Study of the Use of Natural Banana Fiber Developing Reinforced Composite Materials, Supporting the SDGs of the 2030 Schedule

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Abstract

The current technological growth has pushed the manufacturing sector to undergo important changes during the latest fashion in the field of advanced manufacturing, manufacturing articles in full technological development under a 4.0 environment, manufacturing is no longer just about manufacturing physical products. Here in this article, we seek to develop a reinforced biobased composite material based on polypropylene with natural fibers in order to improve its mechanical properties, for its application in the automotive and aeronautical sectors or others in general. Highlighting the objective, interest, argument of the study and importance of the problem, a chemical characterization methodology was used in the natural fibers of banana pseudostem to obtain the best possible results from this study and to be able to adhere to a polymeric matrix, thus obtaining a composite material. already prepared, for a study in the second methodology now is a physical characterization and to be able to submit it to a scanning electron microscopy (SEM). And to other universal tension and compression equipment, to know their morphology and characterization of the fiber and polymeric matrix. This concept of the circular economy has recently been questioned by studies that show that the innovation of new composite materials provides remanufacturing, recycling, non-extraction of non-renewable materials and the use of clean energy, this is a contribution to the sustainable development objectives of the 2030 agenda. And it is a very involved topic with today's industrial engineering, since it has a very advanced profile for materials, manufacturing, and sustainability.

Keywords
Industrial Engineering, Composites, Natural Fibers, ODS 2030.

1. Introduction
This work seeks to develop a reinforced polymeric material based on a polymeric matrix of polypropylene and natural fiber of Banana pseudostem, in the manufacturing industry it produces a considerable impact on the environment that is through the extraction of resources. non-renewable natural Natural resources are limited and non-renewable resources.. That today manufacturing continues with linear thinking generating more waste instead of switching to circular thinking manufacturing, as mentioned in the summary of this article. For this reason, human beings have an important role in the construction of sustainability as mentioned in the sustainable development goals of the 2030 agenda. One of the objectives is to develop a reinforced biobased composite material based on polypropylene with

natural fibers with the in order to improve its mechanical properties, for its application in the automotive and aeronautical sectors. This article is the essence of writing a doctoral thesis in advanced manufacturing, it is what motivates this work. This investigation of the development of a composite material is needed so that it can be applied in the manufacture of automotive and aeronautical parts in which it can be used as a new raw material, which must resist the conditions of impact, torsion, as well as the mechanical forces that are apply to them for their operation, as is the case of tension, compression to which they are subject. The problem that needs to be solved with this work is the reduction of the impact represented by auto parts made with polymers of artificial origin from their obtaining, processing to disposal, such a problem involves a high consumption of energy resources in their first stages of the life cycle. and an additional energy consumption in its recycling in addition to the environmental pollution produced by the parts that are not recycled. What is already known in these topics is that there are many authors involved in research on composite materials and sustainability. Technological systems often require energy and materials both for the manufacture of their technical components and for their operation. Therefore, the design and practical use of technology will often determine the energy and material performance of modern society. After having carried out the bibliographic search, it is considered that the hypotheses proposed are to be able to obtain a polymeric composite, which by adding loads of natural fiber (banana pseudostem) to the polypropylene increases its aging, Young's Modulus, rigidity, and resistance and that improves mechanical properties in micrographic studies, then there would be the possibility of developing a composite that is cheaper than a composite with synthetic fibers. Regarding Frugal Innovation, it is related to the development of self-sustaining solutions focused on achieving a Maximum Possible Impact through the minimum use of resources, According to (Briseño 2022), with a perspective that includes the largest number of people, in alternatives that satisfy human needs, but that include the purchasing power of the base of the socio-economic pyramid, without losing sight of the socio-environmental impact of the area of influence of the project, to achieve a triple impact: social, environmental and economic. Briseno (2022).

1.1 Objectives

The objective of this project is to develop a new composite material based on Polypropylene and a natural fiber, and to evaluate the chemical and mechanical properties of the material obtained, to form a structure, with which it is intended to evaluate the possible substitution of synthetic fibers. such as carbon, glass, and others, in this way the work through green manufacturing would also be increased, as well as taking it into account to be used in any other automotive application.

