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Extraction and Formulation of a Paper from the Cellulose Extracted from the Water Hyacinth in the Wouri Lake-Douala (Eichhornia *crassipes*)

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Abstract:- The present work aims to optimize the formulation of a paper from the cellulose extracted from water hyacinth. The major concern was to define the best proportions of the constituents used in the formulation of the paper in order to obtain a precise paper. To this end, 13 paper samples were made from cellulose, starch, Tio2 and kaolin. The objectives are to define the parameters influencing the quality of the paper, to formulate tests to understand the role played by each of these parameters, to develop an optimal mathematical model by using the mixing plan method. Because it offers the advantage of considerably reducing the number of experiments. We have defined an experimentation matrix taking into account all the factors necessary for the formulation of our paper. The main response functions being: the moisture content or water content and the mass. We obtained quadratic models of each answer and checked the validity of these by a global, mathematical and statistical analysis of the models. It emerges from these analyzes that each model has a significant adjusted R^2 and R^2, i.e. R^2=87.27% and adjusted R^2 =62.26% for the mass and R^2=86.53% and adjusted R^2 = 73.07% for the water content. These different values of R^2 and adjusted R^2 show that the descriptive quality of the model is acceptable. This study is intended to provide background information for engineers striving to make their paper products more competitive and for researchers seeking to achieve results beyond the current state of the art.

Keywords: *cellulose, formulation, kaolin, mixtures, extraction, water hyacinth*

I. INTRODUCTION

The water hyacinth is in some regions of a very remarkable abundance especially in the LITTORAL region of CAMEROON. Water hyacinth (Eichhornia crassipes) is an invasive aquatic plant native to the Amazon, and spread by humans through horticulture in tropical and subtropical regions (Holm L G et al, 1977) (Gopal, B., 1987). These plants have interesting mechanical properties that make them interesting for many applications. In Cameroon, waterways are invaded by water hyacinth, which is increasing exponentially. It is a major obstacle for fishing, electricity production, irrigation and the conservation of biological diversity because it causes the disappearance of many flora and fauna species. Despite the mechanical and chemical control integrated in 2016 by the Ministry in charge of the environment in Cameroon to eradicate water hyacinth, the latter is only proliferating.(joseph antoine njanda tchouyou, 2017)Water hyacinth for parchment paper (Erlinda, L. Mari ., (2012)).Paper from the Latin papyrus is a material made from plant cellulosic fibers. Each type of paper is characterized by its mass, its grammage, its water content, its manufacture, and its finish that determine its transparency, its visual and tactile aspect, etc.(Sarah, 02-Aout-2019)**.**The degree of depolymerization (DP) of cellulose varies depending on the origin of the fibers. Thus, molecular mass measurements have shown that native cotton cellulose has DPs of around 15,000 glucose units, while that present in wood has lower DPs, around 10,000 (Sjöström J:, 1990). This degree of polymerization directly influences the mechanical characteristics of the pastes produced: a DP of less than 500-600 leads to significant degradation of the latter. They are mainly used in printing-writing papers (newspapers, magazines, etc.), improving their opacity, surface finish and whiteness in some cases. On the other hand, they negatively affect the mechanical properties of the papers. The fillers can be added in the mass of the paper, or on the surface during the coating step. Mineral fillers, in particular calcium carbonate ($CaCO_3$), being less expensive than cellulosic fiber, are also added for economic reasons. The rate of fillers can range from 5 to

