

# Production Of Paper From The Residue Of The Cellulose Extracted From The Corn Cob (Zea Mays L. Var. Ceratina)

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## Abstract

Paper was obtained from the cellulose from the corn cob (*Zea mays* L. var. *Ceratina*), the cob was subjected to a grinding and sifting process to obtain a particulate matter with a diameter of 120  $\mu\text{m}$  of average, for its extraction different proportions of sodium hydroxide were used for every 100 grams of raw material (1:5, 3:10, 2:5). The resulting pulp was dry at 95 Celsius grades later it was bleach with sodium hypochlorite at 45 Celsius grades for 0,75 hours. The sheets of paper dried on absence of light at room temperature were characterize obtaining as a result a grammage of 1,63 g/square meters, rupture rate of 189 kgf, caliber of 1,152 mm and a whiteness index with a variation of reflectance of 13,61% in relation with the standard. The most optimal pulp process gave a performance of 44,73% and a kappa number of 32,88 with a proportion of 3:10 NaOH (Sodium Hydroxide) for 3 hours and a temperature of 95 Celsius grades stance, in addition to taking advantage of the modulable dissolution capacity.

Keywords:

**A:** Corn Cob.

**C:** Corn (*Zea mays* L. var. *Ceratina*).

**D:** Cellulose.

**E:** Caustic soda.

**F:** Pulp.

**G:** Bleached.

**H:** Kappa number.

**I:** Rupture Rate

## 1. INTRODUCTION

Ecuador in 2019 used 543 million dollars in pulp and paper imports, as well ensures NOSIS TRADE (2019) due to the lack of industries that transform wood into pulp for the manufacture of paper. This represents a strong investment by the state, Therefore, it is necessary to look for alternative processes to produce paper pulp with a accessible and efficient projection. Waste originating from agricultural activity that does not have a correct final disposal result in environmental pollution that affects the environment. The INEC in the Technical Bulletin No. 01-2018-ESPAC, mentions that at the national level the corn harvested area in

Ecuador was 365,334 hectares, being a product that generates abundant waste. Corn cob (*Zea mays*. L) is classified as agricultural waste non-timber due to its limited applicability in the food or livestock industry, for which multiple investigations have found interesting aspects for participation as a substratum microbial, filter for wastewater treatment, utilization of xylanases presents in its composition, among others. This by-product of agricultural origin generated in large amounts in the process of separating the grain from the cob, it is estimated that for each ton of corn, 170 kg of cob are obtained (CIMMYT, 1995).

Through hydrothermal degradation, the cob has 45-50% cellulose in its structure, this figure is also confirmed by the research by Córdova et al. (2013). On the other hand, olote having a considerable amount of cellulose in its structure according to Huiertaa et. al., (2012) makes this material an element suitable for the production of sheets of paper. Today the materials have not reached any economic value after an agricultural activity are considered as waste, destined for conventional disposal, but the research opens a door for that the waste participate in an industrial process that gives it an added value that covers asocial need and be friendly to the environment.

Therefore, in this investigation it is proposed to subject the cob to pulping in caustic soda to different concentrations, under subcritical conditions, that is, at temperatures from 95 °C to atmospheric pressure in order to obtain sheets of paper with the appearance of bond paper through the extraction of a pulp rich in cellulose. In this way, you take advantage of a residue that replaces heavily attacked timber sources with a friendlier option with the environment.

## 2. MATERIALS AND METHODS

### 2.1 Reception and washing of the raw material

0.5 kilograms of the corn cob were collected following the sampling criteria of the ISO 7002 and ISO 874 standards, waste generated in the San Alfonso market in the Riobamba canton. The raw material entered the selection process to separate cobs that had worms, decomposing organic matter, cob hairs (corn stigma), corn grains or other undesirable elements. After this, the raw material is washed with abundant water on a stainless-steel table until the remaining contaminants have been eliminated.

Fig 1. Raw material



### 2.2 Chopping of the raw material

The corn cobs entered the manual chopping process, reducing them to small pieces of approximately 2cm wide by 3cm long in order to facilitate their handling and the subsequent drying process.

