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Comparación de dos métodos de coagulación del látex de *Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg.

Comparison of two methods for *Hevea brasiliensis* latex coagulation (Willd. ex A.Juss.) Müll.Arg.

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RESUMEN

El caucho (*Hevea brasiliensis*) es un cultivo ampliamente producido en la zona del Magdalena medio colombiano. Para obtener caucho natural a partir de látex se utilizan coagulantes que permitan su solidificación, siendo el ácido fórmico el más empleado; sin embargo, estas sustancias tienen consecuencias en quienes las manipulan y en el medio ambiente. En el presente trabajo se compararon dos métodos de extracción el convencional (uso del ácido fórmico) con otro método no convencional (uso de ácido cítrico). El ácido fórmico se destacó por su rapidez, aunque resulta más caro que el ácido cítrico. Los dos métodos generaron láminas de similar elasticidad, El ácido cítrico, por su parte, produjo mejores resultados en elasticidad e impacto ambiental; siendo recomendado su uso para la extracción de látex, para la región del Magdalena medio.

Palabras clave: Métodos de coagulación, látex, *Hevea brasiliensis*, ácido fórmico, ácido cítrico

ABSTRACT

Rubber (*Hevea brasiliensis*) is a crop widely grown in the Magdalena Medio region in Colombia. To obtain natural rubber, coagulants are used to solidify latex, being formic acid being the most used. However, coagulating substances have consequences in those who manipulate them and in the environment. In the present work, two extraction methods, one conventional (use of formic acid) and the other non-conventional (use of citric acid), were compared. Formic acid stood out for its speed, although it is more expensive than citric acid. The two methods generated sheets of similar elasticity. Citric acid, on the other hand, produced better results in elasticity and environmental impact; its use is recommended for the extraction of latex, for the Magdalena Medio region.

Key words: Coagulation methods, *Hevea brasiliensis* latex, formic acid, citric acid.

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INTRODUCCIÓN

Natural rubber is obtained from the latex emanated by a large number of plants; however, commercially, rubber tree (*Hevea brasiliensis*) species from the Amazon region is exploited (Agrocadenas, 2004).

Rubber was used by Native Americans many years before the arrival of the Europeans, who upon arrival observed how useful it was rubber for Native Americans and got very interested in that 'strange' material they began to study (Compagnon, 2008).

A proper development of a rubber production system requires complete knowledge of every stage for a good quality product. This stages are: system cycle time is very important. With that cycle time we can make the tree to completely show its phenotypic and genotypic qualities; Benefit stage: látex extraction. Agribusiness stage: latex is used, according to its qualities, for elaborating different kinds of products. Different qualities of natural rubber are obtained after processing the latex obtained for bleeding the latex trees.

About alternate coagulation methods, considering that in the Middle Magdalena the number of natural rubber plantations has increased by 22%, Instituto Universitario de la Paz (Unipaz) has conducted researchs since 2009 and has found a new craft alternative for reducing costs in the process of coagulation of the latex. It can be done by substituting formic acid for citric acid obtained from crosslinked Citrus species (Tangerine) and latifolia species (*Tahiti lime*) (Camargo y Ramos, 2012). This substitution reduces hazards to operators who handle acids and proves to be a more friendly method to nature and environment.

According to Procaucho S.A., in his Materials and compounds for the tire industry report, "Peruvian Indians called (that material)

caoutchouc, 'waterproof', hence its name. For many years, the Spanish tried to imitate the water resistant products natives had (such as shoes, coats and layers) without success".

Latex is a waste product of the tree and the more it draws, the more a tree regenerates. For its coagulation, formic or acetic acid was used; the amount of required acid depends on the state of the tree and weather conditions of the area where the tree is located. For example, it is common for young trees to generate an unstable latex. If that happens, it is necessary adding ammonia to preserve and ensure their stability until manufacturing process (Anacafe 2004).

Latex preservation is done by increasing the pH of the colloidal dispersion, adding a base capable of increasing the mutual repulsion of the rubber globules by increasing its negative charge (Haiku, 2010).

