. As a fifth step we proceeded with the drying in the laboratory stove at 100° C for 24 hours for S. *tuberosum*, *L. meyenii,* and 72 hours for *M. paradisiaca*. Once the skins were dry, the grinding was carried out; finally, it was sifted with a mesh No. 40, where the fine flour obtained from the three coagulants were packed in polyethylene bags and preserved at room temperature [26].

2.3. Stock Solution

For the preparation of the stock solution of *M. paradisiaca*, *S. tuberosum and L. meyenii*, the same procedure was used for each one. The stock solution of 10000 ppm was prepared, taking into account the methodologies of Aquino and Tovar [28], Salome and Salvatierra [29], Mallqui and Romero [30]; the three natural coagulants at 1%, using 2 gr of the powders of each raw material in 200 ml of boiled distilled water (2gr / 200 ml) [31], then the sample was homogenized for 30 minutes at 60 rpm. At the end of this time, it was left to rest for 10 minutes; finally, the stock solution of the natural coagulants *M. paradisiaca*, *S. tuberosum* and *L. meyenii* was obtained. According to Chethana et al. [32] the solution has to be preserved for a maximum of one month.

2.4. Dosages of natural coagulants.

From the stock solution, the concentration volumes for each dose of 25, 50, 75 and 100 pm were obtained. The equation used to obtain the volumes [33]:

$$C1 * V1 = C2 * V2$$

Where C1 is the coagulant stock solution (2gr/200mg), C2 is the dose with which 25, 50, 75 and 100 ppm were worked, V1 is the volume that was taken out of the stock solution and V2 is the volume of the water sampling with which the Jar-test was worked. In our case a sample volume of 1000 mL was taken; replacing data in the equation, the volumes of 2.5, 5, 7.5 and 10 mL respectively were obtained.

Table 1. Doses used

Volumes found by dose	
Dosage - ppm	Volumes
25	2.5
50	5
75	7.5
100	10

2.5. Jar-test

4 treatments were performed where the doses of 25, 50, 75 and 100 ppm of each natural coagulant were applied. The Jar-test was performed on equipment (Model velp scientifica, JLT 4 series, 100 -240V, 50-60 Hz-F105A0109) that presented 4 pallets; where 4 beakers of 1000 mL were used, then each beaker was labeled with the corresponding dose and natural coagulant. Each beaker received the concentration volumes of 2.5, 5, 7.5 and 10 ml were applied per each coagulant.

For the coagulation process, 100 rpm were considered for 10 minutes; after those10 minutes the speed was decreased to 40 rpm for 20 minutes; this allowed the formation of flocs. At the end of the agitation, it was left to rest for 10 minutes, so that the colloids could settle [26]. After that, 300 mL were extracted from each beaker for the analysis of the physicochemical parameters; this procedure was performed in the same way for the three types of coagulants and the control treatment.

2.6. Parameter analysis
The analysis of the samples obtained from the lower basin of the Cunas River, before and after treatment, were carried out in a laboratory certified by INACAL, where physical-chemical parameters were evaluated: Color, turbidity, pH and TSS.

3. Result

3.1. Pre-test results
To know the characteristics of the Cunas River, an initial measurement of the physicochemical parameters of turbidity, SST, pH, and color was made. Table 2 shows that turbidity had a value of 240 NTU. Regarding TSS, it was 235 mg / L; 6.93 for pH. According to previous research, it is shown that the Cunas River presented a pH of 7.21 in 2017 and 8.30 in 2019 [17]. As for the color, it was 900 PCU.