Fig 2. Chopping of the raw material



### 2.3 Drying of the raw material

The cob pieces entered a drying oven to eliminate the moisture present in its composition and obtain a suitable material for the grinding process. The drying conditions were carried out at 90°C for 12 hours.

Fig 3. Drying of the Raw material



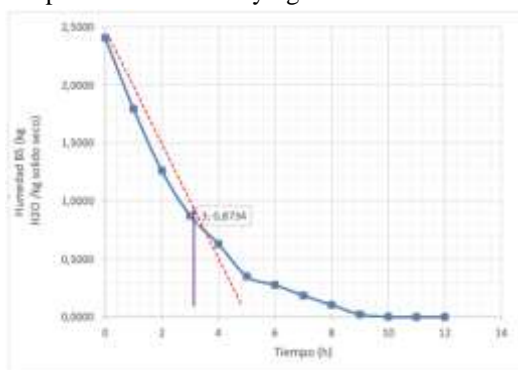
Chart 1. Data for the calculation of humidity of the raw material

Tiempo (h)	Peso olate de maíz (kg)
0	0,5
1	0,4842
2	0,4158
3	0,3466
4	0,2694
5	0,1983
6	0,1875
7	0,1741
8	0,1622
9	0,1501
10	0,1478
11	0,1469
12	0,1469

Chart 2. Energy balance data of the drying oven

Tiempo (h)	Muestra (kg)	Humedad base seca (kg H <sub>2</sub> O /kg sólido)	Humedad media	M0 (h)	ΔX	W (kg/h·m <sup>2</sup> )	1/W (h·m <sup>2</sup> /kg)
0	0,5	2,4037	2,0980	1	-0,5718	0,5364	1,864
1	0,4102	1,7024	1,5262	1	-0,4595	0,4310	2,320
2	0,332	1,2600	1,0667	1	-0,3152	0,2957	3,382
3	0,2752	0,8734	0,7515	1	-0,2617	0,2455	4,073
4	0,2394	0,6297	0,4198	1	-0,1767	0,1637	6,035
5	0,1983	0,3499	0,3131	1	-0,0824	0,0773	12,942
6	0,1875	0,2764	0,2308	1	-0,0861	0,0808	12,379
7	0,1741	0,1852	0,1447	1	-0,0817	0,0786	13,050
8	0,1622	0,1042	0,0630	1	-0,0512	0,0440	20,831
9	0,1501	0,0218	0,0118	1	-0,0109	0,0102	97,875
10	0,1478	0,0018	0,0009	1	-0,0009	0,0008	1184,470
11	0,1469	0,0000	0,0000	1	-0,0004	0,0004	2375,000
12	0,1469	0,0000	0,0000	1	-0,0004	0,0004	2375,000

Graphic 1. Corn cob drying curve



## 2.4 Grinding and sifting

Dried cob chunks enter the hammer mill feed hopper for a period short time, collecting the pulverized material in plastic bags and submitting as many times large chunks may be necessary to the grinding process. Subsequently, the operation of sieved, allowing small or fine particles to pass, and retaining those of larger sizes, a uniform chip size being necessary for process efficiency and quality of the pulp as mentioned by Bajpai (2015). The criterion for choosing the particle diameter was made taking as reference the NTE INEN 616 standard: Wheat flour; which requires a sieve of 210  $\mu\text{m}$  to obtain a quality product. In the case of corn flour, it does not require an excessively small diameter so he used a diameter greater than the particle size in a 360 $\mu\text{m}$  sieve.

Fig 4. Grinding raw material



## 2.5 Pulped in Caustic Soda

For this process, an amount of pulverized cob equivalent to 0.0956kg was weighed and entered into a stainless-steel container trying to resemble some conditions of a digester suitable for this process. The amount of water used was 2500 mL for every 100 g of matter premium for a pulping of 2 hours, the same that increases in relation to time. The dissolved NaOH in water was deposited in the stainless-steel container next to the pulverized cob. The cooking is brought to 95°C, controlling this temperature with a thermometer for a period of 3 hours. This process allowed to separate the cellulose from the lignin and from the rest of the components present in the pulp that does not intervene in the papermaking process.