2. Literature Review

Most Recent Technological Developments in Composites

Author 1

An important contribution to the current scientific literature is since manufacturing became an industrial event, the manufacture of products has required the entry of new technologies, different materials to obtain new products. A composite developed by Stelescu, M. Development and characterization of polymeric eco-composites based on natural rubber reinforced with natural fibers is mentioned here. He says that Natural rubber compounds filled with short natural fibers (flax and sawdust) were prepared by a blending procedure and elastomer crosslinking was done using benzoyl peroxide. The microbial degradation of the compounds was carried out by incubating with Aspergillus Niger, recognized for its ability to grow and degrade a wide range of substrates. Stelescu (2017). The degree of biodegradation was evaluated by weight loss and the study of the degree of cross-linking of the compounds after 2 months of incubation under pure shake culture conditions. Scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy (FT-IR) have proven to be valuable and valuable tools for the morphological and structural characterization of compounds before and after incubation with Aspergillus Niger. The series of analyzes carried out examined that the results show that, after incubation with microorganisms, there is a weight loss of the NR / FN compounds, influenced by the amount of FN in the mixtures. A higher weight loss is also observed in mixtures containing flax fibers compared to those containing sawdust. These results have been correlated with those obtained for the gel fraction, the degree of crosslinking, the rubber-fiber interaction and water absorption. It is observed that, for the incubated samples, the gel fraction shows lower values, and that the crosslinking density is lower than the non-incubated samples. Stelescu (2017).

Author 2

The research topic of this thesis is the development of a biobased composite polymeric material based on a polymeric matrix of polypropylene and natural fiber, this concept has recently been questioned by studies that show that research on the creation of a composite material is a constant concern within sustainability (Elbehiry and Mostafa 2020). One of the challenges of the century is to achieve compatibility between the required strength and the use of lightweight construction materials that can negatively affect mechanical properties (Elbehiry and Mostafa 2020). Likewise, natural fibers are used today as fillers, they are materials that are added in the form of particles or fibers to a polymer, in order to alter its mechanical properties or just to reduce the cost of the material in the industrial field. (Grower 2007). Therefore, the fibers contribute by providing an ideal solution to improve the mechanical properties of structural elements such as resistance to traction and impact. Natural fibers have many interesting characteristics, such as being strong, light, economic and ecological. (Elbehiry and Mostafa 2020). This is an author as a first contribution, he comments that natural banana fibers are very low cost, precisely the place where the work will be carried out is in San Andrés Tuxtla, Veracruz, southern part of the state, where banana plants abound. , and the other contribution that is rescued from the author is the use of a finite element analysis using the CATIA V5R21 program, where they show good correlations between the experimental results. Author's point of view and critical analysis: Very few studies have investigated the impact of environmental circularity, the author (Elbehiry and Mostafa 2020). he carries out his research focused on the mechanical properties of the Finite Element Analysis of beams reinforced with banana fiber bars. In a particular point of view, it is acceptable, because it was a priority in his research work.

Author 3
This following bibliography is an indexed article by the author Gómez Berrezueta and Méndez (2017). The topic is "Natural Fiber Reinforced Polypropylene for the Manufacture of Internal Panels for Automobile Doors". It has a great similarity to the topic which is developed in this thesis. This author develops in his study, the analysis of natural fibers that are replacing other materials in various automobile parts due to their light weight, low cost, low CO2, recyclability. The objective of this project is that the components meet the following requirements: simplicity of construction, ease of manufacture, placement of materials and low cost. Research on a polymeric material composed of natural fibers is a constant concern within the effects of various material parameters such as fiber treatments, microstructural composition, composite manufacturing techniques, technical properties, amount of fiber to be added established in% of weight, type of polymer and Charpy tests allowed to establish the influence of the fiber on the resilience of the composite material and scanning electron microscopy (SEM) to analyze the type of fracture produced. Gómez Berrezueta and Méndez (2017). As mentioned at the beginning of this bibliography, this article by said author has a great similarity with the work to be developed of a composite material reinforced with natural fiber (Banana Stem) for application in the automotive sector under the circular economy model. Before starting this bibliographic search on the subject that is being addressed. Sources, bibliographic citations are needed to support the report to be presented. The work may consider theoretical, statistical, institutional, administrative, legal sources or information from research or technological developments carried out in the area. In reviewing the literature on the topic, your task is to indicate the directions that other authors have taken in relation to your work.

3. Methods
The investigation begins by carrying out a preliminary study on the project to determine the state of the composite materials and find the problems that exist.

