The ecological paper obtained from *Ananas comusus* waste as an alternative for use in a circular economy

David Velásquez Berru[1], Jhonny W. Valverde Flores [2], Carlos Castañeda Olivera[1], Rosario del Pilar López Padilla[1], Jorge Jave Nakayo[3], Elmer Benites-Alfaro[1]*

[1]Universidad César Vallejo, Av. Alfredo Mendiola 6232, C.P. 15314, Perú, david2512d@gmail.com, castanedao@ucv.edu.pe, rlopezp@ucv.edu.pe, * ebenitesa@ucv.edu.pe
[2]Universidad Nacional Agraria La Molina, CP. Lima 15024, Perú, jhovalverdeflo@gmail.com.
[3]Universidad Nacional Mayor de San Marcos, Ciudad Universitaria, Av. Venezuela, CP. 15081, Perú, joljave@gmail.com

Abstract– ***The generation of waste from plastic wrappings used in the packaging of products of various types and activities progressively constitutes a problem of environmental contamination due to their non-biodegradable nature. In view of this reality, an investigation was carried out with the objective of producing paper with ecological characteristics by using the pineapple crown, which is one of the non-consumable parts of the fruit Ananas comosus, which becomes part of the organic waste that is discarded at a cost for its final disposal. In the process, 5 kg of Ananas comosus crown was used, testing three processes, the first: Ananas comosus crown pulp, Second: Ananas comosus crown bleached with NaClO, and third: Ananas comosus corone pulp bleached with*** H_2O_2***. A yield of 26.6% of production of ecological paper was obtained with characteristics of grammage between 73.66 and 86.18 g/m2, thickness of 113 to 116 µm, whiteness of 22 to 59.2% photovlt, Resistance (tension 5760.2m, humidity between 7.84 to 9.18 %, cobb 164.7 to 424 g*** H_2O***/m2 and tear resistance between 9.96 to 13.16 mN-m2/g). The use and recovery of waste converted into paper for later use is an objective achieved within the concept of circular economy.***

Keywords-- Eco paper, organic waste management, pineapple wreath, waste and circular economy.

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LACCEI2021.1.1.350
ISBN: 978-958-52071-8-9 ISSN: 2414-6390

The ecological paper obtained from *Ananas comusus* waste as an alternative for use in a circular economy

David Velásquez Berru[1], Jhonny W. Valverde Flores [2], Carlos Castañeda Olivera[1], Rosario del Pilar López Padilla[1], Jorge Jave Nakayo[3], Elmer Benites-Alfaro[1]*

[1]Universidad César Vallejo, Av. Alfredo Mendiola 6232, C.P. 15314, Perú, david2512d@gmail.com, castanedao@ucv.edu.pe, rlopezp@ucv.edu.pe, * ebenitesa@ucv.edu.pe
[2]Universidad Nacional Agraria La Molina, CP. Lima 15024, Perú, jhovalverdeflo@gmail.com.
[3]Universidad Nacional Mayor de San Marcos, Ciudad Universitaria, Av. Venezuela, CP. 15081, Perú, joljave@gmail.com

Abstract*– The generation of waste from plastic wrappings used in the packaging of products of various types and activities progressively constitutes a problem of environmental contamination due to their non-biodegradable nature. In view of this reality, an investigation was carried out with the objective of producing paper with ecological characteristics by using the pineapple crown, which is one of the non-consumable parts of the fruit Ananas comosus, which becomes part of the organic waste that is discarded at a cost for its final disposal. In the process, 5 kg of Ananas comosus crown was used, testing three processes, the first: Ananas comosus crown pulp, Second: Ananas comosus crown bleached with NaClO, and third: Ananas comosus corone pulp bleached with H_2O_2. A yield of 26.6% of production of ecological paper was obtained with characteristics of grammage between 73.66 and 86.18 g/m2, thickness of 113 to 116 µm, whiteness of 22 to 59.2% photovlt, Resistance (tension 5760.2m, humidity between 7.84 to 9.18 %, cobb 164.7 to 424 g H_2O/m2 and tear resistance between 9.96 to 13.16 mN-m2/g). The use and recovery of waste converted into paper for later use is an objective achieved within the concept of circular economy.