Fig 5. Grinding raw material

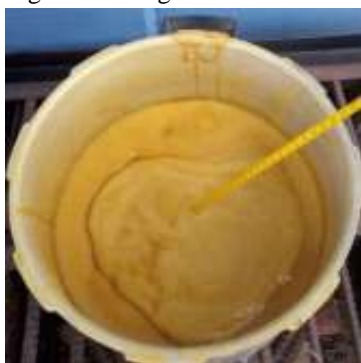


Chart 3. Data to calculate the performance of the pulping process

Agua		Olote de maiz particulado		NaOH		Tiempo (h)	Temperatura (°C)
%	Kg	%	Kg	%	Kg		
96,29	3,3	2,61	0,095	1,1	0,04	3	95

Chart 4. Data to calculate the performance of the pulping process

Tiempo de cocción (h)	Cantidad de NaOH (kg)	Olote de maiz pulverizado (kg)	Pulpa obtenida al final de la cocción (kg)
2	0,02	0,095	0,0581
	0,03	0,095	0,0512
	0,04	0,095	0,0484
3	0,02	0,095	0,0534
	0,03	0,095	0,0463
	0,04	0,095	0,0474
4	0,02	0,095	0,0497
	0,03	0,095	0,0425
	0,04	0,095	0,0396

## 2.6 Black liquor filtration

The cellulosic pulp solution and black liquor were separated by a filter medium (fabric, canvas), collecting the black liquor in a beaker for further analysis and residual treatment. The pulp retained on the canvas is transferred to suitable containers for its post processing.

Fig 6. Filtering of black liquor



Chart 5. Data for the determination of residual soda

Tiempo de cocción (h)	Agua (L)	Licor negro (L)
2	2	0,723
3	2,750	1,095
4	3,500	2,050

## 2.7 Pulp washing

The washing of the pulp was carried out with distilled water in order to obtain a pulp free of undesirable soluble, this process ends when the pH of the washing water is neutral.

Fig 7. Filtering of black liquor



## 2.8 Bleached

The bleaching of the pulp was carried out in a solution of sodium hypochlorite in proportion 2:1 in relation to water for 45 minutes at a temperature between 20° and 60°C to reduce color browning of the pulp and obtaining optimum whitening. The pulp washing process is repeated to remove the chlorine solution with several milligrams of water until a clean pulp is obtained.

Fig 8. Bleached of the pulp



Chart 6. Pulp Bleaching Process Data

Agua (L)	Hipoclorito de sodio(L)	Tiempo (h)	Temperatura (°C)
0,2	0,1	0,75	45

## 2.9 Preparation of mixture

For the formation of the paper sheet, a mixture of 0.0424 kg of bleached pulp is made with 0.2 L of water in such a way that the solution reaches an adequate consistency of 0.321% according to states the regulations. The mixture obtained was 0.260 L and for the formation of a sheet of 17x12 cm paper requires a quantity of 0.06 L; having at the end of the process 4 sheets of paper.

Fig 9. Preparation of mixture



Chart 7. Data for the preparation of the mixture

Agua (L)	Pulpa blanqueada (kg)
0,2	0,0424

Chart 8. Data for the determination of pulp consistency

Muestra de solución de pulpa (mL)	Peso papel filtro (g)	Temperatura (°C)	Tiempo (h)	Peso papel + pulpa seca (g)
Pa	F	T	ti	P
100	1,030	90	0,33	1,358

To calculate the consistency of the pulp solution for the formation of the paper sheets, follows the Tappi 240 om-93 standard.

$$\%C = \frac{(P - F)}{Pm} \cdot 100$$

Donde:

$\% C$  = Porcentaje de consistencia (%)

$P$  = Peso seco de fibra + papel filtro seco (g)

$F$  = Peso seco del filtro (g)

$Pm$  = Peso neto de la muestra (mL)