Table 2. Characterization of the water of the Cunas River

Code	Parameter	Result	Unit
RC-0	Turbidity	240	NTU[to]
	Sst	235	mg/L
	pH	6.93	pH Unit
	Colour	900	PCU[b]

[a] NTU (nephelometric turbidity unit)

[b]PCU (platinum-cobalt unit)

3.2. Post-test results

3.2.1. Turbidity. Table 3 shows that the control treatment (BK-00) results in 137 NTU (nephelometric turbidity unit) in turbidity after the Jar-test, whereas treatment with natural coagulant of *M. paradisiaca* with doses of 75 ppm (CRT-PL03) gave the lowest turbidity value of 40.40 NTU than the other treatments. Also, it is observed that the highest value of 120 NTU was with the natural coagulant of *S. tuberosum* with a dose of 25 ppm (CRT-P01). Comparing the averages of the treatments with the control treatment, a notable reduction in turbidity could be observed in each treatment at different doses where the natural coagulant was applied; likewise, the treatment with CRT-PL shows better results of turbidity removal compared to CRT-P and CRT-M as it is shown in Figure 1.

Table 3. Turbidity Results

Natural Coagulant	Code	Dosage - ppm	Result	Unit
Treatment Control	BK a-00	0	137.00	NTU
Paradise muse	TRC-PL01	25	57.30	NTU
	TRC-PL02	50	42.70	NTU
	TRC-PL03	75	40.40	NTU
	TRC-PL04	100	65.00	NTU
Solanum tuberosum	TRC-P01	25	120.00	NTU
	TRC-P02	50	63.80	NTU
	TRC-P03	75	60.80	NTU
	TRC-P04	100	60.60	NTU
Lepidium meyenii	TRC-M01	25	100.00	NTU
	TRC-M02	50	66.70	NTU
	TRC-M03	75	66.20	NTU
	TRC-M04	100	58.80	NTU

[a]BK: Control treatment – target without application of natural coagulants

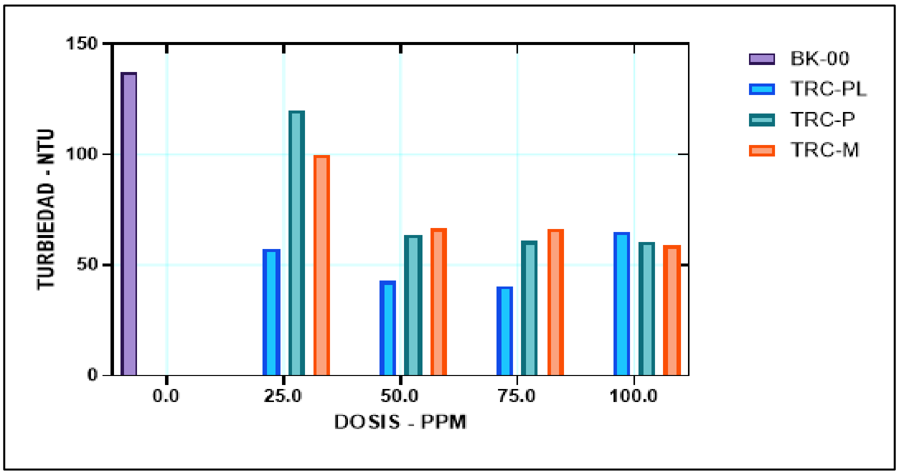

Figure 1. Comparison of doses (PPM) with turbidity (NTU).

3.2.2. Total suspended solids (TSS). Table 4 shows that the control treatment had a value of 204 mg / L after the Jar-test; similarly, it is observed that *M. paradisiaca* is the natural coagulant that presented the lowest values in all its applied doses, being the lowest value 42 mg / L with a dose of 100 ppm (CRT - PL04). Likewise, it was observed that *L. meyenii* is the natural coagulant that presents the highest values in all its applied doses, being the highest value 125 mg / L with a dose of 25 ppm (CRT - M01). Comparing the averages of all treatments with the control treatment, it was observed that a reduction in TSS is shown in each treatment; likewise, treatment with PL-CRT shows better results than CRT-P and CRT-M as it is shown in Figure 2.