Keywords*-- Eco paper, organic waste management, pineapple wreath, waste and circular economy.

I. INTRODUCTION

Given the need to find new ways of packaging and moving food without risk of being contaminated by the composition of the packaging, in recent years packages with many additional advantages have been offered that also comply with the conservation of the environment, that is, packaging called smart for the preservation of food [1] that gives the quality and safety of the product that contains it, as well as the reuse of the residues that are produced. In this context, paper as use in wrapping is undoubtedly very advantageous because it is ecological and biodegradable; it is recyclable, helping with the solution of waste problems and conservation of forest resources [2].

The research also seeks to demonstrate the reuse of organic waste that is sent to final disposal, among them the crowns of the Ananas comosus that in large quantities are discarded for being the non-consumable part as fruit. In Peru about 56% of the waste generated is of organic type [3], in what corresponds to the production of Ananas comosus, the Ministry of Agriculture in 2016 reported 460,000 tons, taking into account that 10 to 13% of said weight is the crown part of the mentioned fruit [4]. It is worth mentioning that, in the commercial center where the sample was obtained produces a daily average of 200 kilos of crown.

On the other hand, cellulose is the fundamental raw material in the production of paper, so it is important to know its chemical properties because it will influence the quality of the paper produced. The main component of crown leaves is cellulose, which is found in the cell wall as in all plants, and is a regular polymer of high molecular weight made up of glucose. There are also hemicelluloses, pentose and hexose polysaccharides, and lignin (phenylpropanoid monomers) that polymerize in an enzymatic oxidation to form a macromolecule without a defined structure [5]. It is important to know its composition of pineapple crown, [6] as it has a composition of 11-45% cellulose,14-50% Heminicellulose and 10-30% lignin.

The paper is manufactured from the wood of the trees being the traditional industry, however, the production of paper from corn cobs and cane bagasse has also been tested, obtaining a mixed pulp with properties with a significant percentage of cellulose [7]. It has also been verified that plant products have chemical properties such as cellulose and lignin that can be used, which is why there is potential for the production of paper, with up to a percentage of 47% cellulose found in the crown of Ananas comosus (pineapple) [8]. Obtaining newsprint from banana rachis waste has been experimented with with economic and environmental benefits [9]. In another case, the mesocarp of the orange peel was used, obtaining 11% yield [10].

II. MATERIALS AND METHODS

The methodology used for this research study is of experimental design, using as a baseline the methodological guide "Elaboration of handmade paper projects with vegetable fibers", prepared by the Ministry of Foreign Trade and Tourism. It should be noted that to ensure the quality of the product obtained, some parameters were analyzed, such as: resistance characteristics (humidity, cobb and tearing), physical characteristics (grammage, thickness and whiteness) and finally the yield obtained (amount of pulp).

Fig. 1 Paper Obtained

For the production of paper it is necessary to carry out a chemical process, which consists of removing the lignin, which is the fundamental component that strengthens and provides rigidity to plant tissues. The procedure is carried out by cooking, where the reagents are added in aqueous solution. They are controlled under some parameters such as temperature, pressure, time and reaction speed.

