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Elaboration of A Biopolymer from Whey and Potato Starch (*Solanum tuberosum)* for the Encapsulation of Liquid Detergent in the Canton of Guaranda, Province of Bolivar

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A B S T R A C T

The present research is carried out with the purpose of using whey and potato starch to produce a biopolymer for the encapsulation of liquid detergent, in which we have proposed to obtain the best combination in the production of biopolymers, analyze the product based on 3 rheological characteristics, determine the useful life of the biopolymer and apply it agroindustrially. For this purpose, three study factors are considered, Factor A (whey concentration), Factor B (starch percentage) and Factor C (type of thickener). By means of an analysis of variance the response variables are determined and with it the best combination in the elaboration of the biopolymer, the response variables to determine were; traction in this way we obtained that the T1 is the best treatment, solubility that obtained the best combination in the T19 and for the variable of Biodegradability it was carried out for the best treatments resulting from the analysis of variance of the T1 and T19. For this we have obtained favorable results, in which the combination of whey and potato starch plus the addition of suitable thickeners, under controlled conditions, allows us to obtain a biopolymer with adequate rheological characteristics with a level of 95% confidence.

Introduction

Whey is a liquid obtained during the cheese making process, characterized by its cloudy yellowish color, slightly sweet fresh flavor, which represents approximately 90% of the milk used and contains more than half of the nutrients found in milk. Whey contains high concentrations of organic matter, mainly composed of proteins, lactose, fat, mineral salts, water-soluble vitamins and some other substances with antioxidant capacities, which helps contribute significantly to the industrial sector due to its varied nutrients and functional properties, Posada (2016).

Pais *et al.,* (2017), mention that cheese is one of the most consumed dairy derivatives in our country, after fluid milk, being thus among the most desired products are, Creole cheese, mozzarella, kneaded and curd in general, and as a result of the production of the different types of cheese, we have as a result the whey. The production of

However, this information may be somewhat limited due to the fact that only information from the countries with the highest cheese production is available. In potato, starch constitutes its main source of energy storage and its content varies according to cultivars and growth stage of the plant between 15% and 20% of its weight and with a high phosphorus content (0.8%) compared to starches from other sources (Vera and Chavarría, 2020). Potatoes can be highlighted for their contribution of carbohydrates, proteins and dietary fiber as major components; B complex vitamins such as thiamine (B1) and (B6), as well as vitamin C and some minerals such as: magnesium, iron, calcium, potassium and phosphorus. According to Isique and Sing (2017), tells us that 75% of the dry matter is composed of starch, dietary fiber represented 1-2% of the total potato and is found in the skin, the percentage of simple sugars, represents 0.1-0.7%, of nitrogenous compounds, which contains from 3 to 15%, an albumin content of 49% and globulins of 26% and glutelins with 8.3% and the lipid percentage in the potato is very low. On the other hand, biopolymers obtained from natural fibers, starch, cellulose or organic components, have the characteristic of being biodegradable. This allows their degradation with ease in different geographical layers, thanks to natural processes or to the exposure of degrading agents, such as bacteria (Molina and Flórez, 2020).

Nowadays, due to the high demand for sustainable products, there has been a search for materials with which non-food grade products can be manufactured, in order to have the least possible impact on the environment, which is why biopolymers or biodegradable plastics are suggested as an answer.

Whey

Whey is the liquid fraction found in milk, which is obtained from the precipitation and recovery of casein, this product comprises 85% to 95% of the total volume of milk, which is used in the production of cheeses Fernandez *et al.,* (2016). Whey has a high concentration of organic matter, mainly consisting of proteins, lactose, fat, mineral salts, etc. (Rigey, 2016).

Potato starch

A white, odorless powder with an unpleasant taste, starch is the main reserve substance in vegetables. It is found in tubers such as potato, sweet potato and cassava, and in all cereals, where it represents between 60 and 70% of their chemical composition, Bergesse *et al.,* (2015). Villaroel *et al.,* (2018), tells us that; starch is the major source of carbohydrates in the human diet and the most abundant storage polysaccharide in plants. It occurs naturally in the form of granules in the chloroplasts of green leaves and amyloplasts of seeds, legumes and tubers.