Table 4. OSH Results

Natural Coagulant	Code	Dosage - ppm	Result	Unit
Treatment Control	BK-00	0	204	mg/L
Paradise muse	TRC-PL01	25	64	mg/L
	TRC-PL02	50	58	mg/L
	TRC-PL03	75	54	mg/L
	TRC-PL04	100	42	mg/L
Solanum tuberosum	TRC-P01	25	119	mg/L
	TRC-P02	50	106	mg/L
	TRC-P03	75	86	mg/L
	TRC-P04	100	84	mg/L
Lepidium meyenii	TRC-M01	25	125	mg/L
	TRC-M02	50	110	mg/L
	TRC-M03	75	94	mg/L
	TRC-M04	100	92	mg/L

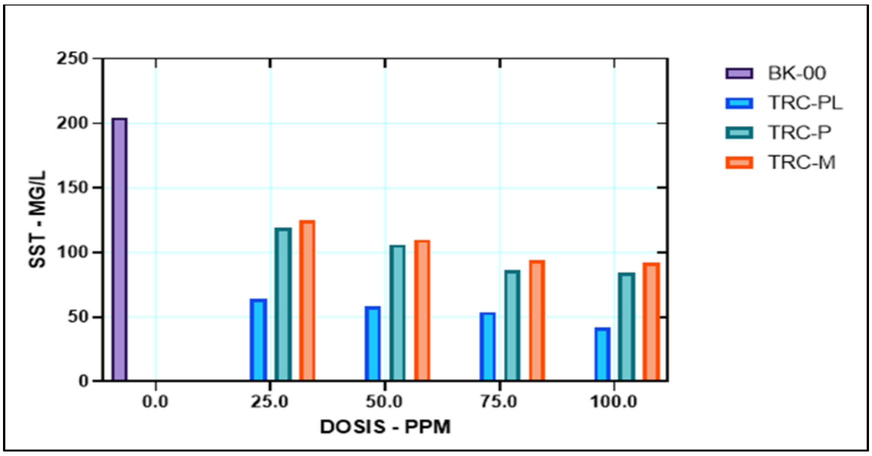

Figure 2. Comparison of doses (PPM) with total suspended solids (Mg/L).

3.2.3. pH. Table 5 shows that the control treatment results in 7.1 pH; similarly, it is observed that the treatment with natural coagulant of *M. paradisiaca* with doses of 100 ppm (CRT-PL04) had the lowest pH of the other treatments, giving a result of 7.05 pH. Likewise, it is observed that the highest value was the treatment with the natural coagulant *L. meyenii* with 7.92 pH with doses of 100 ppm (CRT-M04). Figure 3 shows that in most treatments there is a slight increase in the pH parameter. This is due to DBO_5 (Biochemical Oxygen Demand) caused by natural coagulants, which when applied in different measures, provide greater BOD_5 in water, presenting higher protein content. Being biodegradable organic matter contained in the water samples, it will be oxidized to CO_2 and H_2O by microorganisms that use molecular oxygen [34].

Table 5. pH Results

Natural Coagulant	Code	Dosage - ppm	Result	Unit
Treatment Control	BK-00	0	7.1	Unid.pH
Paradise muse	TRC-PL01	25	7.52	Unid.pH
	TRC-PL02	50	7.51	Unid.pH
	TRC-PL03	75	7.53	Unid.pH
	TRC-PL04	100	7.05	Unid.pH
Solanum tuberosum	TRC-P01	25	7.06	Unid.pH
	TRC-P02	50	7.38	Unid.pH
	TRC-P03	75	7.45	Unid.pH
	TRC-P04	100	7.43	Unid.pH
Lepidium meyenii	TRC-M01	25	7.13	Unid.pH
	TRC-M02	50	7.46	Unid.pH
	TRC-M03	75	7.66	Unid.pH
	TRC-M04	100	7.92	Unid.pH