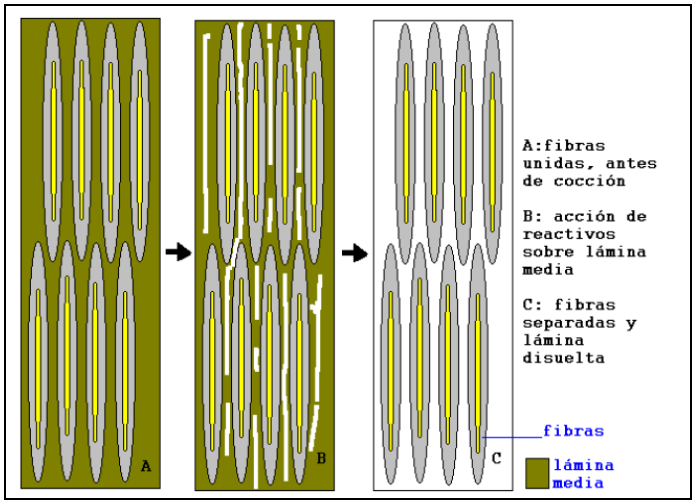


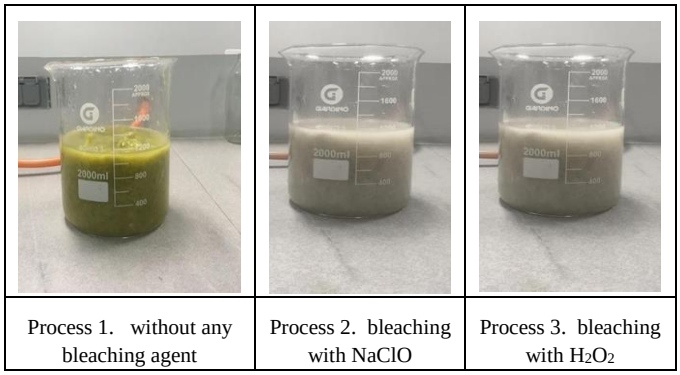
Fig. 2 Graphical Representation of Chemical Delignification

For the production of paper it is carried out through three processes:

Process 1: *Ananas comosus* crown pulp paper was made without any bleaching agent.

Process 2: Sodium Hypochlorite (NaClO) was added as a bleaching agent to the pulp of Ananas comosus,

Process 3: Hydrogen peroxide (H2O2) was added as a bleaching agent to the pulp of Ananas comosus.



Process 1. without any bleaching agent	Process 2. bleaching with NaClO	Process 3. bleaching with H_2O_2

Fig. 3 Obtaining the crown pulp of *Ananas comosus* (pineapple)

It is important to mention that no physicochemical analysis of the wastewater (black liquor) generated when cellulose was obtained was carried out in this research.

The stages of the research for the production of handmade paper are:

Stage 1: Collection of the Ananas comosus crown coming from the “Unicachi” product market, Los Olivos-Lima.

Stage 2: Elaboration of the ecological paper, which is indicated below.

- Selection of Ananas comosus crowns in good condition (Figure 4).

Fig. 4 Crown of Ananas comosus

- Ananas comosus crowns were chopped by hand, a 5 kg sample was taken and cut to a size between 0.5 cm to 2 cm to facilitate homogenization in the following phases.
- Washing and soaking, in order to remove impurities and then soak them for 12 hours in a container to soften the fibers and facilitate obtaining the cellulosic pulp of the Ananas comosus crowns.
- Cooking for one hour at a constant temperature between 180º to 200º, with the addition of sodium hydroxide (in proportion of 10% per kilo of Ananas comosus crowns) to remove the lignin from the crown, obtaining the cellulosic pulp.
- Washing until reaching a neutral pH, to eliminate the sodium hydroxide with the lignin leaving only cellulosic pulp of Ananas comosus crown.
- Bleaching, in order to remove the natural color of the pulp from the crowns, sodium hypochlorite (process 2) and hydrogen peroxide (process 3) were used. The amount of 80 mL was incorporated with stirring and then allowed to stand for 1 hour. See figure 3.
- Liquefying of the pulp of the Ananas comosus crowns, in order to obtain a pulp of fine granulometry and to be able to enter the subsequent phase. It is worth mentioning that an Oster blender with a 3-speed rotary control and a power of 600 watts was used.
- Preparation of the pulp. The mixture obtained is placed in a tank with water, the mixture being constantly stirred to avoid the adherence of the pulp.
- Elaboration and Molding of ecological paper. A frame is introduced into the tank with the cellulose mixture and is removed looking for the thickness that is required for the paper.It is important to mention that the size of the sheet will have as a reference the measurements of the frame, for the present investigation a frame of the size of an A4 sheet was used.
- Drying of ecological paper. The ecological paper of Ananas comosus crown is removed from the frame and placed on a Bombay cloth to remove the water initially and then placed on a sheet of melamine allowing it to dry at room temperature. See figure 5.