Today a number of different preservatives are used, but the best known and used is ammonia (3 to 4 g of ammonia per liter of latex) (Bastidas, 2000). The classic process of transforming collected latex comprises a series of operations, whether in small or large installations. Once the latex is harvested, operations illustrated in figure 1 were applied:

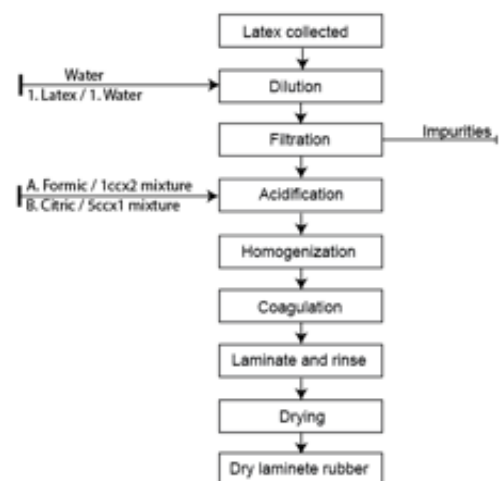


Figura 1. Block diagram of the process of rubber profit

The amount and type of acid used in the coagulation depends on rolling operations and drying. So when the coagulated mixture has a high pH, aging time should be higher (Rincón, 1996).

If producers wish to obtain almost white, clear rubbers during coagulation, sodium metabisulfite must be added in order to prevent oxidation. It must be an amount of 1 gram per liter of the diluted latex (Martinez, 2006).

In Colombia, natural rubber is processed mostly in traditional ways. The only plant in the country for crumb rubber is in Caquetá and was made possible by a grant from the Japanese government. However, due to the low processing capacity, currently 10% of its capacity is being used (Agriculture Ministry and National University, 2009).

According to reports contained in Foresight Research and Technological Development for the Natural Rubber Production Chain in Santander, there are plans for building a similar plant to process rubber produced in different cultures throughout Middle Magdalena. Currently, Procaucho is the largest producer in that department and does all of its work in traditional ways (Agriculture Ministry and National University, 2009).

As for innovation in methods used for coagulation with diverse sources, taking into account that in Middle Magdalena the number of natural rubber plantations has increased in (22%) (DANE, 2009), Unipaz research brings a new alternative for rubber growers for decreasing costs by replacing formic acid with citric acid. 95% of latex production nationwide is done by hand. Natural sources of citric acid from limes are not immune to this type of production, because they decrease the risk of operator injuries when handling (Torres, 2009). In Middle Magdalena there is currently a

large number of planted and producing acres. Moreover, this area is a major producer of citrus fruits that make this process much more feasible with raw material for this process at hand (Federación Nacional de productores de caucho, 2005).

According to a research developed in Unipaz at Barrancabermeja (Camargo y Ramos, 2012), *Hevea Brasiliensis* latex coagulation can be achieved also by using citric acid from acid limes.

In this method, once collected, latex is taken to a processing plant, where water is added for homogenization. After that, mix is passed through a strainer to remove impurities. Previously prepared lemon juice with a pH between 2.4 and 2.6 must be added then in a 17 cc per liter relation. This relation allows a fast coagulation speed and gives a sheet of good quality in color, texture and elasticity (Camargo y Ramos, 2012).

The coagulation rate is slow when applied per liter of latex mixture of water and 7 ml of citric acid, the result being a film of good color, texture and elasticity.

This method allows a better management of the environment because the waste resulting from the washing of the sheets does not pollute the environment in which it is discharged. That waste often unfolds quickly through the action of soil and climate factors, which makes them attractive in the beneficiation process of *Hevea brasiliensis* (Procaucho, 2008).

MATERIALS Y MÉTHODS

This research was conducted in the Middle Magdalena region of Colombia, located between the Magdalena River rapids near Honda (Tolima) and the entry of the same tributary to the plains of the Atlantic Coast.

In conducting this study authors took into

account research conducted by different companies and micro rubber growers in Colombia, using traditional methods of coagulation for rubber latex. Also, research about coagulation on organic sources in Cimitarra and Barrancabermeja was reviewed (Berthier, 2012; Camargo y Ramos, 2012).

In order to make this work, it has been used an experimental research method "performed by manipulating an experimental variable not checked in rigorously controlled conditions in order to clarify how it causes or a situation occurs or particular event" (Tamayo, 2011).

This research aims to compare two methods of coagulation of rubber latex *Hevea brasiliensis*: the conventional method and the other non conventional method, analyzing the current method in latex coagulation, study the benefits and advantages of the new coagulation method and Compare the efficiency of the two methods. For which a bivariate distribution experiment was designed completely at random. The two experimental factors were: Factor 1: Method of coagulation with two variants. Method 1: formic acid (f). Method 2: citric acid (c).