Sabiendo que 100 mL = 100 g

$$\%C = \frac{(1,358 \text{ g} - 1,030 \text{ g})}{100 \text{ g}} \cdot 100$$

$$\%C = 0,328$$

## 2.10 Sheet formation

In a container with water, the 17x12 cm frames were introduced in such a way that both submerged the  $\frac{3}{4}$  parts of its structure, proceeded to dose the pulp solution of cob-water with a suitable consistency in the upper part of the rack, making parallel movements housing in the mesh a film of cellulose paste. The movie of Cellulose is placed on a canvas until it is incorporated into it and the excess water is absorbed with a sponge and kitchen towels. Finally, it is pressed with a smooth surface for a few minutes to improve the texture of the paper.

Fig 10. Sheet formation



Chart 9. Sheet formation process data

Tiempo de formación de hoja / unidad (s)	Tiempo promedio de formación de hoja / unidad (s)
300	294,17
285	
294	
321	
274	
291	

Chart 10. Sheet formation process data

Dosificación de solución de pulpa (L)	Consistencia (%)	Viscosidad (Pa.s)	Tiempo formación de hoja (s)
0,060	0,328	0,15	294,17

## 2.11 Sheet drying

The fabric is dried in a dark room in the absence of sunlight to prevent damage to the foil paper for 48 hours at a temperature of 21 °C, when the process was finished it was carefully removed the paper sheet of the fabric, in this way the final product was obtained.

Fig 11. Sheet drying



Chart 11. End product data

Muestra	Formación de láminas de papel		Número de láminas de papel	Peso lámina de papel (g)	Peso promedio (g)
	Si	No			
k1		X	-	-	-
k2		X	-	-	-
k3	X		4	1,199	1,376
				1,323	
				1,564	
				1,398	
m1	X		4	2,781	2,544
				3,183	
				2,010	
				2,355	
m2	X		4	3,174	2,657
				2,446	
				2,281	
				2,756	
m3	X		3	2,388	2,786
				1,711	
				4,279	
p1	X		3	2,917	3,621
				2,498	
				2,645	
p2	X		3	2,331	2,344
				2,433	
				1,967	
p3	X		4	3,010	3,273
				2,662	
				3,431	
				4,049	

Fig 11. Process diagram for papermaking



### 3. RESULTS

#### 3.1 Characterization of the corn cob

The chemical characterization of the corn cob was carried out according to the guidelines of the standards INEN and TAPPI. The results are according to fractions of moisture, ash, cellulose and lignin.

Chart 12. Characterization Results corn cob chemistry

Propiedad	Porcentaje (%)
Humedad	16,11
Ceniza	2,340
Celulosa	40,225
Lignina	15,482

Hydrothermal treatment under subcritical conditions according to Tappi 9m, 1954 given by Cordoba et al. (2013) points out that the cellulose content is 45% present in the cob of corn. And the lignin content in the composition was 15.8%. under the same guideline Portugu ez et al. (1992) points out that the percentage of cellulose in the cob is 59.2% and the lignin at 17.9%. When comparing the results obtained with the cob sample analyzed at the laboratory, we see that these values are below those referred to by the authors mentioned; being 40.225% cellulose and 15.482% lignin. This is because it was used a method of delignification to the cob sample based on various NaOH solutions at 80  C, thus separating the lignin from the cellulose so that the latter component is purer and your results are more accurate. The high percentage of cellulose present in the corn cob makes this residue an ideal material for making paper, alluding to what was affirmed by Grant et al. (1966) that the basic structure of pulp and paper in a network of fibers of cellulose.

### 3.2 Scanning Electron Microscopy SEM

Using a scanning microscope, the microscopic structure of the corn cob was observed. Figure 12 (c) (d) shows the diameter of the corn cob fibers and the length of the fiber.