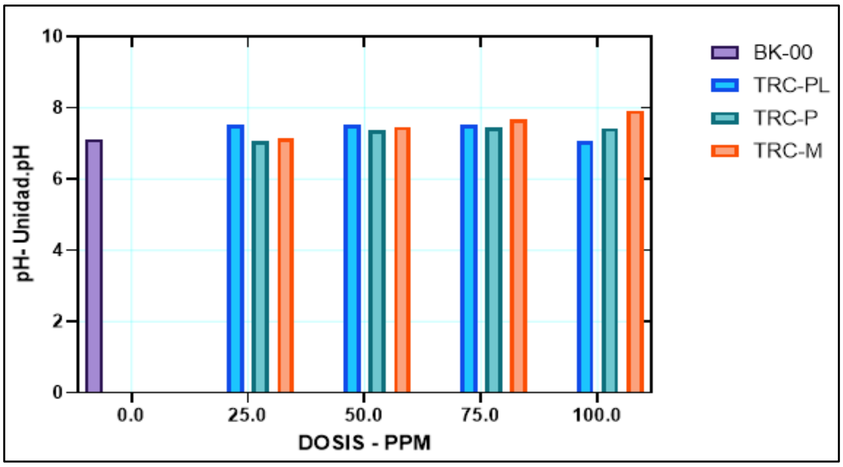

Figure 3. Comparison of doses (PPM) with pH (pH Unit).

3.2.4. Color. Table 6 shows that the control treatment has a value of 850 PCU (platinum-cobalt unit) after the Jar-test; similarly, it is observed that *M. paradisiaca* is the natural coagulant that had lower values in all its applied doses, being the lowest value 290 PCU with a dose of 100 ppm (CRT – PL04). Likewise, it was observed that *L. meyenii* is the natural coagulant that presents the highest values in all its applied doses, being the highest value 460 PCU with a dose of 100 ppm (CRT – M04). Comparing the averages of all treatments with the control treatment, a notable reduction in color could be observed in each treatment of different doses where natural coagulants were applied; likewise, the TRC-PL treatment shows better results compared to CRT-P and CRT-M as it is shown in Figure 4

Table 6. Color results

Natural Coagulant	Code	Dosage - ppm	Result	Unit
Treatment Control	BK-00	0	850	PCU
Paradise muse	TRC-PL01	25	330	PCU
	TRC-PL02	50	320	PCU
	TRC-PL03	75	305	PCU
	TRC-PL04	100	290	PCU
Solanum tuberosum	TRC-P01	25	370	PCU
	TRC-P02	50	440	PCU
	TRC-P03	75	390	PCU
	TRC-P04	100	400	PCU
Lepidium meyenii	TRC-M01	25	405	PCU
	TRC-M02	50	415	PCU
	TRC-M03	75	450	PCU
	TRC-M04	100	460	PCU

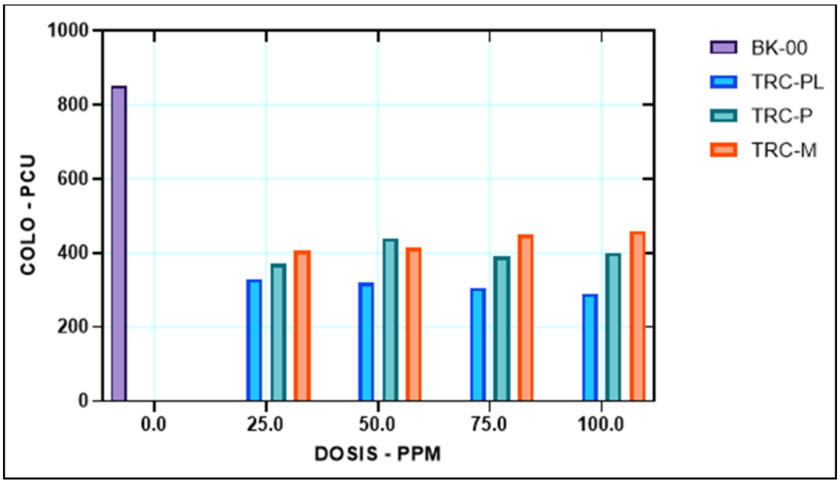

Figure 4. Comparison of doses (PPM) with color (PCU).