Biopolymers

They are polymeric biomolecules containing monomeric units that covalently bond together to form larger molecules. The prefix "bio" means that they are biodegradable materials produced by living organisms. The term "biopolymer" can be used to describe a wide variety of materials that are usually derived from biological sources, such as microorganisms, plants or trees. Mohan *et al.,* (2016); Molina and Castillo (2020), mention that biopolymers are used in various fields, within which biomedicine, the food industry, packaging and water purification, among others, can be highlighted. They have been used and applied as encapsulation systems for substances or microorganisms, such as enzymes, antioxidants, microbial agents, flavors and other bioactive materials. In this way, factors such as bioavailability, flavor, texture and consistency of food, antimicrobial activity of encapsulated drugs, among others, are improved.

Study factors

The factors considered for the study were whey concentration, percentage of starch addition and type of thickener.

Materials and Methods

Experimental material

- Sweet whey
- Potato starch variety chola (*Solanum tuberosum L.*).
- Analytical glycerin ($C3H3O3$).
- Cartagenin (300,000 Dalton).
- Pectin ($C6H10O7$).

Reagents

Best combination

For the methods used, we can find tensile, solubility and biodegradability tests, of which the best combination obtained from these tests is the following.

Sweet whey, potato starch variety chola (*Solanum tuberosum* L.) analytical glycerin ($C3H3O3$), cartagenin (300,000 Dalton), pectin ($C6H10O7$).

Traction test

For this test, we followed the methodology proposed by (Demera and Meza, 2021), which consisted of using a 100 N dynamometer and a universal support. The measurement procedure was to cut the biopolymer sheets 15 cm long and 2 cm wide, then the cut samples are placed on the hook of the dynamometer, and this is placed on the universal support in order not to have alterations in the results, then the samples are stretched to reach its breaking point, in order to determine how much resistance it has. This test was performed in triplicate for each treatment.

Solubility test

To determine the percentage of solubility, in this study to followed the methodology of (Mohan *et al.,* 2016), in this way proceed to cut pieces of each film with dimensions of 2 cm by 3 cm and the weight is recorded, subsequently, it is placed in a beaker with 80 ml of distilled water with continuous agitation at 125 rpm, at a temperature of 60°C. finished the agitation, the remains of the sample are filtered and dried in an oven at 60°C for 2 h. then the dry sample is weighed, to finally determine the percentage of soluble matter, which was calculated with the following equation:

$$\% \text{ Solubility} = \frac{\text{initial dry weight} - \text{final dry weight}}{\text{final dry weight}} \times 100$$

Biodegradability Tests

The Biodegradability test was performed following the methodology of (Demera and Meza, 2021), this consists of a composting process in anaerobic conditions, which consists of cutting sheets of 2.5 x 2.These samples are placed in plastic containers with soil selected from the surroundings of the laboratory, then their weight is recorded every 7 days, which will be carefully extracted from the soil, cleaned and weighed, in order to determine their biodegradability according to the weight loss, until they present a constant weight. The test was carried out in triplicate for each treatment and the following formula was used:

$$\% \text{ weight loss} = \frac{\text{initial dry weight} - \text{final dry weight}}{\text{final dry weight}} \times 100$$

Results and Discussion

ANOVA for the traction test

The table of variance analysis of the traction variable, decomposes the variability in contribution due to the factors: whey percentages, starch percentage and type of thickener, the P factors test the statistical significance of each one of the factors, for the analysis of the effect that each factor has on the traction variable, the AxBxC interaction is taken into consideration, whose result is highly significant.

This table applies a multiple comparison procedure to determine which means of the levels of Factor A, are significantly different from others. In the top of the page, 2 homogeneous groups have been identified according to the Alignment of the A's in columns. There are no statistically significant differences between those levels that share the same column of A. The method used Currently, the minimum difference procedure is used to discriminate between means significant (LSD) of Fisher. According to the data obtained, it can be seen that level a1 is the one that presents the highest value with respect to its average, and is different to the other levels, as shown in the figure 1.

This table applies a multiple comparison procedure to determine which Factor B level means are significantly different from others. At the top of the page, we have identified that there are no homogeneous groups according to the alignment of the A and B in columns. There are no statistically significant differences between those levels sharing the same A and B column. The method currently used to discriminate between the means is Fisher's Least Significant Difference (LSD) procedure. According to the data obtained, it can be seen that level b1 is the one that presents the highest value with respect to its mean, and is different from the other levels, as shown in Figure 2.