3.1 What theory is it going to be based on?
Here the methodology or theory to develop a composite material based on Polypropylene and a natural fiber is explained, and to evaluate the mechanical properties of the material obtained, to form a structure, with which it is intended to evaluate the possible substitution of synthetic fibers, such as carbon, glass, and others, in this way the work through green manufacturing would also be increased, as well as taking it into account to be used in any other automotive application. Next, the description of the materials to be used is detailed, which is Polypropylene and natural fiber. (Plantain stem or pseudo stem as mentioned by the author López and Montaño (2014).
The polypropylene: is the partially crystalline thermoplastic polymer obtained from the polymerization of propylene. It is a synthetic fiber, and its characteristics are:

- Formula: $(C_3H_6)_n$
- Density: 946kg/m³
- Melting point: 160°C
- Degradation temperature: 287 °C
- Monomer: Propylene (Propene)
- Classification: Thermoplastic

A study of the alternatives of compounds (thermoplastic polymer / natural fiber) is carried out, so that the tests, procedures, and results can be determined. The tests are carried out in accordance with international standards of institutions such as ASTM, ISO, SAE mainly.

Natural fibers: Nowadays, more and more materials reinforced with fibers that are cheaper and have a lower environmental impact are being used. In addition, if the reinforcing fibers come from vegetables, the total environmental impact in the manufacture of the parts is much lower. Research effort is being devoted to the manufacture of completely ecological or green composite materials. In them, the matrix of the synthetic polymer is reinforced with the natural fiber.
Potential of working with natural fibers: The advantages of working with composite materials reinforced with natural fibers, proposed by the Food and Agriculture Organization of the United Nations, are replacement of artificial fibers (glass and asbestos). In many countries, environmental restrictions have been placed on the disposal of fiberglass-based post-consumer products, and some have even banned their use, such as for asbestos. The reinforcement of conventional thermoplastics and thermosetting resins with natural fibers or polymers can reduce the demand for (carbon-based) petroleum products. Pedraza and Cristy (2019). In Figure 1, the parts of a banana plant are named.

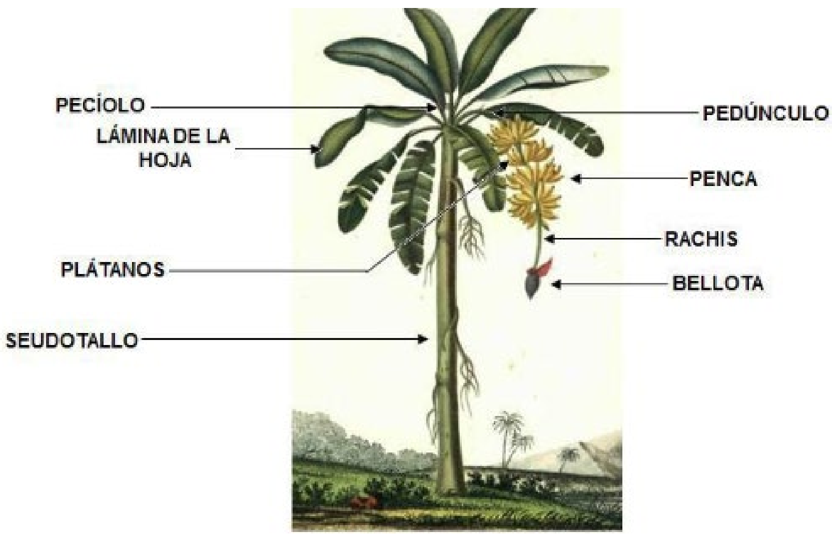


Figure 1. Parts of the banana plant. Source: López, Montaño (2014).

3.2. Manual defibrating method
This is a manual shredding method, it can be said that this process was more complicated, as for the shredding of the pseudostem fiber, it is a bit tedious to shred manually, it hurts the fingers of the hand. But now it is proposed to continue with the method part II, to look for another pseudostem and thus freshly cut, defiberize it until it can be left as a hair, and subject it to a cleaning treatment with distilled water or NaOH (Sodium Hydroxide). And being able to appreciate its texture and that resulting natural fiber, take it to the CIATEQ laboratories, (State of Mexico), and begin to carry out the first experiments on microscopy and advance to this doctoral work, the fiber can remain, as shown in figure 2.