Factor 2: Quantity of coagulant used for latex coagulation. This factor was set for four levels: n1 = 1.0 ml of acid (20 drops); n2 = 2.5 ml of acid (50 drops); n3 = 3.5 ml of acid (70 drops); n4= 5.0 ml of acid (100 drops). Each treatment was repeated four times for a total of 32 experimental units (eight experimental unit per repetition). The dependent variables were: Variable 1: Latex coagulation time Variable 2. Rubber sheets quality (elasticity and plasticity).

Replication treatments

Replication 4: r1, r2, r3 y r4

Treatments fn1, fn2, fn3, fn4, cn1, cn2, cn3, cn4.

Where

r: Replications. f: formic acid. c: citric acid.
n: level of coagulating acid. n1=20 drops, n1=50 drops, n1=70 drops, n1=100 drops

The study was conducted in St. Lucia Research Centre of the Instituto Universitario de la Paz, located on the left bank of kilometer 14 on the road that leads from Barrancabermeja to Bucaramanga; N 7 "03" 48 "W 73" 51 "50" and 78 masl. For the experiment the following materials were used: rubber trees, latex, formic acid, citric acid tahiti lime, water, slices of dried rubber, laboratory.

The process of collecting latex, was made into a rubber plantation located in St. Lucia Research Centre with an eighteen years plantation. 15 trees were chosen for latex obtention. Once the trees were striped for latex obtention, they were left bleeding for a time of three hours. After this time, the latex was collected and brought to the lab where dilution, filtration, acidification and coagulation processes were applied.

The measurement of the dependent variables under experiment was performed in two stages: 1 hour and 24 hours. In these periods of time of coagulation was measured and respective data records were made. For that purpose, a structured data format was designed according to the characteristics of the experiment. For statistical analysis of data F test and ANOVA for bivariate completely random distribution experiments were used. Similarly, the information obtained in the investigation underwent an economic cost analysis to determine the most recommended treatment from a lowest cost perspective.

RESULTS AND DISCUSSION

To carry out the coagulation process, once the tree has bled for three hours, latex must be obtained and taken to the processing lab. Then, it must be diluted with water (water quantity depends on the season of the year). In winter, one liter of latex and five liters of water

are recommended; in summer, there must be one liter of latex and two liters of water. In normal weather conditions, for every liter of latex, there must be a liter of water. After that, filtration process is made in order to remove clots, insects, and other waste.

To regroup rubber particles in latex, formic or acetic acid with a 90% concentration must be added. For every cubic centimeter of acid, there must be two liters of the latex-water mix. That mix must be poured on coagulation canoes and must be left to rest for 24 hours. As a result, an easy to laminate homogeneous clot must be obtained.

Unconventional method follows the steps of conventional method until beginning acidification. In that step, the product used for coagulating latex changes. Instead of formic or acetic acid, citric acid obtained from Persian lemon or acid Tahiti lime is used.

This method offers the next advantages: easy to get raw material, it does not pollute environment, it does not require personal protection equipment, low cost, its result is a good physical features (plasticity, elasticity, colour, texture). Disadvantages: slower regroup of latex particles, slower coagulation process.

Determining percentage of coagulation compared methods. For establishing a

comparison between methods, four different volumes of formic and citric acid were added to latex. Coagulation was measured after one and 24 hours. Four replications were made, in order to get more reliable information.

Table 1 has coagulation percentage obtained after one hour of applying coagulant to latex (f: formic acid; c: citric acid). Promedies were consolidated in the mentioned table. In Table 1, it can be seen that fn1, fn3 and fn4 treatments have the same coagulation percentage in all four replications. In table 1 it can also be seen that highest coagulation percentage treatment was fn4 with a 60%. Cn1 was the lowest results treatment with 1.8%. Table 1 shows coagulation percentage results after 24 hours of applying coagulant (f: formica acid; c: citric acid) to latex. After four replications, a promedy was found for every treatment.

As table 1 shows, treatments fn3, fn4, cn3, cn4 have the same coagulation percentage for all four replications, but best behaviour treatments were fn3, fn4, cn3 y cn4 with 100% coagulation.

