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POTATO STARSCH (*Solanum tuberosum*) AND ITS EFFECT ON WATER TURBIDITY FOR POPULATION CONSUMPTION

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Abstract
The objective of this research was to evaluate the coagulating power of potato starch (*Solanum tuberosum*) cultivar Unica, and aluminum polychloride for the removal of turbidity from water entering the Samegua treatment plant, Moquegua/Peru. The completely randomized design (CRD) was applied, under a factorial arrangement of A and B where nine mixtures were made. The sampling point chosen was the intake of water from the Ollería catchment to the Samegua water treatment plant. The natural potato starch coagulant was obtained using crushing, filtering, sedimentation, drying and sieving operations, with a yield of 17.5% starch. The analysis of the results obtained allowed establishing that the optimum concentration of potato starch was 133.0 mg/l (0.2 g of starch), achieving the removal of the turbidity parameter at 6.3 NTU, and the most suitable concentration of aluminum polychloride was 2072.0 ml/l (13.0 ml of aluminum polychloride), achieving the removal of the turbidity parameter at 9.1 NTU. The results of the optimum mixtures correspond to treatment 5 with 133.0 mg/l of potato starch (0.2 g) as a coadjuvant agent mixed with 1597.0 ml/l of aluminum polychloride (10.0 ml), achieving a turbidity of 7.8 NTU. In conclusion, it was found that the coagulating power of potato starch, cultivar Unica, gave better results than aluminum polychloride for the removal of turbidity at the entrance of the water to the Samegua treatment plant.
Key words: coagulant, potato starch, aluminum polychloride, turbidity, removal.

Resumen
El presente trabajo de investigación tuvo como objetivo evaluar el poder coagulante del almidón de papa (*Solanum tuberosum*) cultivar Unica, y el policloruro de aluminio para la remoción de la turbidez de las aguas al ingreso a la planta de tratamiento Samegua, Moquegua/Perú. Se aplicó el diseño completamente aleatorio (DCA), bajo un arreglo factorial de A y B donde se realizaron nueve mezclas. Se eligió como punto de muestreo el ingreso de agua de la captación Ollería a la planta de tratamiento de agua Samegua. La obtención del coagulante natural de almidón de papa se logró utilizando operaciones de triturado, filtrado, sedimentado, secado y tamizado; con un rendimiento de 17.5% de almidón. El análisis de los resultados obtenidos permitió establecer que la concentración óptima del almidón de papa fue 133.0 mg/l (0.2 g de almidón), lográndose remover el parámetro turbidez a 6.3 NTU, y la concentración de policloruro de aluminio más adecuada fue 2072.0 ml/l (13.0 ml de policloruro de aluminio), lográndose remover el parámetro turbidez a 9.1 NTU. Los resultados de las mezclas óptimas corresponden al tratamiento 5 con 133.0 mg/l de almidón de papa (0.2 g) como agente coadyuvante mezclado con 1597.0 ml/l de policloruro de aluminio (10.0 ml), se logró la turbidez de 7.8 NTU. Como conclusión se encontró que el poder coagulante del almidón de papa, cultivar Unica, dio mejores resultados que el policloruro de aluminio para la remoción de la turbidez al ingreso de las aguas a la planta de tratamiento Samegua.

Palabras clave: coagulante, almidón de papa, policloruro de aluminio, turbidez, remoción.

Introduction

Water quality is a growing concern in all developing cities of the world. Natural water sources are under increasing threat of contamination; therefore, the consequences are far-reaching for the health of children's populations as well as for the economic and social development of communities and nations (UNICEF, 2014).

The water resources of the planet earth are subject to a risk of physical, chemical and/or biological contamination. The growing advance of human activities such as industry, agriculture, livestock, population growth, the lack of programs and measures to respond to these changes generates an environment that favors the advance of pollution. Because of this, measures must be taken to favor the decontamination of effluents and this should be increasingly urgent, thus making it necessary to search for new environmentally friendly alternatives based on research on different natural water treatment systems that facilitate better quality and adequate protection of water resources (Sanchez *et al*., 2010).