Fig 12. SEM of corn cob

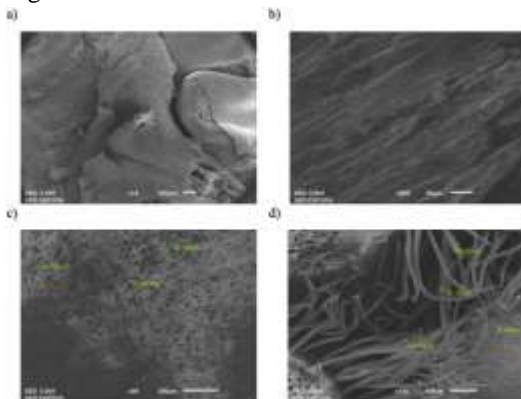


Chart 13. Biometric properties of corn cob

Variable	Medida (um)
Longitud de la fibra (L)	150,7
Di�metro de la fibra (D)	14,125

Chart 14. Raw material quality indices

�ndice	Valor
Coficiente de rigidez (CR)	0,3
Coficiente de flexibilidad (CF)	0,285
Coficiente de Peteri (IE)	10,67
Relaci�n Runkel (RR)	1,05

Urias (1996) establishes that the value of the stiffness coefficient that is in a range of 0.20-0.35 indicates that the thickness of the cell wall is "thin", affecting the adherence between the cell's fibers and thus the resistance of the paper in an alarming but not total way. The CR result in corn cob as indicated in table 13, has a value of 0.3 that was affected by moment of forming the sheets of paper where the cellulosic fibers had difficulty adhere to each other in low concentrations of caustic soda, but improving with the increase of the concentration of it. The resistance was low when monitoring the variables of paper quality.

The flexibility index has a parabolic relationship with the breaking length, this index when values >50 are reached, the tensile strength will be greater and the tear and tear strength will be higher bending will be favored (Araiza & Quiñones, 2000). The CF of corn cob is in the last denomination with a value of 0.285 that when compared with the table in Annex D, we observe that there is little surface contact and poor fiber-to-fiber bonding at the time of drying of the sheet of paper.

Porres & Valladares (1979), present a classification of the quality of pulp present in the Annex B, being < 0.25 excellent for making paper considered grade I, while the Results greater than 2 determine that the raw material is a poor choice for making paper. In the test carried out to measure this index we can see that the result is 1.05, which when locate in the aforementioned Table we observe the corn cob is a good-regular species for paper making. Araiza & Quiñones (2000) when determining the Peteri index of the Casuarina equisetifolia wood obtained a value of 72.9, which falls into the category of quality moderate. When comparing with the index determined in the investigation, it was 10.67, which places it in a pulp of regular quality.

### 3.3 Characterization of pulp for paper

Infrared transmission spectroscopy allows us to observe the functional groups that make part of a compound through wavelength vibration, studies by Requejo (2011) present the IR of virgin cellulose. It can be seen in figure 13 the bands O-H bond stretching characteristics at  $3353\text{ cm}^{-1}$ , the C-O bond at  $1052\text{ cm}^{-1}$ , the tension C-H at  $2871\text{ cm}^{-1}$  and C-H of the methyl groups  $1454\text{ cm}^{-1}$ . As confirmed by the study of cellulose carried out by Contreras et al. (2010) locating the bands in the spectrum in a way minute C-H<sub>2</sub> ( $2918, 2851, 1471$  and  $1375\text{ cm}^{-1}$ ), C-H ( $1360$  AND  $1280\text{ cm}^{-1}$ ), C-O ( $1054$  and  $1030\text{ cm}^{-1}$ ), C-O-C ( $1160\text{ cm}^{-1}$ ).