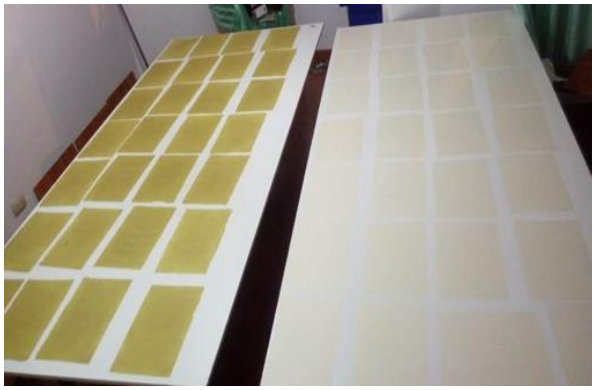


Fig. 5 Ecological paper in the drying process

III. Results

A. Pulp Yield obtained by Ananas comosus Crowns

From 5000 g of Ananas comosus crown, the treatment processes indicated were proceeded with the results indicated in Table 1. From this, the yield percentage was calculated, finding 26.26%, 26.12% and 26.18% for each process respectively.

TABLE I
RESULTS OF THE PROCESS AND PERFORMANCE OF THE CROWN OF PINEAPPLE COMOSUS IN OBTAINING PULP

Process type		Process 1: without any bleaching agent	Process 2: bleaching with NaClO	Process 3: bleaching with H_2O_2
Cronw amount (g)		5000	5000	5000
NaOH amount (g)		500	500	500
Washing and Soaking (L)		40	40	40
Amount of water used during paper production	Washing (L)	20	20	20
	Cooking (L)	15	15	15
	Washing (L)	40	40	40
	Sheet molding (L)	15	15	15
	Total wáter consumption (L)	90	90	90
Input of whitening	H_2O_2 - NaClO (ml)	–	100	100
	Time (minutes)	–	60	60
Amount of pulp obtained (g)		1313	1306	1309
Yield (%)		26.6	26.12	26.18

B. Physical characteristics of the ecological paper of the crown of Ananas comosus

The physical characteristics of the sheets evaluated in process 1 indicate that a higher grammage was obtained than in processes 2 and 3 with an average of 86.18 g/m2, 78.47g/m2 and 73.66 g/m2 respectively. Likewise, process 1, obtained greater thickness than processes 2 and 3 with an average of 116 µm, 114 µm and 113 µm respectively. It is worth mentioning that each leaf was made with 110 g of moist pulp. Finally, process 2 presented a higher percentage of whiteness with respect to processes 3 and 1, which reached percentages of 59.5%, 41.3% and 22.1%, respectively. See Table 2

TABLE II
PHYSICAL CHARACTERISTICS OF THE ECOLOGICAL PAPER OF THE CROWN OF ANANAS COMOSUS

	Repetitions	Grammage (g/m2)	Thickness (µm)	Whiteness (%photovlt)
Process 1	R1	85.88	116	23
	R2	85.3	116	23
	R3	87.38	116	22
	R4	87.4	116	21
	R5	84.95	116	21
	Average	86.182	116	22
Process 2	R1	77.2	114	62
	R2	77.12	114	61
	R3	78.71	114	57
	R4	79.29	114	55
	R5	80.04	114	61
	Average	78.472	114	59.2
Process 3	R1	75.37	113	40
	R2	73.22	113	43
	R3	72.7	113	43
	R4	72.02	113	40
	R5	75	113	42
	Average	73.662	113	41.6

C. Resistance characteristics

Regarding the resistance characteristics, process 1 of the Cobb factor presented higher percentages than processes 2 and 3 reaching values of 201 gH20/m2, 182 g H2O/m2 and 164 gH20/m2 respectively. Likewise, these processes are directly related to the Humidity factor, since process 1 presented a higher percentage with respect to processes 2 and 3, reaching values of 9.2%, 8% and 7.9% respectively. On the other hand, the stress factor in process 3 registers higher levels than processes 2 and 3 with an average of 5731 m, 4379 m and 3542 m respectively. Finally, in the tear factor, process 1 presented better properties than processes 3 and 2 with 12.2 mN-m2/g, 12.1 mN-m2/g and 10 mN-m2/g respectively. see Table 3.