Drinking water should be aesthetically acceptable, free of turbidity, color and perceptible taste, and should have a reasonable temperature (Kiely, 1999; Abbasi et al, 2021). So, water treatment involves a physicochemical process known as coagulation and flocculation. Coagulation is defined as the addition of chemicals and/or the provision of mixing, so that suspended particles and some dissolved contaminants flocculate into larger particles that can be removed by various solids removal processes (Newcombe & Dixon, 2006).

Aluminum polychloride ($Al2(OH)_{3Cl}$) is a chemical coagulant made from low molecular weight polymerized salt and aluminum hydrochloride, that is effective in water clarification in industrial processes and drinking water treatment (Andía, 2000), and is used in the treatment of water for human consumption in the Samegua district.

The aluminum parameter at the Samegua water treatment plant inlet is within the national environmental quality standards (ECA) category 1, subcategory 2. However, the water at the plant outlet shows an increase of 1.3 mg/l of aluminum, exceeding the maximum permissible limits (MPL) established in the water quality regulations for human consumption, approved by DS N° 031- 2010-SA (GERESA, 2016).

Developing countries have adopted as an alternative a number of traditional technologies to remove turbidity from domestic water. The most widely studied of these is the use of natural plant-based coagulants for water clarification (Dorea, 2006). The use of coagulants based on biological material for the treatment of turbid water dates back several millennia (Martínez *et al*., 2003).

Environmental scientists through various studies and evaluations have been able to identify and distinguish various types of plants for this purpose. The use of natural coagulants can help minimize or avoid the importation of chemical coagulants (Chun-Yang, 2010).

The potato crop, cultivar Única, is the result of participatory research with farmers (Producers' Associations), national agricultural research institutions (National University "San Luis Gonzaga" of Ica) and the International Potato Center (CIP). The name Unica is in recognition of the National University "San Luis Gonzaga" of Ica, as the alma mater of professionals in that region and represents an abbreviation and initials of that university (Gutiérrez-Rosales *et al.*, 2007).

Therefore, the objective of this research was to evaluate the coagulating power of potato starch (*Solanum tuberosum*) cultivar Unica, and aluminum polychloride ($Al2(OH)_{3Cl}$) for the removal of turbidity from water entering the Samegua treatment plant, Moquegua/Peru.

Materials and methods

Experiment area

The experimental tests of this research work were carried out in the laboratory of the Samegua water treatment plant and in the laboratory of the Universidad José Carlos Mariátegui.

Experimental design

In the present research, a completely randomized design (CRD) was used, in an AxB factorial arrangement (Table 1) with 3 replications, whose factorial combination provided 6 treatments (Table 2).

A	Potato starch	B	Aluminum polychloride
a0	0.0 g (0.0 mg/l)	**b0**	0.0 ml (0.0 ml/l)
a1	0.2 g (133.0 mg/l)	**b1**	10.0 ml (1 597.0 ml/l)
a2	0.3 g (200.0 mg/l)	**b2**	13.0 ml (2 072.0 ml/l)

Table 2. Factorial combination of the experiment

Factor B Aluminum polychloride

		b0	b1	b2
Factor A Potato starch	a0	a0b0	a0b1	a0b2
	a1	a1b0	a1b1	a1b2
	a2	a2b0	a2b1	a2b2

Population and sample

The water sample was collected from the Ollería water intake at the entrance of the Samegua water treatment plant, which has an inlet flow of 41 l/s. The random water sampling was 36 gallons of water (45 l) that was distributed in 9 tests of 1.5 l with a repetition of 3 times.

Parameter evaluated

Potato starch and aluminum polychloride in turbidity removal at the Samegua treatment plant inlet.

Statistical analysis

For data analysis of the variables under study, ANVA (Analysis of Variance) was used, using the F (Fisher) test at a significance level of 0.05 and 0.01, and for the comparison of multiple means, Tukey's significance test was used at a probability $\alpha = 0.05$.

Results

In Table 3 of the ANVA for turbidity (NTU, Nephelometric Turbidity Unit), for factor A, since the results were statistically different with respect to the control (a0 = 0.0 g), it is considered that the treatment effects were significant. For factor B, as the results were statistically different from the control (b0 = 0.0 ml), it is considered that the treatment effects were significant. For the A x B combination, it is observed that there is high statistical significance. The main factors acted dependently; that is, the levels of factor A show a significant difference under any combination of B and vice versa; therefore, the analysis of simple effects (Table 4) is required to obtain conclusions of the behaviors of the levels in consideration to the other factor. The coefficient of variability of 2.7% is acceptable for the experiment and is within the established ranges for experiments.