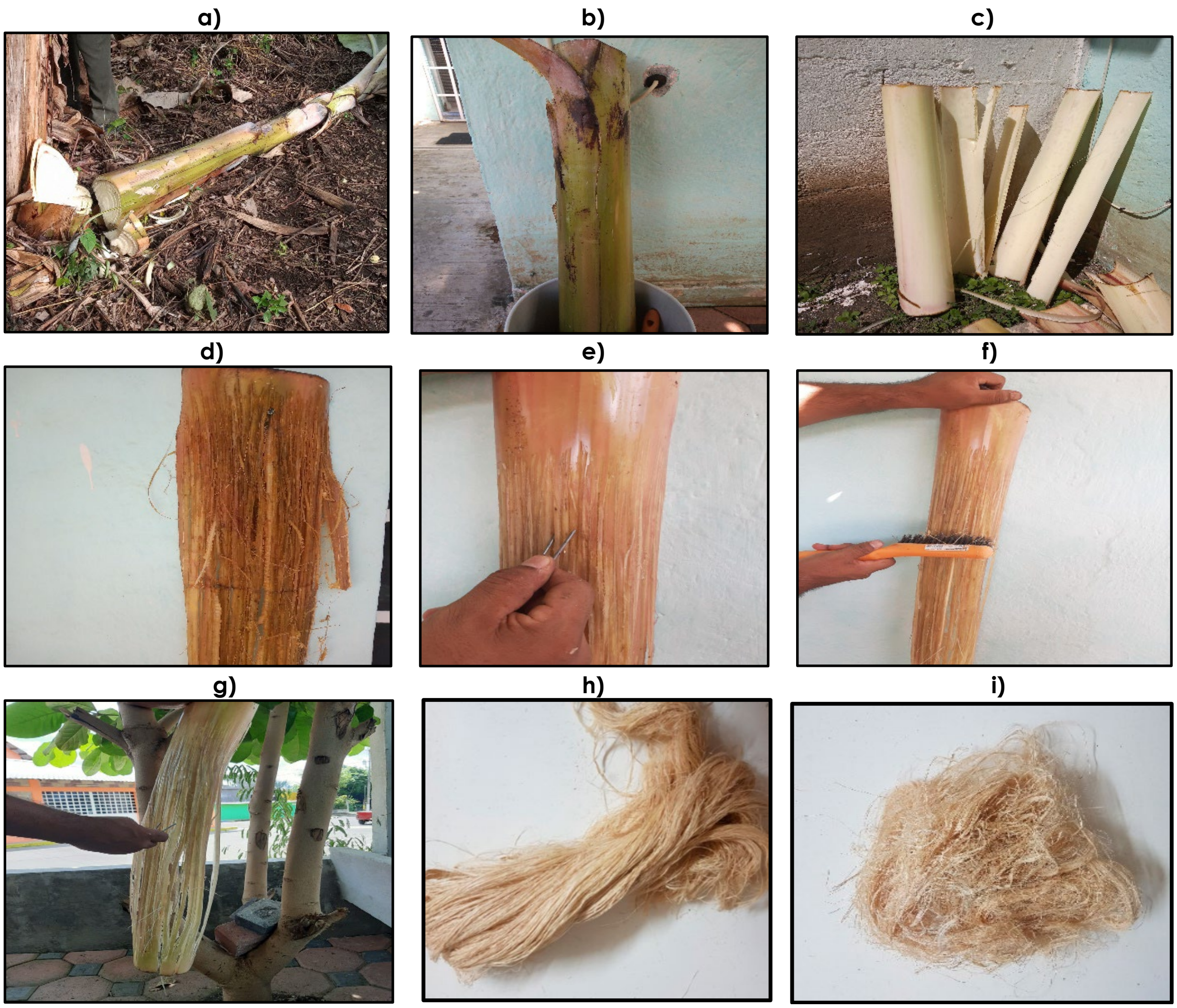


Figure 2. a) Banana pseudostem fiber bark, **b)** Pseudostem presentation**, c)** Pseudostem layers, totally juicy, **d)** Manual shredding, **e)** Shredding with a pair of nails, **f)** Shredding with a wire brush, to thin the strands, **g)** One ply wash with H2O only, **h)** Long end fiber skein, **i)** Short end finer shred forms. Own source. (Work carried out from Comoapan, Veracruz.).

3.2. Alkaline treatment for washing and cleaning the fiber.

Based on previous investigations for the characterization activities of the pseudostem fibers, the following table of concentrates of articles of authors is made where they carry out studies of cleaning and bleaching of fibers, which was taken as a reference to define the conditions of cleaning and bleaching of the fiber. Table 1 is presented below.

Table.1. Concentrate of background of authors referring to alkaline treatment of natural fibers. (Own source).