The pulp yield did not vary significantly in any of the 3 processes, registering the lowest value in process 2 with 26.12% and reaching a maximum yield in process 1 with 26.26%.

TABLE III
STRENGTH CHARACTERISTICS OF ANANAS COMOSUS PAPER

	Repetitions	Strain o length of break (m)	Humidity (%)	Cobb (g deH_2O/m^2)	Tear (mN-m^2/g)
Process 1	R1	4087	8.2	183	12.2
	R2	4172	9.2	217	13.2
	R3	4598	10	460	9.2
	R4	2555	9.6	660	10.3
	R5	2555	8.9	600	10.6
	Average	3593.4	9.18	424	11.1
Process 2	R1	3836	8	172.8	11.1
	R2	4678	8.2	195	11.3
	R3	5427	7.8	178.1	13.6
	R4	3930	8.3	185.5	15.5
	R5	4397	7.9	178.4	14.3
	Average	4453.6	8.04	181.96	13.16
Process 3	R1	4516	7.9	158.7	9.6
	R2	7025	8	163.6	10.5
	R3	4616	7.7	141.6	10.2
	R4	6623	8.1	181.9	9.3
	R5	6021	7.5	177.7	10.2
	Average	73.662	113	164.7	9.96

III. DISCUSSION

The process of obtaining ecological paper from Ananas comosus waste turned out to be possible by means of an artisan method with projection to scale to an industrial level. The results obtained were subjected to manufacturing processes taking into consideration from a due selection of Ananas comosus crowns followed by cooking for 1 hour where the removal of the lignin must be sought so that the cellulosic pulp presents the best characteristics in the subsequent manufacture of the ecological paper (8%) of final residual lignin verified by the kappa number), in addition to eliminating the high water content that the fruit presents, which is up to 86% as indicated [11].

Another parameter that was controlled was the pH of the pulp, which was initially around 12 in all the three processes tested, so by washing it was adjusted to a neutral pH, in this way the paper to be obtained would have good quality and conservation characteristics. Since it is less than 5, the paper tends to yellow, has less resistance and deteriorates [12], and if it is greater than 7, the pulp presents sizing problems in the production of paper [13].

The average weight obtained in the three processes was varied by the artisanal methodology used, where the humidity , quantity of fiber [14] influences, the same happens with the thickness that is not exactly uniform having paper of the same weight but of uneven thickness that may depend on the understanding in its manufacture.

In the research on the bleaching of the pulp for the paper, when sodium hypochlorite was used, better whiteness was obtained than with hydrogen peroxide due to its better

oxidizing power [15]. According to NTP 272,128 [16] the paper obtained in processes 1 and 3 corresponds to the type of dark papers (whiteness less than 45%) and to that obtained from process 2 of the type of semi-white paper (whiteness in the range 45 -75%). Bleaching is favorable to the tear resistance of the paper as there is more fiber per unit of weight [17] as well as it improves the stress factor or rupture length [14].

The Cobb factor, which has to do with the sizing of the paper, a property that prevents ink from running on the paper, was found between 164 and 201 g H2O/m2 due to high humidity (7.9 to 9.2%), but can achieve low values by drying up to around 13 to 24 g H2O/m2 as stipulated by the NTP 272.128, as well as adding binders [18].

In the trials of processes 1, 2 and 3, pulp was obtained for the manufacture of paper in a higher percentage in process 1 with 26.26%, allowing the manufacture of an average of the three repetitions of 5.8 A4 size sheets with possible use in wrapping or bags for food and other species, due to the advantages it presents among them of biodegradability, low cost and high benefit, it is recyclable, not thermally conductive, it can adhere to coatings, it is light, it can withstand oil and grease, easy to mold and its very versatile use [19].