Table 3. Turbidity ANVA (NTU)

Sources of Variation	**GL**	**SC**	**CM**	**FC**	**FT**		**Sig.**
					0.1	**0.0**	
Factor A	2	109.3	54.7	834.9	3.6	5.6	**
Factor B	2	6.7	3.4	51.2	3.6	6.0	**
A x B	4	79.6	19.9	303.9	2.9	4.6	**
Error exp.	18	1.2	0.1				
Total	26	196.8					

Table 4. ANVA of simple effects of turbidity (NTU)

Sources of variation	**GL**	**SC**	**CM**	**FC**	**FT**		**Sig.**
					0.05	**0.01**	
A en b_0	2	164.4	82.2	1255.3	3.5	6.0	**
A en b_1	2	24.3	12.1	185.4	3.5	6.0	**
A en b_2	2	0.2	0.1	1.9	3.5	6.0	NS
B en a_0	2	75.1	37.5	573.4	3.5	6.0	**
B en a_1	2	9.4	4.7	72.0	3.5	6.0	**
B en a_2	2	1.8	0.9	13.5	3.5	6.0	**
Error Exp	18	1.2	0.1				
Total	30	276.4					

Table 4 shows the simple effects analysis; high statistical significance was found when factor A was combined with the volumes of aluminum polychloride b0 and b1, but no statistical significance was found when factor A was combined with volume b2; likewise, a highly significant difference was found when factor B was combined with each of the levels of factor A (potato starch) a0, a1 and a2.

Tukey's test of simple effects of turbidity (NTU) for potato starch x aluminum polychloride.

A in b0	**NO.**	**Sig.**	**A in b1**	**NO.**	**Sig.**	**A in b2**	**NO.**	**Sig.**

		0.1			0.1			0.1
a0	16.1	a	a0	11.5	a	a0	9.1	a
a2	8.0	b	a2	7.9	b	a2	9.0	a
a1	6. 3	c	a1	8.3	b	a1	8.8	a

Table 5 shows the results of the Tukey significance test for simple effects of turbidity (NTU). Factor A shows statistical differences when combined with the levels of factor B, the highest average being a0b0 with 16.1 NTU, followed by a0b1 with 11.5 NTU; the lowest average is the combination a1b0. Figure 1 shows the treatments performed in the Jar Tester equipment.

Figure 1. Treatments performed on the Jar Tester equipment

Table 6. Tukey's test for single effects of turbidity (NTU) for aluminum polychloride x potato starch.

B in a0	NTU	Sig. 0.05	B in a1	NTU	Sig. 0.05	B in a2	NTU	Sig. 0.05
b0	16.1	a	b2	8.7	a	b2	9.1	a
b1	11.5	b	b1	7.9	ab	b1	8.3	a
b2	9.1	c	b0	6.3	b	b0	8.1	a

Table 6 shows the results of the Tukey test for simple effects of turbidity (NTU). The a0b0 combination achieved the highest average with 16.1 NTU, followed by a0b1 with 11.5 NTU, but since the aim is to reduce the amount of turbidity, we can see that the lowest average is the a1b0 combination with 6.3 NTU.