Fig 13. Cellulose FTIR

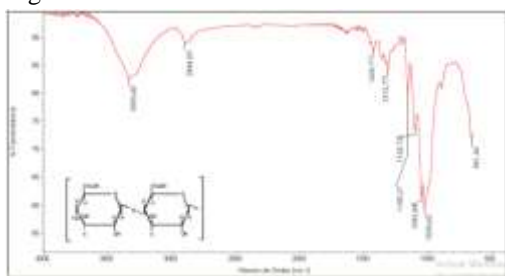


Fig 14. FTIR maize cob pulp

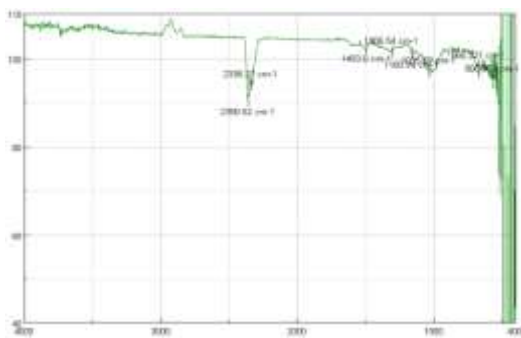


Chart 15 and Figure 14 show the IR of the cellulosic pulp obtained after treating the corn cob with caustic soda at temperature, the peaks present in the bands 2338.27; 2358.58; 1493.6 and 1306.54  $\text{cm}^{-1}$  refer to the crystalline bands of the CH and C-H<sub>2</sub> bonds according to the bibliographic comparison. The vibration of the C-O-C bond can be clearly observed at the frequency 1160.54  $\text{cm}^{-1}$  and for the C-O bond only 1035.59  $\text{cm}^{-1}$ .

Chart 15. Wavenumber vs. %T

Wavenumber [cm-1]	%T
2358.52	90.3417
2338.27	93.7937
1493.6	102.297
1306.54	101.379
1160.94	100.85
1035.59	96.8111
665.321	98.0921
566.969	95.0783

### 3.4 Kappa number in corn cob pulp

Chart 16. Results of the Number of Kappa the corn cob pulp.

Muestra	Número de Kappa
k1	24,16
k2	23,12
k3	34,55
m1	27,31
m2	29,15
m3	22,15
p1	31,12
p2	32,88
p3	38,08

The value of the kappa number of a pulp intended for papermaking, the higher be indicates that the separation process of the cellulose from the lignin was deficient and vice versa. It is stated by Espinoza & León (2017). Hernandez (2008) also mentions that the number of kappa between 30-35 is acceptable for pulps intended for the bleaching process getting pretty good effects. The results presented in Chart 16 of this project give a kappa number greater than 30 for the 40% NaOH treatment (p1, p2, p3) in comparison to the rest of the results, because the increase in caustic soda allows obtaining a more effective

delignification. And at the time of submitting the pulp (p1, p2, p3) of cob to the process bleaching with sodium hypochlorite, a characteristic white color of paper was obtained desktop, unlike the rest of the sheets of paper that presented an opaque appearance

### 3.5 Lignin in corn cob pulp

According to the results obtained in the elaboration of paper from the peanut shell Espinoza & León (2017), it is observed that the percentage of lignin present in the pulp decreases with increasing concentration of Caustic Soda, because this base will separate the lignin from cellulose. In Chart 17 we observe that the last 3 treatments (p1, p2, p3) have a lower lignin content in the pulp, this results in a better result in bleaching, the opposite happens with pulps with a high percentage of lignin that are difficult to bleach, as established by Bajpai (2015). The percentage of alpha cellulose increases proportionally when the attack of caustic soda on lignin increases, obtaining an increasingly pure cellulose free of other components that can affect the appearance of the sheet of paper.

Chart 17. Results of the percentage of lignin and alpha cellulose present in the pulp.

<i>Muestra</i>	<i>% lignina</i>	<i>% Alfacelulosa</i>
<i>k1</i>	4,55	74,92
<i>k2</i>	4,05	76,06
<i>k3</i>	3,78	77,85
<i>m1</i>	4,09	86,25
<i>m2</i>	3,54	88,30
<i>m3</i>	3,11	89,28
<i>p1</i>	2,57	91,52
<i>p2</i>	1,83	93,06
<i>p3</i>	1,60	94,85

### 3.6 Residual soda in the Black Liquor

The black liquor is the waste generated in the corn cob pulping process, when analyzing its composition, we find that Chart 18 details the amount of sodium hydroxide that does not was consumed in the process. We can see that NaOH is consumed as a function of time, that is, that the longer the time, the greater the consumption of this base and vice versa. The pulping of the treatment k3, m3, p3 have a small amount of unconsumed hydroxide in relation to the rest of the treatments developed in 60 and 120 minutes. This feature is ideal because it can improve the dosage of NaOH to a smaller amount saving capital to the paper activity.