3.3. Effectiveness of natural coagulants

Table 7 shows the effectiveness of natural coagulants; using *M. paradisiaca*, a turbidity removal of 70.51% (75 ppm) was obtained; for the TSS, a removal of 79.41% (100 ppm) was obtained; finally, for the color, a removal of 65.88% (100 ppm) was obtained. With *S. tuberosum* a turbidity removal of 55.77 % (100 ppm) was obtained; for the TSS, a removal of 58.82 % (100 ppm) was obtained; for the color, a removal of 56.7 % (25 ppm) was obtained. Finally, using *L. meyenni*, it is observed that it reached a turbidity removal effectiveness of 57.08% (100 ppm). It can be observed that the TSS had a removal effectiveness of 54.90% (100 ppm); in the same way, it is observed that for the color, it was possible to remove 52.35% (25 ppm). Finally, for the pH, the variations after the Jar-test were considered. Figure 5 shows that the highest percentage of effectiveness of turbidity was achieved with the TRC-PL03 treatment, and the lowest effectiveness was that of the TRC-P01 treatment. For the TSS parameter, it is observed that the TRC-PL04 treatment presents the highest effectiveness unlike the TRC-M01 treatment that had the lowest result in the TSS parameter. In addition, it is observed that for the Color parameter, the TRC-PL04 treatment had the greatest effectiveness, and the TRC-M04 treatment had the lowest effectiveness

Table 7. Effectiveness of coagulants

Natural Coagulant	Code	Turbidity BK-00= 137 NTU Effectiveness (%)	Sst BK-00=204 mg/L Effectiveness (%)	Colour BK-00=850 PCU Effectiveness (%)	pH BK.00= 7.1 pH Variation (+/-)
Paradise Muse	TRC-PL01	58.18	68.63	61.18	+0.42
	TRC-PL02	68.83	71.57	62.35	+0.41
	TRC-PL03	70.51	73.53	64.12	+0.43
	TRC-PL04	52.55	79.41	65.88	-0.05
Solanum tuberosum	TRC-P01	12.41	41.67	56.47	-0.04
	TRC-P02	53.43	48.04	48.24	+0.28
	TRC-P03	55.62	57.84	54.12	+0.35
	TRC-P04	55.77	58.82	52.94	+0.33
Lepidium meyenii	TRC-M01	27.01	38.73	52.35	+0.03
	TRC-M02	51.31	46.08	51.18	+0.36
	TRC-M03	51.68	53.92	47.06	+0.56
	TRC-M04	57.08	54.90	45.88	+0.82

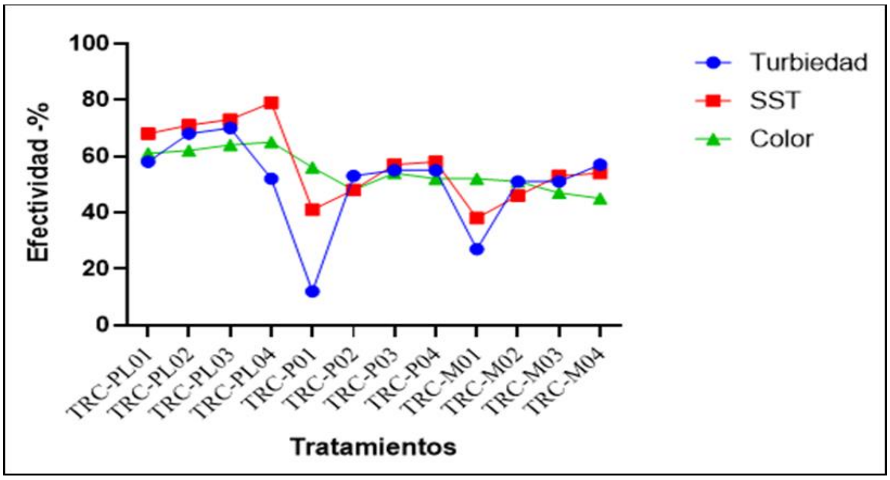

Figure 5. Percentage of treatment effectiveness.