35% compared to the fibers. The most used are kaolin, talc, calcium carbonate, titanium dioxide. The fillers are not always very well retained in the sheet during its formation on the machine and leave with the water during the draining stages. Retention products are then added to promote their retention (CAEL Cédric, 2012).Mineral fillers rank first among papermaking additives in terms of amounts used. Many paper and board grades contain little or no filler, while printing papers typically contain up to 25% filler, by mass (M A Hubbe , 2004). The pulp yields from the fiber bundles were within commercially acceptable ranges, but on a whole water hyacinth plant basis, they were extremely low. The freeness values (drainage rate) of all the water hyacinth pulps were so low that it is possible to consider these pulps as having any commercial value for the paper industry.(W.J Nolan and D.W Kirmse). There is a high ash content. E. crassipes is widely distributed in the sites of the city of Douala and shows significant carbohydrate contents(Tchiaze et Priso. J. Appl. Biosci, 2016).The chemical compositions of each part were also measured and showed approximately 29% hot water extract in leaf and air bladder, 42% holocellulose in leaf, 47% holocellulose in air bladder. Application of water hyacinth biomass without root parts to papermaking provided bulkier structure, but decreased tensile strength(Dongsung Kim, Yunseong Huh et al, 2014).Faced with this problem, some researchers propose the recycling of used paper; however, paper cannot be recycled indefinitely because the quality of the wood fiber decreases with each treatment, hence the need to search for new raw materials (Gomes, ,2009).In addition, fiber processing would significantly reduce the unemployment rate in Cameroon. (KotPlanet., 04-Août-2019).However, the development of paper pulp by the empirical method resulted in a crumbled pulp after five months, this because of the non-control of certain parameters such as the temperature and the proportions of each constituent. (Maurice N.K et al, 2012)Furthermore, similar work carried out on sugar cane bagasse (JAPAN WASTE PAPER ASSOCIATION L.T.D, 1962)led to the production of papers, one of which was rigid and the other flexible. To overcome this problem of formulation we considered through this work, to propose the formulation of a paper from water hyacinth by using the methodology of mixing plans. If the general objective of this work is to extract the formulation of a paper from the cellulose extracted from water hyacinth, the specific objectives are threefold. This involves (i) evaluating the effects of the various constituents on the quality of the paper (ii) formulating tests to understand the role played by each of these parameters (iii) developing an optimal mathematical model. The papers were carried out at the Laboratory of Materials Science of National Advanced school of Engineering of the University of Yaoundé I. Faced with the various obstacles encountered on the way to the formulation of a paper; the mixing plans, which aim to minimize the tests and facilitate the interpretation of the results, were used. We thus worked on thirteen samples with different proportions of the constituents in order to extract and formulate the paper based on the cellulose of the water hyacinth.

II. MATERIALS AND EXPERIMENTAL METHODS

A. *Working Materials*

The Eichhornia crassipes is considered the tallest grass in theworld(Wouri River, April 18th, 2012), it contains a large quantity of cellulose fiber, which is why we are interested in the water hyacinth collected in the Littoral region as part of our work.

(a) (b) (c)

Fig. 1: (a) Numerical balance (b) Water hyacinth (c) Sodium Hydroxide

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Table 1 below lists the materials and reagents that were used in our various experiments.

Glassware	Reagents	Non-consumable materials
Analytical balance	Caustic soda	Magnetic agitator
Test tube	Starch	Scissors
Carrycot	Kaolin	Mussel
pH paper	Titanium dioxide	Machete
Spatula	Distilled water	Buckets
Glass box	Hydrogen peroxide	Electric mixer
Beakers	Reagents	Gloves

Table 1: Materials and reagents

B. Experimental method

Our work is focused on the extraction of the formulation of a water hyacinth-based paper, several previous works having been carried out on the extraction of cellulose.

A mass of 2500 g of water hyacinth previously cut into small pieces was soaked for 48 hours in soda obtained by dissolving 8750 g of sodium hydroxide in 25 L of distilled water; this knowing that it takes 350g of soda, for 100g of water hyacinth and 1L of distilled water(ELOUNDOU J P, Ntede N H, et al, July 2004)The cellulose obtained was washed several times with distilled water until a pH equal to 7 was obtained, then bleached in 4L of hydrogen peroxide for 30 min. then it was dried at room temperature for 2 to 3 days.

(A) (B) (C)

(D) (E) (F) (g)

Fig. 2: some pictures of the WH fiber extraction process: (a) WH plant, (b) WH stems harvested, (c) WH boiling, (d) Pouring of WH, (e) Stretching and grinding of WH, (f) WH Brown cellulose extracted, (g) Whitening of the cellulose.

C. Formulation of parameters for paper optimization

The appearance of paper is the result of a judicious and optimal mixture of the main materials that compose it (cellulose, starch, titanium dioxide and kaolin). The purpose of this optimization is to determine the areas of variation of the proportions of the main components to obtain a paper with the different constituents knowing that these proportions vary from 65-95% for cellulose and 5-35% for fillers, pigments, glues and other additives**.**(Maurice N.K et al, 2012).For the construction of the experimental design, we used an indirect method of optimization proposed by(MCLEAN and ANDERSON, 1966)bearing the generic name of extreme summits(Jacques, G., 2001).

This plan consists in the manufacture of paper with additives to obtain the cellulose of the water hyacinth for a good optimization, the empirical expensive part of the blind tests by a scientific methodology defining precise tests to be carried out for the construction of mathematical models. These models will have to be not only descriptive, but also and above all as predictive as possible, in order to be able to announce with a good degree of belief mixing results not yet tested.