Chart 18. Results of residual soda present in black liquor

<i>Muestra</i>	<i>pH</i>	<i>Concentración soda residual (gNaOH/Lico negro)</i>	<i>Hidróxido no consumido (g)</i>
<i>k1</i>	12,27	6,28	3,14
<i>k2</i>	12,81	0,71	0,258
<i>k3</i>	12,90	2,22	0,59
<i>m1</i>	12,96	5,448	1,70
<i>m2</i>	13,33	13,264	4,80
<i>m3</i>	13,36	6,52	1,53
<i>p1</i>	13,53	18,41	9,2
<i>p2</i>	13,42	5,68	2,07
<i>p3</i>	13,23	5,01	1,34

### 3.7 Performance of the pulp

Chart 19. Performance Results of the pulping process

Muestra	% Rendimiento
k1	61,16
k2	53,89
k3	50,94
m1	56,21
m2	48,74
m3	48,73
p1	51,26
p2	44,73
p3	41,68

The concentration of sodium hydroxide and the maceration time of the pulp after cooking directly influence the yield of the pulp. According to Jeetha (2015), if the maceration time is excessive, the yield of the pulp decreases. Just as NaOH breaks the hydrogen bonds that hold the molecules together, its excessive contact with organic matter can degrade cellulose according to Huerta (2012). The results presented in Chart 19 allow us to deduce that the pulping yield is high when the concentration of NaOH is low, the opposite happens when the concentration of this compound increases. However, the yield can be increased by a small percentage by making a better filtering of the pulp, because losses were evidenced at the time of carrying out this process.

### Whiteness of the paper sheet

Chart 19. Whiteness results of paper sheets

Muestra	X <sub>L</sub>	Y <sub>L</sub>	Z <sub>L</sub>	ΔE	Longitud de onda (nm)	Reflectancia (%)
Estándar	80,13	83,64	100,82	-	400	33,20
k1	-	-	-	-	-	-
k2	-	-	-	-	-	-
k3	75,60	79,87	74,24	13,91	400	61,17
m1	70,41	74,31	69,9	15,74	400	50,18
m2	75,74	80,19	74,48	15,86	400	55,19
m3	67,53	71,60	67,47	16,26	400	49,91
p1	80,79	85,38	85,32	15,38	400	51,87
p2	78,98	83,40	81,63	13,61	400	61,64
p3	80,13	84,87	82,48	15,51	400	61,63

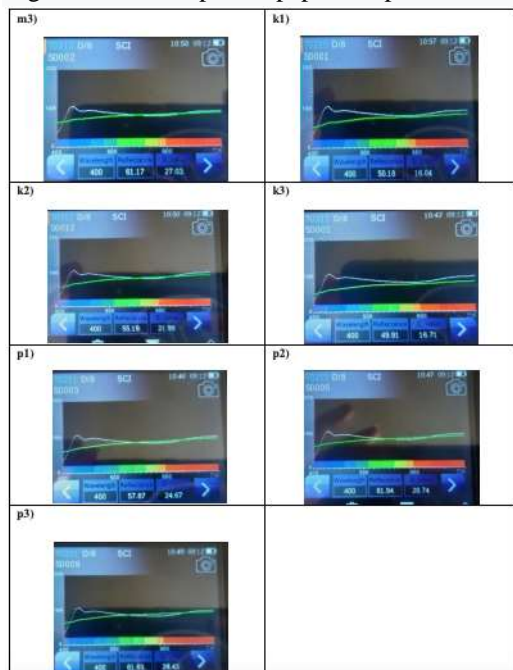
The brown pulp bleaching process requires different bleaching agents at specific concentrations, temperatures and times, on the contrary, there is a loss of pulp yield due to the destruction of the fiber (Bajpai, 2015, p. 23). For this reason, bleaching was carried out with a hypochlorite solution of sodium in a 2:1 ratio, at a temperature of 45 °C for 0.75 h, if these parameters reached Exceeding the pulp lost the adhesion capacity at the time of forming the paper sheets.