3.4. Optimal doses

Table 8 shows the optimal doses selected by natural coagulant based on the average effectiveness. For *M. paradisica*, the optimal dose is 75 ppm, with an average effectiveness of 69.39%. For *S. tuberosum*, the optimal dose is 75 ppm, with an average effectiveness of 55.86%, and finally for *L. meyenii*, the optimal dose is 100 ppm, with an effectiveness of 52.62%. Figure 6 shows that the highest percentage of effectiveness was achieved in the CRT-PL03 treatment with an optimal dose of 75 ppm; in addition, it is appreciated that the TRC-P03 treatment had an7 intermediate effectiveness with an optimal dose of 75 ppm. Likewise, it can be observed that the least effective treatment is the CRT-M04 with an optimal dose of 100 ppm.

Table 8. Optimal doses

Natural Coagulant	Code	Optimal dose (ppm)	Average effectiveness (%)
Paradise muse	TRC-PL03	75	69.39%
Solanum tuberosum	TRC-P03	75	55.86%
Lepidium meyenni	TRC-M04	100	52.62%

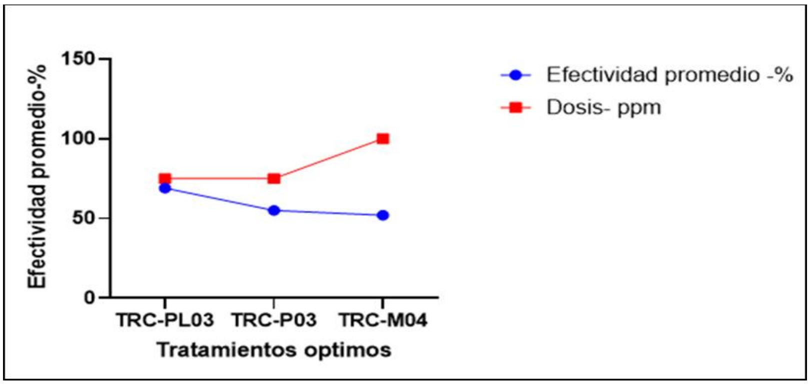

Figure 6.Average effectiveness of optimal treatments.