In Figure 2, "coagulation speed" variable behaviour can be found for comparing formic acid with citric acid treatments after one hour. Treatment with 5.0 cc of formic acid shows better results after one hour. However, after that time, there is a significative difference between

Tabla 1. Latex coagulation percentage after one hour / 24 hours

Treatments	Latex coagulation percentage after one hour					24 hours latex coagulation percentage				
	Replications					Replications				
	R ₁	R ₂	R ₃	R ₄	\bar{x}	R ₁	R ₂	R ₃	R ₄	\bar{x}
Formic acid										
fn ₁	28%	28%	28%	28%	28%	85%	85%	85%	85%	85%
fn ₂	42%	40%	42%	42%	41.5%	95%	95%	95%	95%	95%
fn ₃	50%	50%	50%	50%	50%	100%	100%	100%	100%	100%
fn ₄	60%	60%	60%	60%	60%	100%	100%	100%	100%	100%
Citric acid										
cn ₁	1.6%	2.0%	2.0%	1.6%	1.8%	70%	75%	80%	75%	75%
cn ₂	5.0%	4.0%	4.0%	5.0%	4.5%	90%	90%	90%	95%	91.2%
cn ₃	6.6%	6.6%	6.0%	6.6%	6.5%	100%	100%	100%	100%	100%
cn ₄	10%	9.3%	8.3%	10%	9.4%	100%	100%	100%	100%	100%

r: Replications. f: Formic acid. c: Citric acid. n: Level of coagulating acid: n1=20 drops, n1=50 drops, n1=70 drops, n1=100 drops

Source: This research

formic and citric acid results.

Figure 2 shows “rubber coagulation speed of formic and citric acid treatments after 24 hours”. The difference between both methods is minimal. This procedure was repeated four times in order to corroborate the effectiveness and accuracy of the process and to clarify the margin of error. Data obtained and showed above was subjected to multivariate statistical analysis, in this case the analysis of variance

(ANOVA).

A two-factor analysis of variance for a completely randomized experimental design was used for determining which factors have a statistically significant effect on the coagulation percentage. It also assesses the significance of the factors and interactions between them.

This ANOVA highlights conventional method predominance over unconventional method.

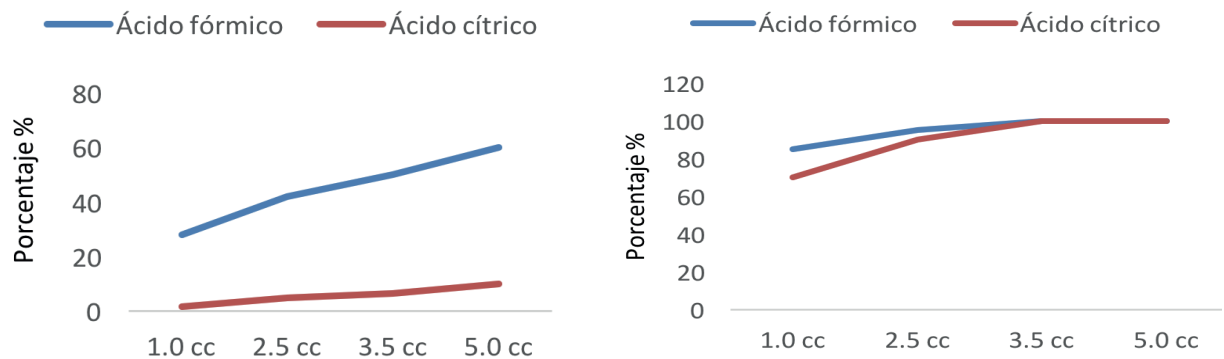


Figura 2. Rubber coagulation percentage after one hour for both coagulants in four experimentation levels / 24 hours for both types of acid.

Conventional method significantly exceeds unconventional method after one hour. As a example, it can be seen that for one hour time, formic acid coagulation percentage was between (44.609 – 45.14), exceeding in more than 100 % that of the citric acid, which percentage was between (5.27 – 5.80). It also shows that as the coagulant dose was increased, coagulation percentage with citric acid slowly increased, while formic acid increase was considerable (Figure 3).