The table.1 applies a multiple comparison procedure to determine which Factor C level means are significantly different from others. At the top of the page, we have identified that there are no homogeneous groups according to the alignment of the A and B in columns. There are no statistically significant differences between those levels sharing the same A and B column. The method currently used to discriminate between the means is Fisher's Least Significant Difference (LSD) procedure. According to the data obtained, it can be seen that level c1 is the one that presents the highest value with respect to its mean, and is different from the other levels, as shown in Figure 3.

Thus, to obtain a biopolymer with good tensile characteristics, the ideal combination is treatment 19 with coding a3b1c1, which corresponds to: 50% whey + 50% distilled water + 30% starch + glycerin. This treatment obtained a breaking or tensile point of 0.43 N.

The average tensile values were compared with the data obtained by Narvaez (2016) with a value of 106.05 MPa and the value of Charro (2015) who obtained a tensile value with a minimum 5.8 N and a maximum of 45.17 N, they also mention that the traction of biopolymers is directly related to the process that exerts destructive pressure that provides better resistance, in order to know the ability to withstand a load or stretching in the short and long term, from what aims to remain to obtain a quality of adequate resistance for the product.

Solubility results

The analysis of variance table of the solubility variable, decomposes the variability in contribution due to the factors: whey concentration, starch percentage and type of thickener, the P factors test the statistical significance of each of the factors, for the analysis of the effect that each factor has on the solubility variable, the interaction A×B×C is taken into consideration, whose result is highly significant. This table applies a multiple comparison procedure to determine which means of Factor A levels are significantly different from others. At the top of the page, no homogeneous groups have been identified based on the alignment of the A's in columns. There are no statistically significant differences between those levels that share the same column of A. The method currently used to discriminate between the means is Fisher's least significant difference (LSD) procedure. According to the data obtained, it can be seen that level a3 is the one that has the highest value with respect to its average, and is similar to level a1, as shown in figure 4.

This table applies a multiple comparison procedure to determine which means of Factor B levels are significantly different from others. At the top of the page, no homogeneous groups have been identified according to the alignment of the Bs in columns. There are no statistically significant differences between those levels that share the same column of B. The method currently used to discriminate between the means is Fisher's least significant difference (LSD) procedure. According to the data obtained, it can be seen that level b1 is the one that has the highest value with respect to its average, and is different from the other levels, as shown in Figure 5. This table applies a multiple comparison procedure to determine which means of Factor C levels are significantly different from others. At the top of the page, no homogeneous groups have been identified based on the alignment of the C's in columns. There are no statistically significant differences between those levels that share the same column of C. The method currently used to discriminate between the means is Fisher's least significant difference (LSD) procedure. According to the data obtained, it can be seen that level c1 is the one that has the highest value with respect to its average, and is different from the other levels, as shown in figure 6.

In this way, to obtain Of the best combination in the production of the biopolymer according to the solubility variable, the best treatment 19 was obtained with the coding a3b1c1, which corresponds to: 50% whey + 50% distilled water + 30% starch + glycerin, which obtained a percentage of solubility of 96.99%.

However, Gallegos (2021), in his study, reports a solubility percentage of 58.42% solubility in water, he also mentions that values lower than 70% solubility are used in food coatings, and higher percentages are used as coatings soluble for encapsulation.

Results biodegradability test

The table shows the percentage of biodegradability of the best treatments, which correspond to T1 with a percentage of biodegradability of 81.57% and T19 with 58.57% biodegradation

These values were compared with those obtained by Herrera (2021) where he reached a biodegradability percentage of 45.85%. He also mentions that the biofilms obtained in his research are absolutely favorable from the environmental point of view, since after 15 days in aerobic conditions they were able to obtain a good degradation.

Table.1 Shows the study factors with their respective levels.