AUTHORS OF ALKALINE TREATMENTS FOR FIBER CLEANING OF BANANA PSEUDOTALLO				
Researched Posts	**Method of preparation to wash the fiber of banana pseudostem**	**NAOH concentrate**	**Preparation of NAOH solution**	**Drying time**
PUBLICACIONES DE INTECHOPEN (Subagyo, Asmanto & Chafidz, 2018) achmad.chafidz@uii.ac.id	el tratamiento de pseudo-fibra de tallo con diferentes concentraciones de NaOH al **5 %** aunque la fibra no es claramente visible. Al **10 %** Las fibras y sus fibrillas son claramente visibles	al **10%** de **NAOH**, reduce la absorción de humedad, limpiar la superficie y mejorar la rugosidad de la fibra		
PUBLICACIONES MDPI (Shahinur et al., 2020) j.haider@mmu.ac.uk	Este tratamiento elimina cierta cantidad de lignina, ceras y aceites cubriendo la superficie externa de la pared celular de fibra	**(NaOH)** o clorito de sodio **(NaClO2)** que generalmente es para blanquear fibras		
UNIVER. NACIONAL DE TRUJILLO (TESIS) (Neira Casana et al., 2016), pag.73	Este procedimiento se hace para los 4 niveles de concentración de hidróxido de sodio (NaOH), para esto se pesaron 30 gr de fibra de pseudotallo de plátano, para la mercerización se usaron **20, 40, 60 y 80 gr/l NaOH**. El proceso inicia con un prelavado y limpieza de las fibras, exponiéndolas a 80 °C como máximo, por 30 minuto en la **primera** etapa de limpieza, en la **segunda** etapa se prepara una solución de agua destilada con alcohol en proporciones de 50% v/v (1 litro de alcohol en 1 litro de agua), se coloca las fibras de pseudotallo de plátano dentro de esta solución a 60°C por un tiempo de 30 minutos, luego de este tiempo se retiran las fibras de la solución y se deja enfriar. (pag.73).	hidróxido de sodio **(NaOH)**	Durante el tiempo de la limpieza de la fibra (1 hr), se procede a la preparación de la solución de NaOH a las concentraciones que correspondan (20, 40, 60 y 80gr/l) con respecto a la cantidad de fibra. Es decir, para 120 gr de fibra se utiliza, 2400 ml de agua destilada, y para 2400 ml de agua destilada se utilizan 48 gr de NaOH. Una vez preparadas dichas soluciones, se las coloca dentro de un cooler llenos de hielo, donde se enfriarán a una temperatura de 2-5 °C como máximo	30 minutos cada etapa
INGENIERÍA E INVESTIGACIÓN VOL. 32 No. 1, APRIL - 2012 (83-87). ISSN 0120-5609 jcmejiao@unal.edu.co	Las fibras tratadas se lavaron primero con detergente-agua al 2% antes del tratamiento con álcali y se secaron a 70ºC durante 24 h para eliminar la cera externa	lavado para quitar grasa, solo se usa **H_2O y** 5 % de **NAOH** para tratamiento alcalino		1 Hora

An alkaline treatment was carried out with an aqueous solution of NaOH (Sodium hydroxide), at a concentration of 10% by weight, to remove certain lignin, waxes and oils that cover the outer surface of the fiber cell wall. of banana pseudostem, for which 20 grams of natural banana pseudostem fiber were added to a glass reactor with stirrer and temperature control. After 20 minutes of reaction, the fiber was repeatedly washed with water until neutral pH (pH=7) was reached. As shown in figure 3.

a) b) c) d)

Figure 3. a) subjecting the pseudostem fiber to alkaline treatment, b) end of dissolution with NaOH, c) reddish color of the pseudostem fiber, d) fiber washing to reach a PH=7. (Own source).

Subsequently, the fiber is dried in a convection oven at 80°C for 2 hours, as shown in figure 4.

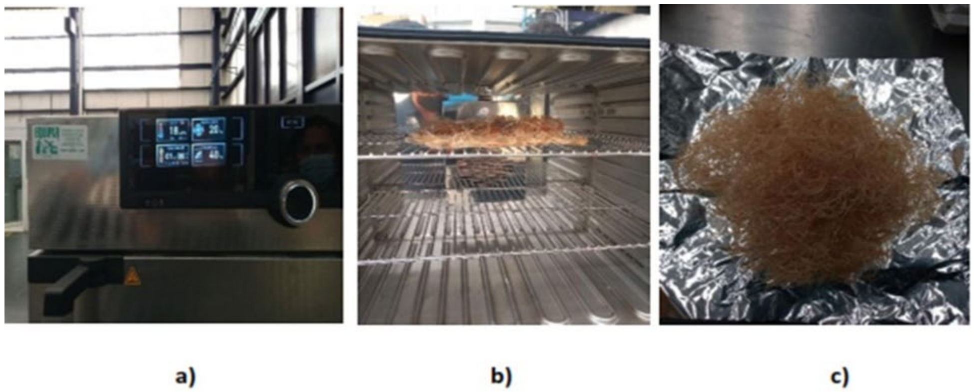


Figure 4. a) Convection oven used, **b)** fiber drying inside the oven, **c)** totally dry fiber. (Own source).