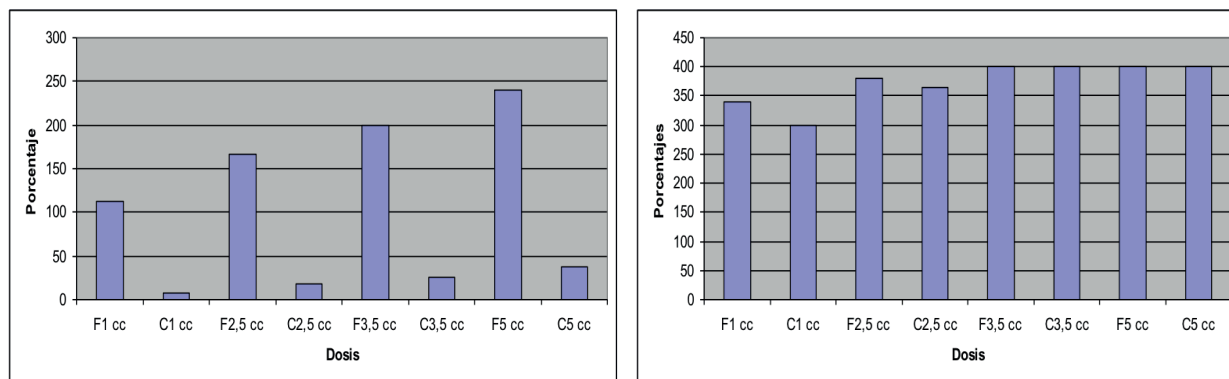
is under $p=0.05$. Also, method and dose interaction have a significant difference, which suggests that when two factor levels interact, at least one of treatments has a more efficient latex coagulation. Multiple promedias test highlights that n4 coagulation dose (5 cc) has an efficiency of 34%. The method with a better efficiency percentage is formic acid, with 98% concentration.

After 24 hours, levels for both coagulation methods are very similar. In both of them, 100 % coagulation was obtained. For 3.5 and 5 cc of formic and citric acid, coagulation percentage were equal, which indicates that after that time, citric acid is completely efficient for coagulating rubber latex. (Figure 3)

ANOVA for 24 hours shows significance between main factors, methods interaction and coagulation doses with a significance level of $\alpha=0.05$. Estimate marginal means for both coagulation methods have very similar percentages: citric acid goes between (90.68 –92.43) and formic acid goes between (94.12 -95.87). After 24 hours, rubber molecules regroup is identical for both methods. The most efficient doses were n3 (3.5 cc) and n4 (5 cc).

ANOVA for one hour shows that coagulation methods and coagulation dose factors have significant differences, given that significance

Economic analysis for studied coagulation methods. Economic analysis within Table 2,



After one hour

For 24 hours.

Figura 3. Total coagulation percentages.**Tabla 2.** Economic analysis of experiment type and acid level used for coagulating rubber latex.

Coagulant (Acid - level)	Coagulant cost	Latex	Latex cost	Other inputs	Other inputs cost	Total cost
A. Fórmico 1.0 cc	\$ 280	150 cc	\$ 300	Tray + water	\$ 380	\$ 960
2.5 cc	\$ 700	150 cc	\$ 300	Tray + water	\$ 380	\$ 1.380
3.5 cc	\$ 980	150 cc	\$ 300	Tray + water	\$ 380	\$ 1.660
5.0 cc	\$ 1.400	150 cc	\$ 300	Tray + water	\$ 380	\$ 2.080
A. Cítrico 1.0 cc	\$ 75	150 cc	\$ 300	Tray + water	\$ 380	\$ 755
2.5 cc	\$ 188	150 cc	\$ 300	Tray + water	\$ 380	\$ 868
3.5 cc	\$ 263	150 cc	\$ 300	Tray + water	\$ 380	\$ 943
5.0 cc	\$ 375	150 cc	\$ 300	Tray + water	\$ 380	\$ 1.045

Source: This research

shows that most expensive applied treatment was the Formic cid one with a cost of \$2.080 per 5cc. The less expensive was citric acid treatment in a 1cc. level, with a cost of \$75. Working with formic acid also requires special equipment for personal safety due to high accidents risk. With citric acid, on the other hand, any of this equipment is required

CONCLUSIONS

Rubber latex coagulation in Colombia is made with aglutinants such as formic and acetic acid. When washed, those acids pollute water sources and soil and affect wildlife. Rubber activity in Colombia is managed by private corporations and regional associations. Nationwide policies are needed for regulating rubber industry.

Rubber latex coagulation with formic acid is faster. Formic acid has a higher cost than that of citric acid. Rubber sheets resulting from both acids have excellent quality. *Hevea Brasiliensis* latex coagulation using citric acid produces

an excellent rubber sheet with low pollution deriving from the process.

Citric acid is a low cost product, which favours coagulation process total cost. Citric acid is a natural source easy to get. It is economically more profitable than conventional acids. Unconventional products use (citric acid) allows an easy handle without accidents risks. Conventional acids use requires personal protection equipment (glasses, rubber gloves, face mask).

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