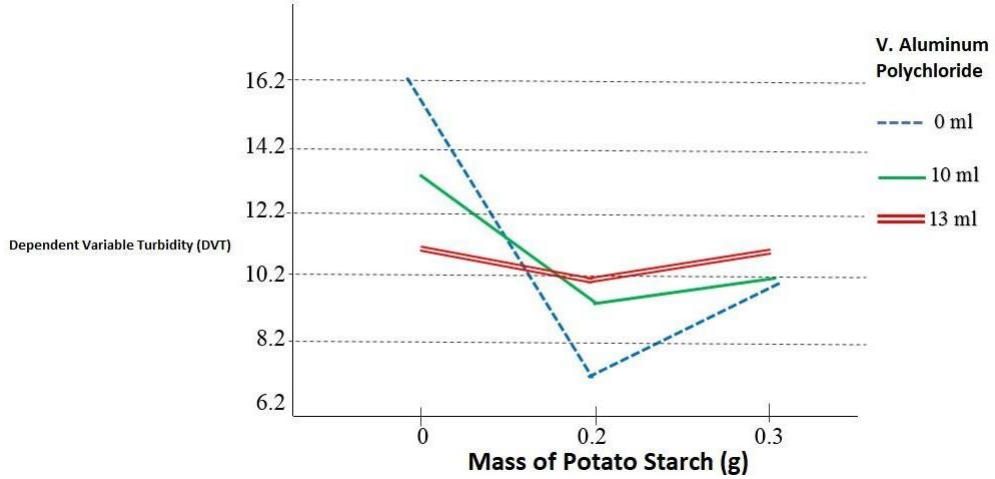

Figure 2. Combination of potato starch x aluminum polychloride for turbidity (DVT)**.**

Figure 2 shows the A x B combination for turbidity (DVT). It indicates that potato starch a1 has a greater effect on turbidity removal combined with aluminum polychloride, highlighting b0 followed by a1. Likewise,

the levels of aluminum polychloride at 10.0 ml and 13.0 ml are significantly equal to each other, but significantly different with respect to the 0.0 ml level.

Discussion

Alvarado (2012) conducted a quantitative experimental research where he evaluated the capacity of potato starch, Diacol Capiro variety, to remove turbidity from water, obtaining color reduction with the third treatment (2.5g of potato peels) and a pH of 7.5; that is, the results of these two parameters are within the values required by current regulations. Likewise, Moscozo (2015) used cassava starch, where he managed to determine that it is indeed possible to replace up to 60% of aluminum sulfate with cassava starch in the coagulation-flocculation process for water potabilization and achieve a turbidity lower than 5 NTU, in order to comply with the maximum permissible limits. Also, Mantilla (2013) developed a research study on the extraction and modification of four-edged plantain starch (Musa ABB of the Silver Bluggoe subgroup) to be used in the treatment of drinking water in Colombia, obtaining as a result a low coagulating power; where once the multifactorial statistical analysis was performed, it showed that there was no significant difference in terms of turbidity and pH, and through the statistical analysis of simple effects concluded that there were no significant differences between one treatment and another.

MINAM (2008), approved the national environmental quality standards for water, specifies and establishes the concentration level or degree of elements, substances or physical, chemical and biological parameters present in water, as a receiving body and basic component of aquatic ecosystems, which does not represent a significant risk to human health or the environment. According to MINSA (2010, 2011), in the framework of DS N° 031-2010-SA, which establishes the maximum permissible limits for organoleptic quality parameters of the water quality regulations for human consumption, the maximum permissible limit is 5 NTU for turbidity parameters; In the present research, it is observed that the potato starch factor, cultivar Unica, presented a similar behavior in terms of turbidity removal with respect to the standard formulation of aluminum polychloride, comparing the turbidity results with the regulation for water for human consumption, approved by DS N° 031- 2010-SA.

Conclusions

The evaluation of the coagulating power of potato starch from the cultivar Unica efficiently removed water turbidity in comparison with the chemical coagulant aluminum polychloride ($Al2(OH)_{3Cl}$) used at the Samegua treatment plant.

The natural potato starch coagulant, cultivar Unica, was obtained using crushing, filtering, sedimentation, drying and sieving operations, which did not involve high costs, obtaining a yield percentage of 17.5% potato starch.

The analysis of the results obtained allowed establishing that the optimum concentration of potato starch is 133.0 mg/l (0.2 g of potato starch), achieving the removal of the turbidity parameter up to 6.3 NTU at the Samegua water treatment plant.

From the results obtained, it was established that the most appropriate concentration of aluminum polychloride was 2072.0 ml/l (13.0 ml of aluminum polychloride), achieving the removal of the turbidity parameter up to 9.1 NTU at the Samegua treatment plant.

The results of the optimum mixtures correspond to treatment 5 with 133.0 mg/l of potato starch (0.2 g) as a coadjuvant agent, mixed with 1597.0 ml/l of aluminum polychloride (10.0 ml), achieving a turbidity of 7.9 NTU.

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