3.3. Fiber bleaching
Various tests were carried out for fiber bleaching, which are described below in the following figures:

Test 1:

The fiber pretreated with NaOH was subjected to a bleaching process, for which 20 mL of a 6% sodium hypochlorite (NaClO) solution were used, to which 20 mL more of H2O were added to obtain a concentration of 3% NaClO. This new solution was used to treat 5 grams of fiber for 2 hours at 35°C with agitation (250 RPM), as shown in figure 5.

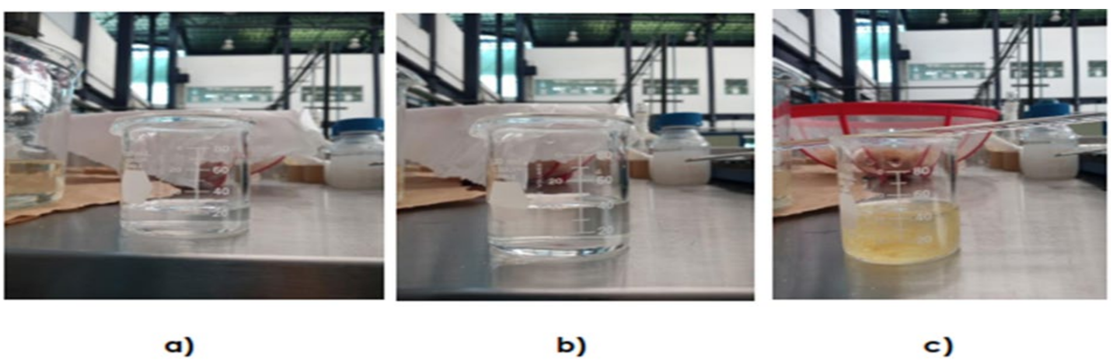


Figure 5. a) 20 ml of NaCLO at 3% concentration, **b)** 20 ml of normal water, **c)** Mixture with the pseudostem fiber. (Own source).

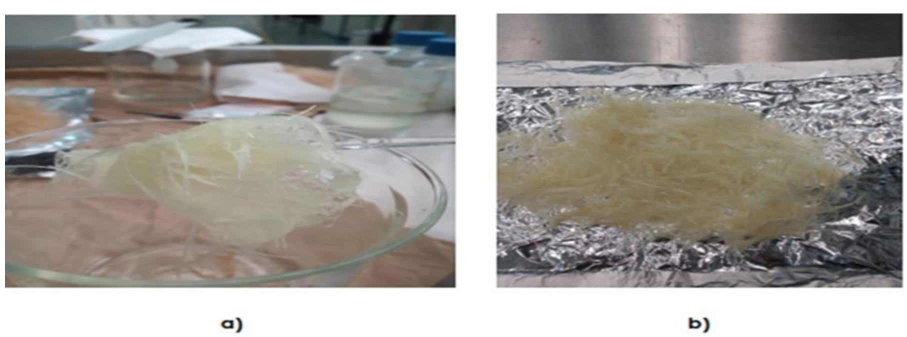


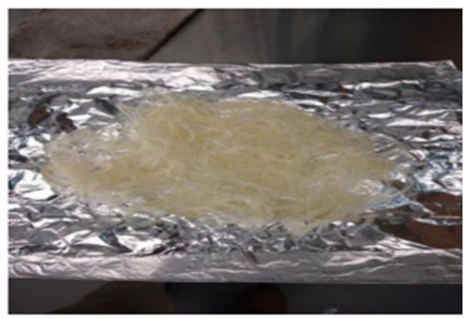
Figure 6. a) Sample 1 bleached fiber with green hue **b)** sample with concentration of sodium hypochlorite. (Own source).

Test 2:
This test was carried out using a glass reactor with heating at 60°C and constant stirring at 150 RPM, in order to improve fiber bleaching. Table 2 lists the reagents and conditions used during the test.

Table 2. Concentrated mixture for fiber bleaching with sodium bisulfite. (Own source).

Solution concentrate for a required bleaching of banana pseudostem fiber			
Chemical solution	**quantity**	**Time**	**Observations**
sodium hypochlorite. (NaClO).	50 mm	60 minutes	None
Sodium bisulfite. ($NaHSO_3$)	20.93 gr	30 minutes	Added per minute 31
Regular water. (H_2O)	150 mm	60 minutes	None
Banana pseudostem fiber	20 gr	60 minutes	None

The reaction mixture (NaCLO + Fibra) was kept stirring at 150 RPM at 60ºC for 60 minutes; then sodium bisulfite (NaHSO3) was added, the reaction mixture was left stirring for another 30 minutes, after which the fiber was repeatedly washed with water until reaching a pH = 7. Figure 7 shows the appearance of the fiber, where the whitening of the fiber can be seen, a little less yellowish than that obtained in test 1.



a) b)

Figure 7. **a)** PH obtained in the fiber, **b)** color less yellowish-greenish than in test 1. (Own Source).