Factors	Code	Niveles
Whey	A	$a1$: whey100% $a2$: whey 80% + 20 % H_2O $a3$: whey 50% + 50% H2O
% of starch	B	b1: 30% b2: 50% b3: 70%
Type of thickeners	C	$c1$: Glycerin $c2$: Carrageenan $c3$: Pectin

Table.2 Tensile test results

Source	Sum of squares	Gl	Half squares	Reason-F	worth-P
Main effects					
A: Whey	0.0166988	2	0.00834938	34.16	0.0000
B: Starch	0.106106	2	0.0530531	217.04	0.0000
C: Thickener	0.323573	2	0.161786	661.85	0.0000
Interaction					
AB	0.104516	4	0.026129	106.86	0.0000
AC	0.0138938	4	0.00347346	14.21	0.0000
BC	0.119842	4	0.0299605	122.57	0.0000
ABC	0.153491	8	0.0191864	78.49	0.0000
Waste	0.0132	54	0.000244444		
Total (Corrected)	0.851321	80			

Table.3 Multiple range test for traction of the concentration of whey factor A.

Whey A	Cases	Half LS	Sigma LS	Homogeneus groups
a3	27	0.0851	0.0030089	A
a2	27	0.0770	0.0030089	A
a1	27	0.1107	0.0030089	B

Table.4 Multiple range test for traction of starch percentage factor B

Starch B	Cases	Media LS	Sigma LS	Homogeneous groups
b3	27	0.0481	0.0030089	A
b2	27	0.0881	0.0030089	B
b1	27	0.1366	0.0030089	B

Table.5 Multi-range test for tensile strength by thickener type factor C.

Thickener C	Cases	Media LS	Sigma LS	Homogeneous groups
c3	27	0.0133	0.0030089	A
c2	27	0.0914	0.0030089	B
c1	27	0.1681	0.0030089	B

Table.6 ANOVA for solubility assay

Source	Sum of Squares	Gl	Half squares	Reason-F	Value-P
Main effects					
A: Whey A	721,622	2	360,811	267,97	0,0000
B: Starch B	2665,02	2	1332,51	989,64	0,0000
C: Thickener C	11779,9	2	5889,95	4374,41	0,0000
Interactions					
AB	1344,89	4	336,222	249,71	0,0000
AC	258,092	4	64,523	47,92	0,0000
BC	1808,34	4	452,086	335,76	0,0000
ABC	2985,06	8	373,132	277,12	0,0000
Waste	72,7086	54	1,34646		
Total (corrected)	21635,6	80			

Table.7 Multiple range test for solubility of whey factor A concentration.

Whey A	Cases	Media LS	Sigma LS	Homogeneous groups	
a2	27	46,95	0,223313	A	
a1	27	53,22	0,223313	B	
a3	27	53,34	0,223313	B	

Table.8 Multiple range test for factor B starch percentage solubility.

Starch B	Cases	Media LS	Sigma LS	Homogeneous groups
b3	27	45,70	0,223313	A
b2	27	48,71	0,223313	B
b1	27	59,09	0,223313	C

Table.9 Multiple range test for solubility by type of thickner factor C.

Thinkener C	Cases	Media LS	Sigma LS	Homogeneous groups
c2	27	38,03	0,223313	A
c3	27	48,32	0,223313	B
c1	27	67,15	0,223313	C

Table.10 Percentage biodegradability of the biopolymer.

Days	T1	T19
Initial weight	0,85	0,94
7	67,22	46,86
14	70,73	49,82
21	72,95	52,19
28	75,12	53,07
35	81,50	58,38
36	81,50	58,38
37	81,55	58,44
38	81,57	58,47
39	81,57	58,47

Table.11 Encapsulation parameters.

Tool	Sealing time	Dimensions	weight
Sleevesealer	7 seconds	4 x 4 cm	3 g

Figure.1 Interaction of factor A and factor B.

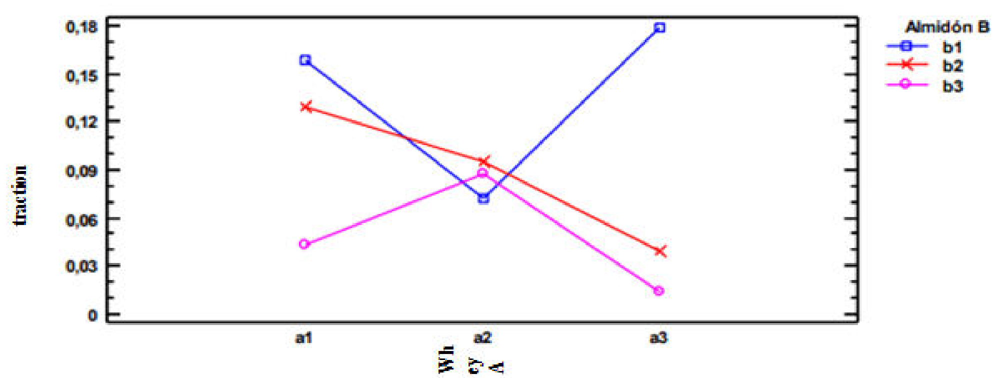


Figure.2 Factor A and Factor C interactions.