III. CONCLUSION

It was determined that it is possible to obtain paper from the crowns of Ananas comosus fruits as an alternative to use these organic plant residues with physical and resistance characteristics similar to paper obtained from wood. In this way, deforestation is avoided with an impact on environmental improvement through the circular economy and being able to address the impacts of greenhouse gas pollution, benefiting from the environmental service offered by forests, which must be cared for and not destroyed.

The paper obtained using vegetable pulp as raw material (Ananas comosus fruit crowns) provides ecological characteristics such as biodegradation and other essential characteristics that facilitate its use in wrapping and packaging for food preservation and transportation, without the risk of contamination due to its nature. On the other hand, the paper obtained can be used in the paper industry since it is possible to write, draw and print on the paper.

This research makes it attractive for use by society, manufacturing by commercial companies and environmental care.

The use of Ananas comosus crown waste to obtain ecological paper means prolonging the life chain of this natural resource, giving it use, value and entering into the concept of circular economy.

REFERENCES

[1] Rodriguez-Sauceda R., Rojo-Mrtinez G, Martinez-Ruiz R., Piña-Ruiz, H., Ramirez-Valverde B., Vaquera-Huerta H., Cong-Hermina M., 2014. Envases inteligentes para la conservación de alimentos. Ra Ximhai, Universidad Autónoma Indígena de México, 10 (6): 151-173. Edición especial julio-diciembre. https://www.redalyc.org/pdf/461/46132135012.pdf

[2] Chacón-Olivares M., Pacheco-Rivera A., Cendejas-López M., Ortega-Herrera F., 2016. Tendencias del crecimiento en la cultura del reciclaje. Revista de Ciencias Ambientales y Recursos Naturales Septiembre 2016 Vol.2 No.5 63-72. https://www.ecorfan.org/spain/researchjournals/Ciencias_Ambientales_y_Recursos_Naturales/vol2num5/Revista_de_Ciencias_Ambientales_y_Recursos_Naturales_V2_N5_7.pdf

[3] FONAM, 2018. Residuos sólidos. https://fonamperu.org.pe/un-fondo-ambiental-para-el-peru/residuos-solidos

[4] Rodriguez R., Becquer R., Pino Y., Lopez D.,Rodriguez R.C., Lorente G., Izquierdo R., Gonzales J., 2016. Producción de frutos de piña (Ananas comosus(I) Merr.) MD-2 a partir de vitroplantas. Revista Cultivos Tropicales, 37(supl 1) LA Habana. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0258-59362016000500006

[5] Ralph J., Lundquist K., Brunow G., Lu F., Kim H., Schatz P., Marita J., Hatfield R., Ralph S., Christensen J., Boerjan J., 2004. Lignins: natural polymers from oxidative coupling of 4-hydroxyphenyl-propanoids. Phytochemistry reviews, 3(1-2): 29-60. https://link.springer.com/article/10.1023/B:PHYT.0000047809.65444.a

[6] Prado-Martínez M., Anzaldo-Hernández J., Becerra-Aguilar B., Palacios-Juárez H., Vargas-Radillo J. & Rentería-Urquiza M.(2012). Caracterización de hojas de mazorca de maíz y de bagazo de caña para la elaboración de una pulpa celulósica mixta. Madera y bosques, 18(3), 37-51. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-04712012000300004&lng=es&tlng=es.

[7] DAZA, Rey [et al.]. Valuación de las propiedades físicas y químicas de residuos sólidos orgánicos a emplearse en la elaboración de papel. *Revista Luna Azul*. [En línea]. Julio- diciembre 2016, nº 43. [Fecha de consulta: 05 de septiembre de 2017]. Disponible en: http://www.scielo.org.co/pdf/luaz/n43/n43a21.pdf / ISSN: 19092474

[8] Gonzales K., Daza D., Caballero P., Martínez C., 2016. Valuación de las propiedades físicas y químicas de residuos sólidos orgánicos a emplearse en la elaboración de papel. Revista Luna Azul. Vol. 43: 493-515. DOI: 10.17151/luaz.2016.43.21. http://www.scielo.org.co/pdf/luaz/n43/n43a21.pdf