Next, it is presented in figure 8, where previous studies made use of the treatment and chemical characterization of natural fibers for the development of the experiments.

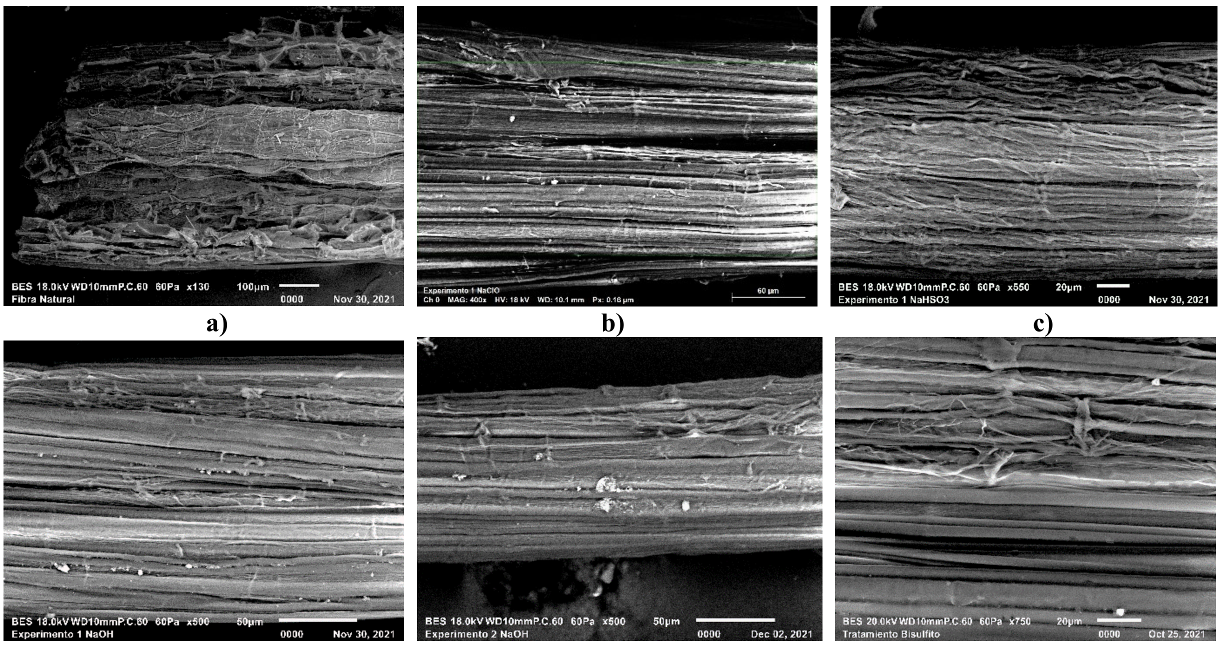
Figure 8. Untreated fiber sample, with NaOH, NaClO and NaHS3O treatment. (Own source).

3.4. Fiber characterization by (SEM).

The treated fibers were evaluated by scanning electron microscopy (SEM) to study their surface morphology. Below are some of the micrographs obtained for the fibers and some results of the elemental analysis to visualize their morphology, which was done in different areas of the fiber with the aim of identifying possible traces of chlorine still present, due to a certain degree of yellowing detected in the fibers.

4. Results and Discussion

In the figure 9 shows the results in scanning electron microscopy (SEM), in a JSM-IT100 equipment, This all-in-one SEM is used in a wide range of fields, such as biotechnology and nanotechnology, and covers various applications, from material development, testing, evaluation and defect analysis to quality control, etc. In this section of results, it is to present the analysis of the morphology of the fiber surface, which was developed in the facilities of CIATEQ, headquarters in the state of Mexico, it is important to determine the structural changes that occur in a fiber after the alkaline treatment.



a) b) c)

d) e) f)

Figure 9. a) Bisulfite treatment, **b)** Hypochlorite treatment, **c)** Bisulfite treatment BES 20. okVWD at 20 µm, **d)** Chemicals in hypochlorite treatment, **e)** Chemicals in bisulfite treatment.