For our formulation, we will need:

- Cellulose: responsible for the fibrous mat and the strength of the paper.
- Starch: link between cellulose and fillers.
- Titanium dioxide: pigment in the paper industry to brighten sheets and improve printing.
- Kaolin: filler in the mass of the paper and as a surface coating. It reduces the amount of paper pulp, which is quite expensive, and improves the optical properties.

The factors of the study which are the elements entering the system are represented by their mass fraction. These factors are subject to individual and relational constraints implicit below:

Constituent proportion i : $\mathbf{0 \leq xi \leq 1}$

Sum of proportions: $\sum_{i=1}^{q} \mathbf{xi} = \mathbf{C^{te}}$

In the context of a mixture, the constant Cte **= 1**;which generates an experimental domain in the form of a simplex.After having determined the number of tests, our formulation is a simple process, which consists of mixing the different constituents in a 1L container following the procedure described below.

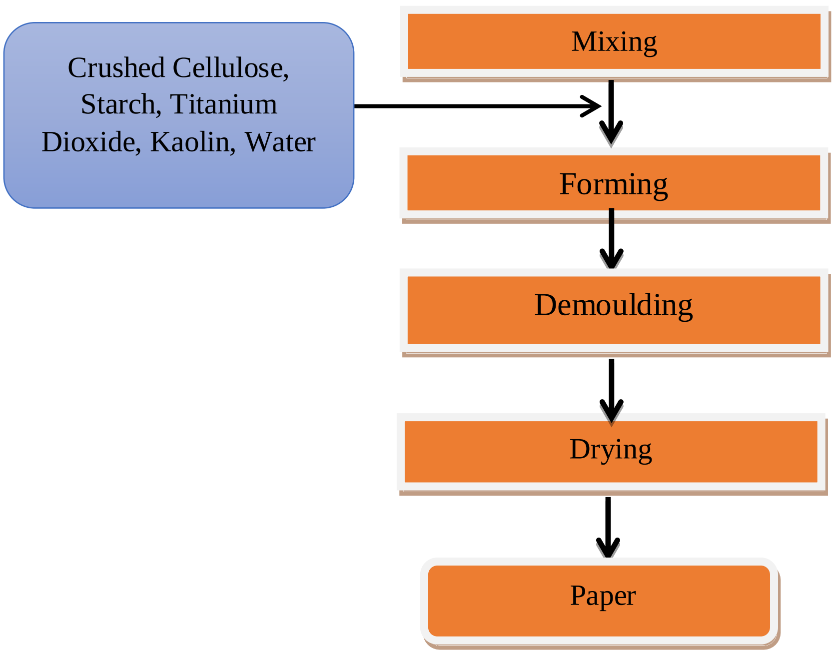

Fig. 3: Synoptic diagram of papermaking

D. Moisture content

The papers obtained were dried in an oven at 110°C for 5 hours to determine their moisture content, its value is given by the following formula:

$$W = \frac{\text{mh} - \text{ms}}{\text{mh}} \times 100$$

M_s=mass of the dry paper
M_h=mass of moist paper
W= expression of water content in %

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E. Mass

The papers obtained were weighed on a digital scale at 10 power minus 4 precision.

Fig. 4

F. Development of models

The differentiation between the different papers will be made at the level of the mass of the paper and the water content. To appreciate the descriptive quality of the different models obtained, we will build graphs called adequacy graph, which are a representation of the responses calculated according to the responses measured.

- Sum of total squares (STS)
  $STS = \sum_i^N (MR_i - MR)^2$
- Sum of squares of the model (SSM)
  $SSM = \sum_i^N (MRi - MR)^2$
- Sum of squares of residuals (SSR)
  $SSR = \sum_i^N (MRi - MR)^2$
  With MR_i:the measured response for a test i
  MR : the mean of the responses measured

- Calculations of the coefficients of determination of R^2 et R^2 adjusted

$$R^2 = \frac{SCM}{SCT} = 1 - \frac{SCE}{SCT}$$

$$R^2 \text{ ajusté} = 1 - \frac{\frac{SCE}{N-1}}{\frac{SCT}{N-1}}$$

With N:the number of tries To calculate the prediction coefficients, we will transform the description discrepancies into prediction discrepancies using the applicationMinitab 18.