[9] Casanova, A, 2014. Implementación de una empresa de papel periódico utilizando el raquis de banano como materia prima. Tesis (Magister en Ciencias Económicas).Guayaquil: Universidad Estatal de Guayaquil, 2014. http://repositorio.ug.edu.ec/bitstream/redug/6048/1/TESIS%20KATTY%20CASANOVA%20ARRATA.pdf

[10] Ríos Á., 2017. Producción de papel artesanal a partir de residuos de cáscaras de naranja de las juguerías del mercado Tahuantinsuyo - Independencia, 2017. Tesis : Universidad César Vallejo. https://hdl.handle.net/20.500.12692/12609

[11] Irías A., y Lutz G., 2014. Composidición química de la biomasa residual de la planta de piña variedad MD2 proveniente de Cuácimo, Limón.

Revista Ciencia y tecnología, 30(2): 27-34. https://revistas.ucr.ac.cr/index.php/cienciaytecnologia/article/view/20347/20496

[12] Condori D., 2010. Evaluación de las propiedades físicas químicas y ópticas del papel tipo glassine obtenido a partir de fibras de totora (schoenoplectus tatora). Tesis pa título de Ingeniería agroindustrial. Puno: Universidad nacional de altiplano, http://repositorio.unap.edu.pe/handle/UNAP/3365

[13] Quihue J., 2014. Obtención de fibras a partir de raquis de plátano para la producción de pulpa de papel. Universidad Nacional San Cristobal de Huamanga, Ayacucho, Perú: Tesis para optar el título professional de Ingeniero Químico. http://repositorio.unsch.edu.pe/bitstream/handle/UNSCH/1039/Tesis%20Q478_Qui.pdf?sequence=1&isAllowed=y

[14] León C. y Fuentes M., 2012. Diseño de un proceso para la fabricación de papel de reciclado ecológico a escala de papel reciclado ecológico a escala laboratorio usando peróxido de hidrógeno. Tesis: Universidad de Cartagena, para optar el título de Ingeniero químico. https://repositorio.unicartagena.edu.co/bitstream/handle/11227/112/TESIS%20DE%20GRADO.pdf?sequence=1&isAllowed=y

[15] Ehman V., 2019. Nanocelulosa a partir de residuos agro y forestoindustriales. Tesis: Universidad Nacional de Misiones, para obtener el grado de Doctor en Ciencias Aplicadas, Misiones, Argentina. https://ri.conicet.gov.ar/bitstream/handle/11336/80941/CONICET_Digital_Nro.29e13ccb-f7f1-40cb-aef2-41f29c4000f4_B.pdf?sequence=5&isAllowed=y

[16] INDECOPI: NTP 272.128, 2010. Principios para la clasificación general de papeles y guía de selección de parámetros de calidad de papeles y cartones 1a.ed. https://busquedas.elperuano.pe/normaslegales/aprueban-normas-tecnicas-peruanas-sobre-papeles-cartones-c-resolucion-n-12-2013cnb-indecopi-910611-2/

[17] Salazar M., 2011. Perfil del proceso de secado de pulpa y sus efectos en las propiedadexs del product final. Tesis: Universidad Federal de Vicosa, Magíster Scienctiae.Brasil. https://www.locus.ufv.br/bitstream/handle/123456789/5922/texto%20completo.pdf?sequence=1&isAllowed=y

[18] Betancourt P., 2014. Fabricación de paneles de papel reciclado para el diseño parcial o total de mobiliario doméstico en el estado de México. Tesis (Grado de maestro en diseño). Mexico: Universidad Autónoma del Estado de Mexico. http://hdl.handle.net/20.500.11799/79941.

[19] Fontani A.L. 2003. Emvase y embalaje. Libro, Editorial Escuela Superior de Gestión Comercial y Marketing (Esic). ISBN 10: 8473563395 / ISBN 13: 9788473563390.