The Figure (a) shows the untreated fiber; it has an irregular surface of varying roughness where the microfibrils appear to be parallel to the fiber axis. Figure (b) shows some impurities on its surface and shows fiber treated with sodium hypochlorite (NaCLO), which has a rougher surface produced by the removal of lignin and hemicellulose. In figure (c), it is treated with sodium bisulfite (NaHSO3), and its roughness shows the most detached fibrils, but most of the impurities have been removed from the fiber surface. In figure (d), the fiber is cleaned with sodium hydroxide (NaOH) at 5% concentration and subjected to a temperature of 60º C, it has little impurity of oils, fats and others, but its fibrils do not reach a complete detachment. In figure (e), said experiment with sodium hydroxide (NaOH) at 10% concentration at a temperature of 60º C, does not manage to detach the fibrils, but sodium residues remain. And the last figure (f), shows total cleanliness and open fibrils, does not present any other residue, has a concentrate of 10 grams of sodium bisulfite (NaHSO3) with 300 ml of distilled water (H2O). are the results presented in this chemical characterization of the banana pseudostem fiber, this cleaner and rougher surface would increase the number of possible interaction sites, thus improving the fiber-matrix mechanical adhesion. This knowledge provides critical information on the interfacial adhesion between a fiber and the matrix when developing the composite.

4.1 Discussion

According to the results obtained in tests 1 and 2, from the alkaline treatments to the natural fibers of banana pseudostem, it is shown with previous works that there is similarity in the differences of fibers that can be used to obtain a composite material, Just as the objective or short summary of this work says, it is to find a new material that satisfies certain requirements of other materials and to know what its application would be. The research question is mentioned in the body of the work, can a polymeric composite be obtained, which by adding loads of natural fiber (pseudo stem of banana) to the polypropylene increases its aging, Young's Modulus, rigidity, and resistance and improves the mechanical properties in micrographic studies, then there would be the possibility of developing a composite that is cheaper than a composite with synthetic fibers. I mention that in this article it is only a first part of the work to be carried out, here only results have been shown where a chemical characterization methodology was used to give alkaline treatment to banana pseudostem fibers and obtain the cleanest sample of impurities and with more open fibrils, to subsequently submit it to a physical characterization, where it will be subjected to destructive tests, such as a universal machine to analyze tension, compression, extension, Young's modulus, aging test, etc. In figure 9 of the results, subsection (f) is shown, fiber treated with sodium bisulfite ($NaHSO_3$) and shows said cleaning, then with that sample a functionalization analysis will be carried out, which has been the art of increasing the affinity and improve chemical reactivity with certain molecules, exposing the parts with the greatest tendency to good fiber-matrix diffusion. The coupling agent to be used in the next research article is with silane, it is a chemical compound whose formula is SiH_4. They are frequently used to modify surfaces of fibers or particles used as reinforcement in organic matrix composites.

6. Conclusion

Due to the approach that this work has taken, which is mainly focused on studying the chemical characterization of the use of banana pseudostem fiber as a reinforcement material for the development of composite plastic materials, the results of this study demonstrate the feasibility of use natural plant fibers to prepare ecological compounds for applications by suitable methods. In the 2010s and onwards with the increase in CO_2 emissions to the environment from material processing, the development of environmentally friendly products from natural sources of raw materials has become an important research topic. The contribution that can be observed in this thesis is frankly the development of a mechanism or theory that leads to the aforementioned theme of this work to a creation of sustainability, but named with new terms such as the application of a circular economy, leaving behind the everyday, no longer working or thinking in a linear economy, which is to extract, produce and dispose of, explains the European researcher, Ellen MacArthur, it is time to start with the circular economy which is, design to last, restore, and regenerate. Elena (2019).

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Biography

The MIA. Pedro Jácome Onofre joined the National Technological Institute of Mexico campus San Andrés Tuxtla, Veracruz, on September 15, 2005, as a full-time professor at the Industrial Engineering academy, teaching Logistics and supply chains, Advanced Manufacturing, Ownership of materials, Metrology and Standardization, and others. He served as coordinator of academic tutorials for the industrial engineering career and has been president of an academy in the same area. He has participated as an advisor in Technological Innovation Projects in continuous years, in 2014 he participated in projects financed by the National Technological Institute of Mexico. And he has also been the author of 9 indexed articles, he has currently renewed his desirable profile by PRODEP, now in 2022 he has completed a doctorate in Advanced Manufacturing at CIATEQ facilities, in the state of Querétaro, Qro. (2018-2021), is now in the process of Thesis to conclude in 2022. He has become an Active Member of IISE (Institute Industrial System Engineering) and Faculty Advisor of Chapter # 632 of Industrial Engineering of ITSSAT. He was awarded in the years 2019, 2020, and 2021 for the third time with the GOLD AWARD. And the last academic activity outside the institution of him being director of the master's Thesis in Advanced Manufacturing by CIATEQ, A.C. Belonging to the (PNPC). AND CONACYT.