- Calculation of prediction coefficients
  The relation gives these coefficients:

$$e_{(i)} = \left(\frac{1}{1-hii}\right) e_i$$

With h_{ii}=leviers

- Calculation of the sum of squares of prediction errors (PRESS)
  $PRESS = \sum_{i=1}^N e^2_{(i)}$

- Calculation of the prediction coefficient Q^2
  $Q^2 = \mathbf{1} - \frac{PRESS}{SCT}$

III. RESULTS AND DISCUSSION

In order to evaluate the concentration of the different constituents on the quality of the paper, an experimentation matrix was built and allowed us to define the key tests to be carried out on 13 samples. We will thus carry out in this part a global, mathematical and statistical analysis of the different responses (grammage and water content or humidity rate).

For each sample of paper, we determined its mass and its water content. The results are recorded in Table2.

	Cellulose	Starch	TiO_2	Kaolin	Mass (g)	Water content (%)
1	0,685	0,18	0,0750	0,06	1,346	08,61
2	0,720	0,1250	0,04	0,115	1,404	11,68
3	0,705	0,1250	0,04	0,13	1,440	09,02
4	0,720	0,1450	0,0750	0,060	1,251	08,87
5	0,670	0,1250	0,0750	0,13	1,381	07,31
6	0,670	0,18	0,04	0,11	1,344	07,73
7	0,720	0,18	0,04	0,06	1,548	11,49
8	0,67	0,16	0,04	0,13	1,380	07,24
9	0,72	0,1250	0,0750	0,080	1,393	10,98
10	0,67	0,18	0,0750	0,075	1,300	07,69
11	0,695	0,1525	0,0575	0,095	1,250	09,53
12	0,695	0,1525	0,0575	0,095	1,308	10,51
13	0,695	0,1525	0,0575	0,095	1,280	08,45

Table 2: Tests retained and results measured

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Once the measurements have been taken, the responses will be interpreted one (mass) after the other (water content); this following a three-step approach, namely: analyzing the results assuming that the restricted quadratic model may be suitable; establish with the first ten tests, ten equations which will make it possible to estimate a first model, and finally to check the similarity of the responses measured and calculated at the control points.

The first model being validated, we incorporated the control points in the calculation of the coefficients. The second model comprising ten coefficients established with thirteen equations leaves three degrees of freedom to evaluate the residual that will be assimilated to the experimental error. Using the detailed analysis of the sum of squares, we evaluated the contribution of each coefficient to the explanation of the model by keeping only the coefficients, which bring a strong sum of squares.

A. Mathematical Analysis.

a) Modeling on ten tests

a. The mass

We used the trials numbered from 1 to 10 to calculate the coefficients using the MINITAB 18 software, the terms starch-kaolin, TiO2-Kaolin not having been estimated by the model. The coefficients obtained are recorded in the following table:

Cellulose	β_1	*-6,99*
Starch	β_2	*-74,9*
TiO2	β_3	*34,6*
Kaolin	β_4	*-32,5*
Cellulose-Starch	β_{12}	*139,9*
Cellulose-TiO2	β_{13}	*-20,2*
Cellulose-Kaolin	β_{14}	*75,9*
Starch-Kaolin	β_{24}	*-25,2*

Table 3: The coefficients of the model

Hence the model:

$$Y_{mass} = -6{,}99x_1-74{,}9x_2+34{,}6x_3-32{,}5x_4+139{,}9x_1x_2-20{,}2x_1x_3+75{,}9x_1x_4-25{,}2x_2x_4$$

This model predicts a mass of 1.283g, while the measurements gave an average value of 1.279g; i.e. 0.0036 mass point less. This value is sufficiently close to the mean value of the measured responses for the model to be considered valid.

In the histogram below, we realize that the highest mass is between 1.375g and 1.425g with a count of 4.