4. Discussion

The optimal dose used for the treatment of the lower basin of the Cunas River with the natural coagulant obtained from the skin of *M. paradisiaca* was 75 ppm, with a turbidity removal effectiveness of 70.51%, agreeing with Ahmad's research [35], where it is used *M. paradisiaca* as a natural coagulant, obtaining a turbidity removal effectiveness of 64.67% with an optimal dose of 100 ppm. Also, it is related to Carrasquero [26] who used, in his research, *M. paradisiaca* as a natural coagulant and whose turbidity removal effectiveness was 94.5% when applying a dose of 25 ppm. Regarding the findings obtained for the color, with M. paradisiaca, the removal was 65.88% with an optimal dose of 100 ppm; this was the best result obtained at the level of the natural coagulants used. This finding coincides with Carrasquero [26] who, when using *M. paradisiaca,* obtained a color removal efficiency of 93.8% with an optimal dose of 25 ppm. On the other hand, the finding of TSS removal using *M. Paradisiaca* was 79.41mg/L. Similar result to that of Carrasquero [26] that identified an average value of 253.33 mg/L of TSS. In addition, in the research of Moreno et al., [36] an optimal dose of 50 ppm of S. tuberosum was used, having a turbidity removal effectiveness of 93.31%. Also, in Carrasquero's [26] research, an effectiveness of 97.8% was obtained using an optimal dose of 500 ppm when using the natural coagulant of the skin's starch of *S. tuberosum*. Regarding the results of turbidity and color, the present research identified a removal of 55.77% and 56.47% respectively using S. *tuberosum*, keeping similarity with Carrasquero [26], who established that using doses greater than 500 ppm of *S. tuberosum,* the effectiveness of turbidity removal would be greater. For the parameter of TSS, Carrasquero [26] mentions that it was obtained as a result of the fact that the highest average value obtained was 240 mg / L, in a water with initial turbidity of 15 UNT applying an optimal dose of 250 mg / L. In the case of the results in the lower basin of the Cunas River, it was possible to obtain 58.82 mg / L of TSS, with an initial turbidity of 137 UNT applying an optimal dose of 100 ppm. The results found in this research would confirm that TSS removal increases when turbidity is greater. The natural coagulant obtained from the skin of *L. meyenii* presented a greater turbidity removal effectiveness of 57.08% when applying the optimal dose of 100 ppm, demonstrating that at lower doses the effectiveness of turbidity removal is lower. With respect to the color parameter, an acceptable effectiveness percentage of 52.35% is shown with a dose of 25 ppm, reducing the control treatment to 405 PCU. For the TSS parameter, it is observed that the highest average value was 54.90 mg / L, in a sample with initial turbidity of 137 UNT, with an optimal dose of 100 ppm. With respect to the pH, the values obtained after applying the natural coagulant of the skin of *M. paradisiaca* varies from 7.52 to 7.05 pH units, the values obtained from the natural coagulant of the skin of *S. tuberosum* vary from 7.45 to 7.06 pH units, and the values obtained from the natural coagulant of the skin of *L. meyenii* vary from 7.92 to 7.13 pH units. The pH of the control sample was 7.1 pH units, demonstrating that when applying natural coagulants, no significant alterations of the pH parameter are observed. This would be in accordance with the research of Carrasquero [26], Vara [37], Camacho [10] and Moreno [36] who found that when using coagulants there are no extreme variations with respect to pH. At the same time, Carrasquero's [26] research mentioned that when using the natural coagulant of the starch of the skin of *S. tuberosum* in higher doses, there is a decrease in pH, which is also reflected in our results. In Camacho's [10] research it is mentioned that the pH must be in the range of 6.5 – 8.0 so that it can be subjected to the coagulation process without the need for a pH correction. As for the findings, there is no need to perform a pH correction because they are within the range mentioned by Camacho [10].

5. Conclusions

The natural coagulant obtained from *M. paradisiaca* presented a higher average effectiveness of 69.39 % when using an optimal dose of 75 ppm, higher than the other coagulants used; however, the greatest effectiveness of removal of TSS and color was given at a dose of 100 ppm. For pH it presents a variation of -0.05 with doses of 100 ppm. The natural coagulant obtained from the skin of *S. tuberosum* showed an average intermediate effectiveness of 55.86% with an optimal dose of 75 ppm; it has a greater effectiveness for turbidity removal of 55.77% with doses of 100 ppm; and also, it has a greater effectiveness of TSS removal of 58.82% with a dose of 100 ppm. For the color parameter, it has a greater removal effectiveness of 56.47% with doses of 25 ppm, and finally in the pH variation it presents -0.04 with doses of 25 ppm compared to our control treatment. The natural coagulant obtained from the skin of *L. meyenii* showed a lower average effectiveness of 52.62% with an optimal dose of 100 ppm. This natural coagulant had less average effect compared to *M. paradisiaca* and *S. tuberosum* on the parameters evaluated. The highest effectiveness of turbidity removal is 57.08% with doses of 100 ppm; it is also obtained that the highest effectiveness of TSS removal is 54.90% with doses of 100 ppm. For the color parameter, the highest removal effectiveness is 52.35% with doses of 25 ppm. Finally, the pH presents a variation of +0.03 with doses of 25 ppm. Natural coagulants prepared from vegetable waste can be used in wastewater treatment plants, in coagulation, flocculation and sedimentation processes, being a more environmentally friendly alternative.

6. References

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