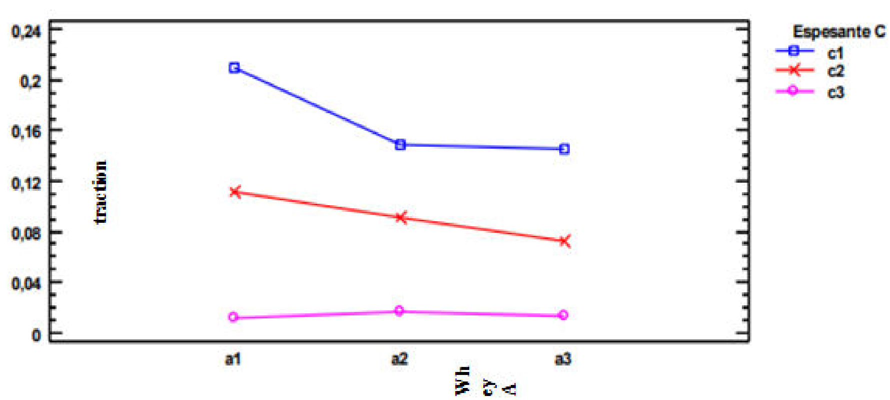


Figure.3 Interaction of factor B and C by traction.

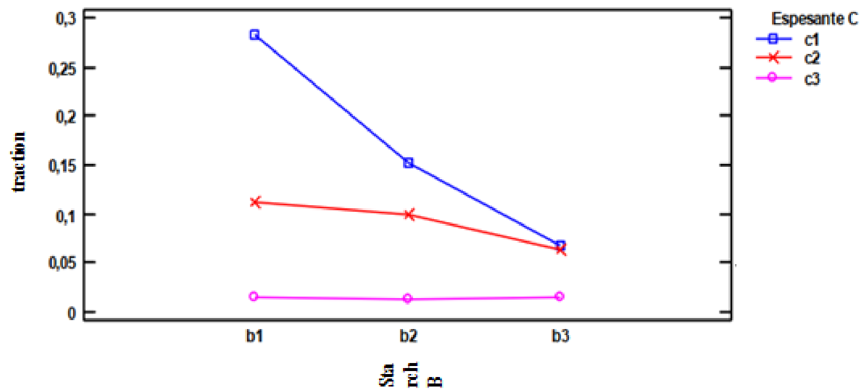


Figure.4 Interactions of factor A and B by solubility.

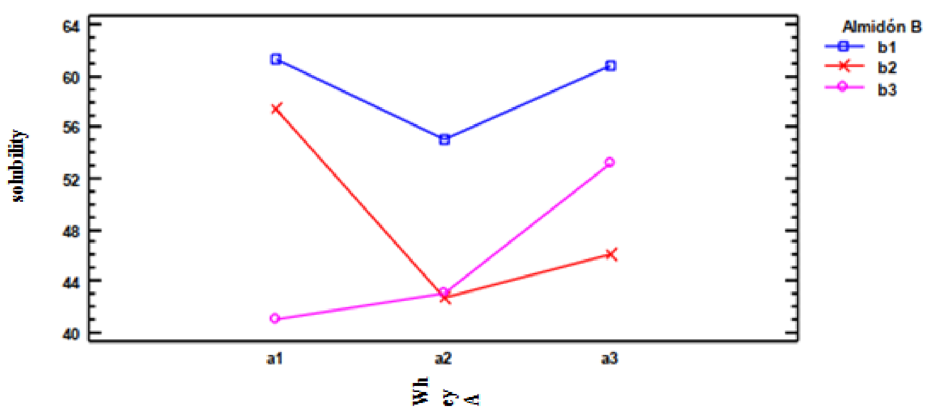


Figure.5 Interactions of factor A and factor B by solubility.