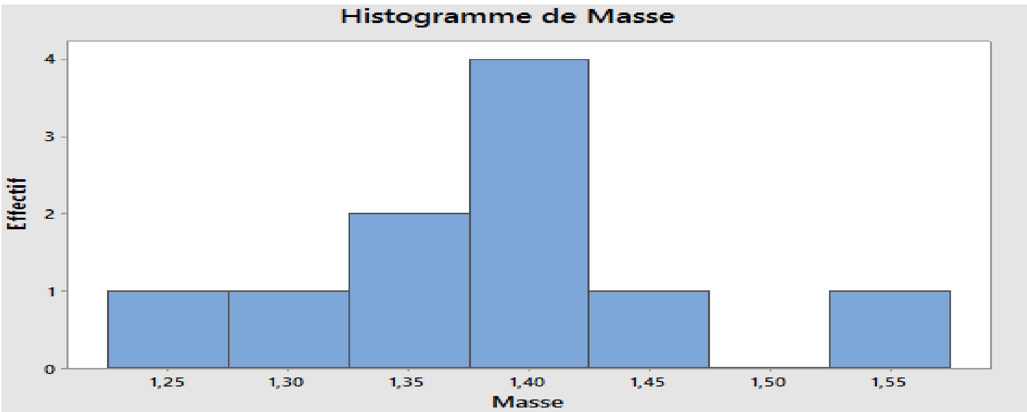


Fig. 3: Mass histogram

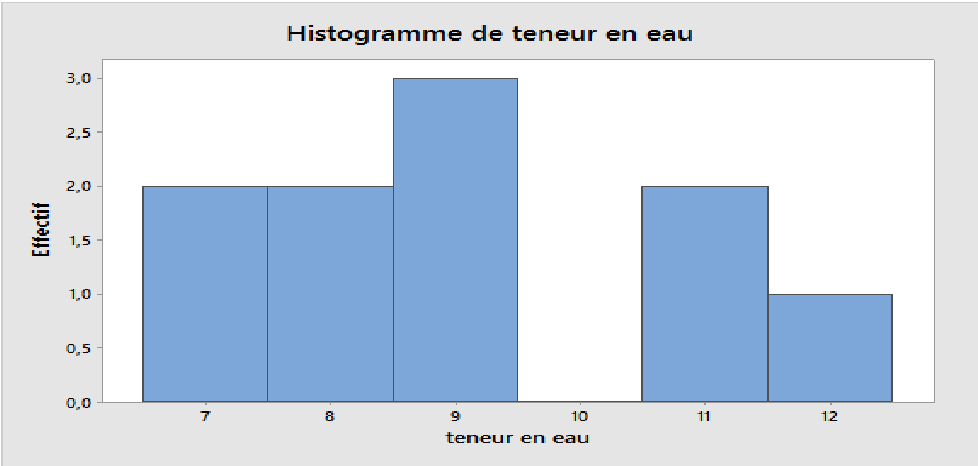
b. Results of the moisture content.

The calculations are carried out in the same way as for the mass and we find:

$$Y_{taux\ d'humidité} = 25x_1+639x_2+1167x_3-1018x_4-829x_1x_2-1263x_1x_3+1310x_1x_4-2759x_2x_3$$

The water content predicted by the model is 9.60%; the average measured value is 9.49%, there is a difference of 0.11% less. This discrepancy comes from the residual errors observed in tests 6 and 12. We used the established models to assess the influence of composition variations around the control point.

In the histogram below, we realize that the highest water content is between 8.5 and 9.5 for a count of 3.



Fig, 4: Histogram of the water content

b) Modeling on thirteen trials

Although the mass model is the only one validated, we resume the calculation of the coefficients on the 13 tests; this offers degrees of freedom to estimate the experimental error evaluated with the residual.

a. The mass

The calculation of the coefficients leads to the model:

$$\mathbf{Y}_{mass} = -8{,}48\mathbf{x}_1-42{,}1\mathbf{x}_2+21{,}1\mathbf{x}_3\ -62{,}2\mathbf{x}_4+103\mathbf{x}_1\mathbf{x}_2+23{,}2\mathbf{x}_3+123x_1\mathbf{x}_4-134{,}2\mathbf{x}_2\mathbf{x}_3-26{,}3\mathbf{x}_2\mathbf{x}_4$$

With the results of the tests and the taking into account of this model, one can build the table of the analysis of the sum of the squares, which makes it possible to appreciate the explanatory power of the model. Table III.3 shows that the model perfectly explains the experimental results.

Source of variation	ddl	Adjusted sum of squares	Mean Square	F	Probability
Model	8	0,053344	0,006668	2,84	0,164
Residue	4	0,009387	0,002347	/	/
Total	12	0,062731	/	/	/

Table 4: Sum of squares analysis (mass)

b. Water content

The calculation of the coefficients leads to the model:

$$\mathbf{W}_{ater\ content} = -13{,}7\mathbf{x}_1+11{,}3\mathbf{x}_2+108\mathbf{x}_3\ -931\mathbf{x}_4+1337\mathbf{x}_1\mathbf{x}_4\ -1015\mathbf{x}_2\mathbf{x}_3+855\mathbf{x}_3\mathbf{x}_4$$

Table III.4 allows us to appreciate the explanatory power of the model.