Fig 15. CIE XYZ graph of the bond paper standard



The analysis of the whiteness index of the paper obtained in this research was carried out with the reading of the spectrophotometer that prints primary valences corresponding to the wavelengths of the colors of some basic colors of a color system. The standard of comparison was a sheet of bond paper whose tristimulus values were  $X=80.13$ ;  $Y=83.64$ ;  $Z=100.82$  than at locating in the three-dimensional plane CIE-1931 confirms that it is white. Figure 16 obtained in the spectrophotometer presents us with the curve wavelength vs. sheet reflectance of bond paper corresponding to the color white, with a wavelength of 400 nm and a reflectance of 33.20 that will be the standard to compare the paper samples obtained in the present investigation.

Fig 16. CIE XYZ plot of paper samples



The m3 sample has a  $\Delta E$  (Reflectance Variation) of 13.91 which is quite a difference small so that the generated curve resembles that of its congruent standard at several points, cataloging the color of the leaf as moderate. The samples of treatment k1, k2 and k3 by means of the optical characterization they presented an opaquer color with a tendency to lead, thus confirmed in Figure 6-4 k1), k2), k3) whose curves are not congruent with the standard sample but they distance themselves from each other.

While the most acceptable results are the treatment samples p1, p2 and p3 whose  $\Delta E$ s are lower in relation to treatment k (30% NaOH), this type of paper has the characteristic color of a sheet of bond paper. We corroborate it by analyzing the graphs that congruent at various points on the curve. We contribute that this characteristic white color of the paper is consequence of the kappa number of the analyzed pulp (table 5-4)

whose parameter predicted that would be suitable for effective bleaching. Using the CIE XYZ 1931 method, the ordered pair is placed on the chromaticity diagram (x,y) calculated with the values of table 9-4 and confirm the white color of the obtained paper on the research. This was done for sample p2 with characteristics similar to the standard.

## 4. CONCLUSIONS

- Cellulose was extracted from corn cob by alkaline treatment in NaOH at 95°C separating the lignin and other components with a yield of 44.73%, thus leaving a cellulosic pulp intended to form sheets of paper.

- At the laboratory level, sheets of white paper were made, characteristic of the bond confirmed by the tests of the NTE INEN 1423:2013 Standard.

- Through experimentation, the process variables were obtained to manufacture paper from the cellulose from the corn cob, the first corresponds to a particle diameter of 360 um in the grinding and screening process, followed by a 3:10 ratio for the amount of soda caustic in relation to the raw material. Also that the best pulping was achieved using 2.75 liters of water, in 3 hours, at a constant temperature of 95° C and a time of 24-hour maceration. Finally, the bleaching process was carried out at 0.75 hours, a temperature of 50° C with a 2:1 ratio of sodium hypochlorite in relation to water, if this proportion is higher, the pulp loses its adhesion properties, making it difficult to formation of the sheets of paper.

- The design of the process to obtain paper from the cellulose extracted from the corn cob will require of the following equipment: a 2HP power grinder, a drying oven that operates 95 °C for 12 hours, a mill with a power of 3 HP, a cooking vessel of 0.288 m3, a bleaching tank of 0.0474 m3 and a stirring tank of 2 HP and 135 rpm; using AISI 304 and ASTM A240 stainless steel resistant to corrosion and useful life time dragged on.

- The process was validated by characterizing the sheets of paper using the standards NTE INEN 536:2013 Paper weight, NTE INEN 1974:2013 Tear resistance, NTE INEN 1399:2013 Paper caliber, NTE INEN 1423:2013 Paper whiteness, TAPPI T 236 om-99 Kappa number, obtaining the following values: grammage (1.15 g/m2), index of tear strength (189 kgf), gauge (0.182 mm), number of stitches (105) and color white of the sheet (by spectrophotometric graph).

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