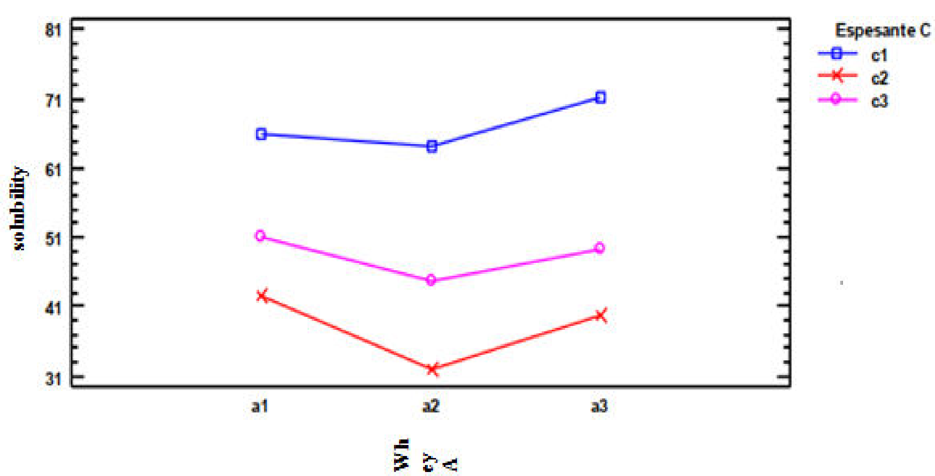
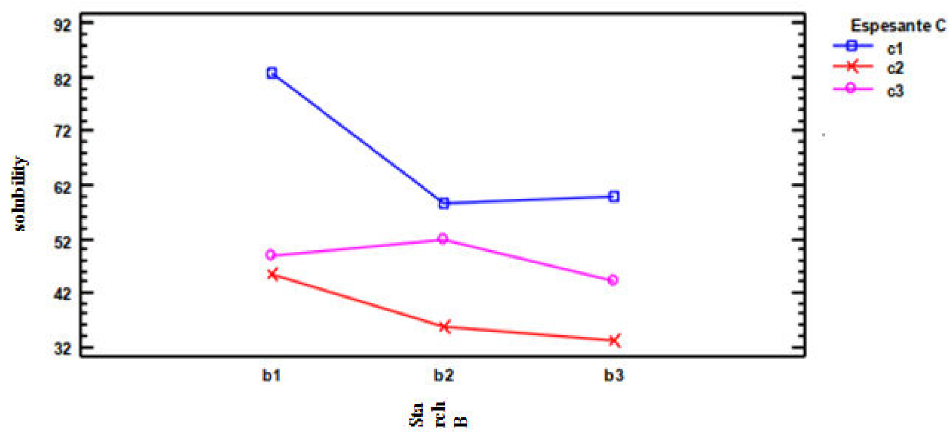


Figure.6 Interactions of factor B and factor C by solubility.



Agroindustrial applications

Table 11 breaks down the parameters that were necessary for the encapsulation of the liquid detergent. All the aforementioned values were established after having carried out several tests in order to obtain the best result.

In based on the research conducted and the results obtained regarding the rheological properties of the biopolymer, there is significant evidence in the study and in the aforementioned bibliography, i.e. that the combination of whey and potato starch plus the addition of thickeners, under controlled conditions, did allow obtaining a biopolymer with adequate rheological characteristics.

The best treatments obtained were: (a1b1b1) corresponding to 100% whey + 30% starch + 5 ml of glycerin in relation to the traction variables, for the solubility variable the best treatment was (a3b1c1) corresponding to 50% whey + 50% distilled water + 30% starch + 5ml glycerin.

As for the biodegradability variable, the best treatments resulting from the analysis of variance were used, where T1 (a1b1b1) presented better physical characteristics than degradation, in addition to presenting the highest percentage of weight loss with 75.12%. They agroindustrial application of the developed biopolymer sheets was to encapsulate liquid detergent, however, the durability of this product is very short because no chemical components are used in the formulation of the biopolymer.

Author Contribution

Galo Mejia: Investigation, formal analysis, writing—original draft. Mabel Ortega: Validation, methodology, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

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Consent to Participate: Not applicable.

Consent to Publish: Not applicable.

Conflict of Interest: The authors declare no competing interests.

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