Source of variation	ddl	Adjusted sum of squares	Mean square	F	Probability
Model	8	0,053344	0,006668	2,84	0,164
Residue	4	0,009387	0,002347	/	/
Total	12	0,062731	/	/	/

Table 5: Sum of squares analysis (Water content)

B. Simplification of the model

a) The mass of the model simplifies

The new mass coefficients are summarized in the following table:

Cellulose	β_1	-8,61
Starch	β_2	-55,2
TiO2	β_3	39,1
Kaolin	β_4	-66,9
Cellulose-Starch	β_{12}	120,3
Cellulose-Kaolin	β_{13}	127,1
Starch-TiO2	β_{23}	-130
TiO2-Kaolin	β_{34}	-9,2

Table 6: The new model coefficients

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Sources	sum of squares
Regression	0,008120
Linear	0,009774
Quadratic	0,007696
Cellulose – Starch	0,005616
Cellulose-TiO2	0,000098
Starch -TiO2	0,00018

The sum of squares of the regression model of the Starch-TiO2 interaction, thus Cellulose-TiO2 having a high probability of being zero, are of little importance and can be minimized (eliminated). The new full calculated model is as follows:

$$\mathbf{Y}_{mass} = -8{,}61\mathbf{x_1} - 55{,}2\mathbf{x_2} + 39{,}1\mathbf{x_3} - 66{,}91\mathbf{x_4} + 120{,}3\mathbf{x_1x_2} + 127{,}1\mathbf{x_1x_4} - 130\mathbf{x_2x_3} - 9{,}2\mathbf{x_3x_4}$$

The sum of squares analysis is presented in Table 7; we note the strong explanatory value of the simplified model. The residual is now established with 05 degrees of freedom.

Source of variation	ddl	Adjusted sum of squares	Mean Square	F	Probalility
Model	7	0,052865	0,007552	3,83	0,079
Residue	5	0,009866	0,001973	/	/
Total	12	0,062731	/	/	/

Table 7: Analysis of the sum of squares of the mass model

b) Simplified Model Humidity Level

The new water content coefficients are summarized in Table 8 below:

Cellulose	β_1	-13,7
Starch	β_2	-11,3
TiO2	β_3	108
Kaolin	β_4	-931
Cellulose-Kaolin	β_{14}	1337
Starch-TiO2	β_{23}	-1015
TiO2-Kaolin	β_{34}	855

Table 8: The new model coefficients

Sources	sum of squares
Regression	2,9338
Linear	1,2949
Quadratic	1,0197
Cellulose – Starch	0,1975
Cellulose-TiO2	0,3832
Cellulose – Kaolin	0,3384
Starch -TiO2	2,1174

The sum of squares of the regression model of the Cellulose-Kaolin interaction, as well as the Cellulose-TiO2 interaction having a high probability of being zero, are of little importance and can be eliminated. The new full calculated model is as follows:

$$\mathbf{Y}_{water\ content} = -13{,}7\mathbf{x_1} + 11{,}3\mathbf{x_2} + 108\mathbf{x_3} - 931\mathbf{x_4} + 1337\mathbf{x_1x_4} - 1015\mathbf{x_2x_3} + 855\mathbf{x_3x_4}$$

The analysis of the sum of the squares is presented in Table 6. Note the strong explanatory value of the simplified model. The residue is now established with 06 degrees of freedom.

Source of variation	ddl	Somme des carrées ajustés	Carré moyen	F	Probalilité
Model	6	25,3335	4,2223	6,43	0,20
Residue	6	1,8191	0,4548	/	/
Total	12	27,1526	/	/	/

Table 9: Analysis of the sum of squares of the water content model

C. *Statistical analysis*

a) The mass

The model that we retain and that we will use is as follows:

$$Y_{mass} = -8{,}61x_1 - 55{,}2x_2 + 39{,}1x_3 - 66{,}9x_4 + 120{,}3x_1x_2 + 127{,}1x_1x_4 - 130x_2x_3 - 9{,}2x_3x_4$$

The main characteristics of this model are:

- The R^2
  $R^2 = 84{,}27\%$
- The R^2 adjusted
  R^2 adjusted = 62,26%
- Thee F
  F = 3,83

- **The Diagram of Residues**

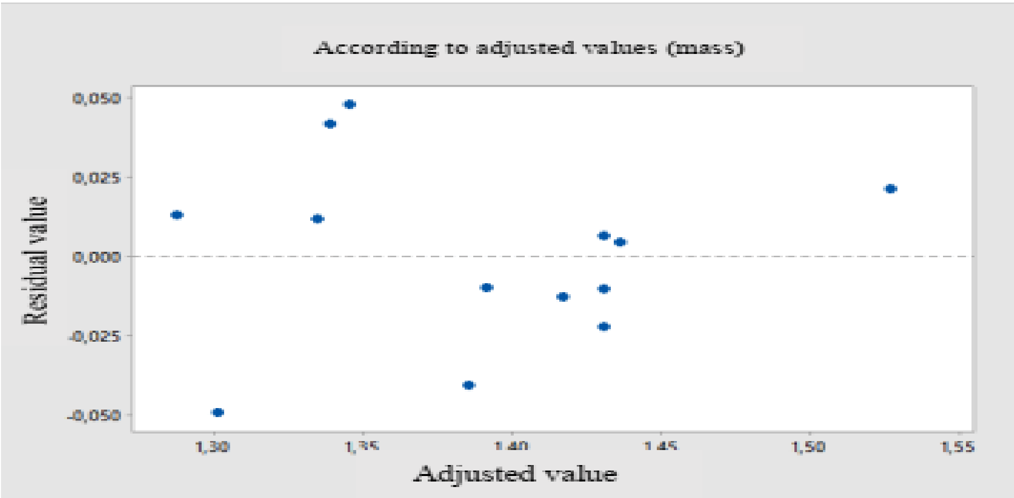

Fig. 5: Mass Residue Diagram

Normalized residuals > -0.050 and < 0.050 are generally considered significant. Based on Figure 5, we notice that the residuals show random arrangements of the residuals, so there is no information left to extract.

This model has good statistical characteristics and the residuals do not reveal anything abnormal. To account for the influence of each constituent on the mass, we will analyze the Cox plot of the mass (**Figure 6**).

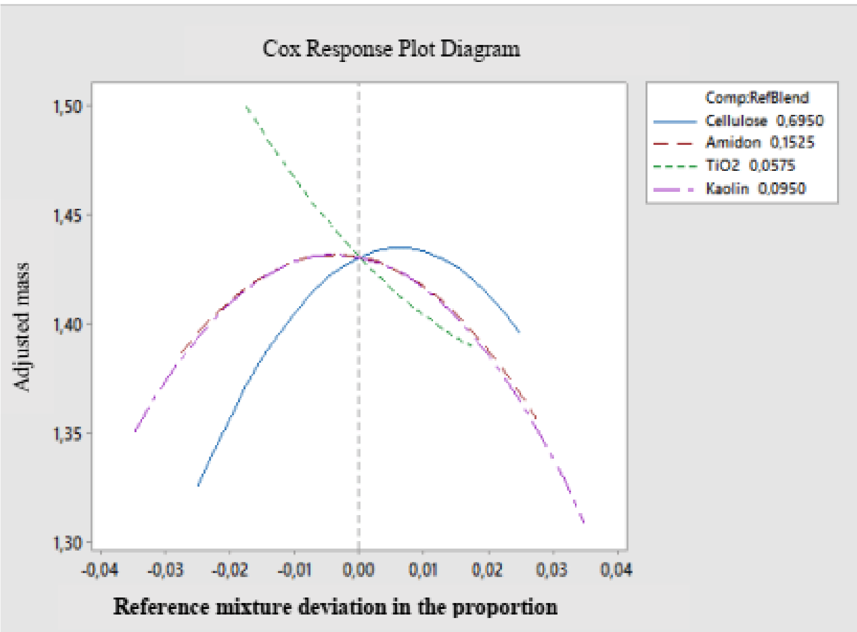

Fig. 6: Plot of the Cox mass

The evolution of the response is determined from the paper occupying the center of the field of study whose composition is as follows:

X_1= 0,695 ; X_2=0,1525 ; X_3= 0,0575; X_4= 0,095

Compared to the test at the center, we note that:

- The increase in TiO2 causes the mass to drop;
- By decreasing or increasing kaolin and starch, the mass drops. Their reference value is then at the center;
- By increasing the cellulose, the mass drops.

We find in our study that the increase in kaolin causes the mass of the paper to drop. Indeed, this can be explained by the fact that the papermaking kaolin used in our formulation did not meet certain specific requirements, namely:

- Chemical and mineralogical analysis to select appropriate bleaching methods ;
- Separation in a horizontal centrifuge after addition of a dispersant such as sodium silicate to extract the coating kaolin then thickened in high acceleration centrifuges before being filtered and dried.

The model that we retain and that we will use is as follows:

$\mathbf{Y}_{\text{teneur en eau}} = -13{,}7\mathbf{x_1}+11{,}3\mathbf{x_2}+108\mathbf{x_3}-931\mathbf{x_4}+1337\mathbf{x_1x_4}-1015\mathbf{x_2x_3}+855\mathbf{x_3x_4}$

Its main characteristics are:

- The R^2
  R^2 = 86,53%
- The R^2 adjusted
  R^2 adjusted =73,07%
- The F
  F=6,4

b) The water content

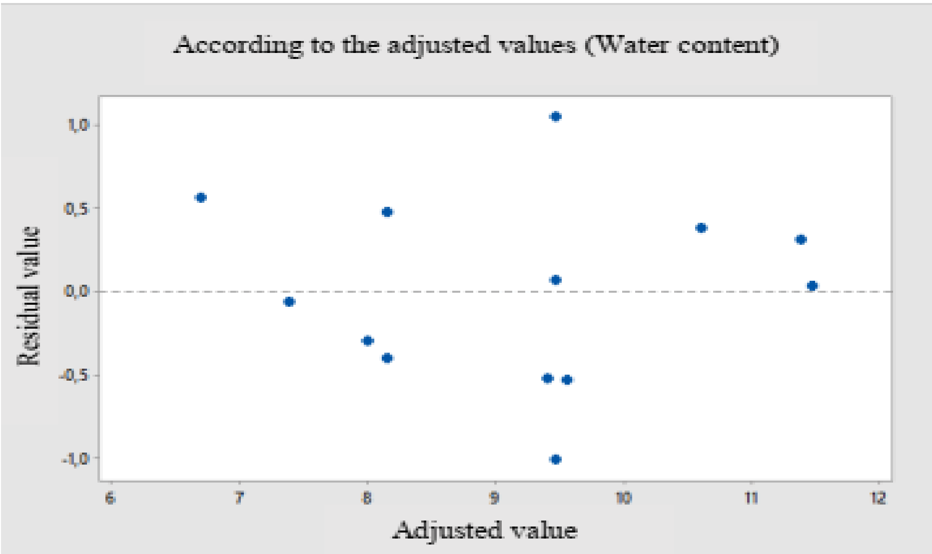

Fig. 7: Residual moisture content diagram

Normalized residuals > -1 and < 1 are generally considered significant. Based on Figure 5, it can be seen that the residuals approach zero. This model has good statistical characteristics and the residuals do not reveal anything abnormal. To account for the influence of each constituent on the mass, we will analyze the cox plot of the water content (Figure 8).

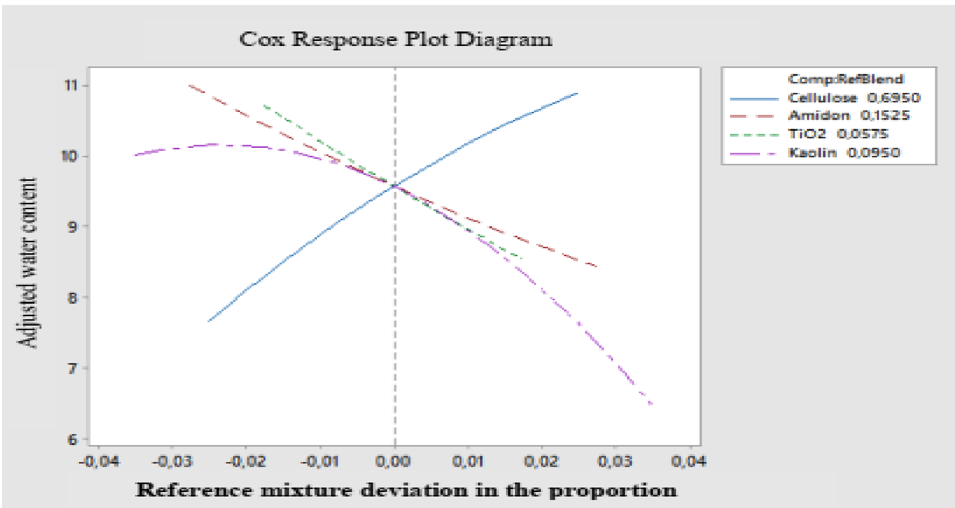

Fig. 8: Cox plot of water content

The evolution of the response is determined from the paper occupying the center of the field of study whose composition is as follows:

X_1= 0,695 ; X_2=0,1525 ; X_3 = 0,0575 ; X_4 = 0,095

Compared to the center test, we note that:

- The addition of TiO2 decreases the water content;
- The addition of cellulose increases the water content;
- By increasing the kaolin, the water content drops;
- By increasing the starch, the water content drops.

D. Illustration of Results

a) The mass

The simplified model is used to draw the curves of equal mass value in the study domain (Figure 9). It can be seen that the objective of a mass between 1.2 and 1.4 is achieved in a very large part of the field of study.

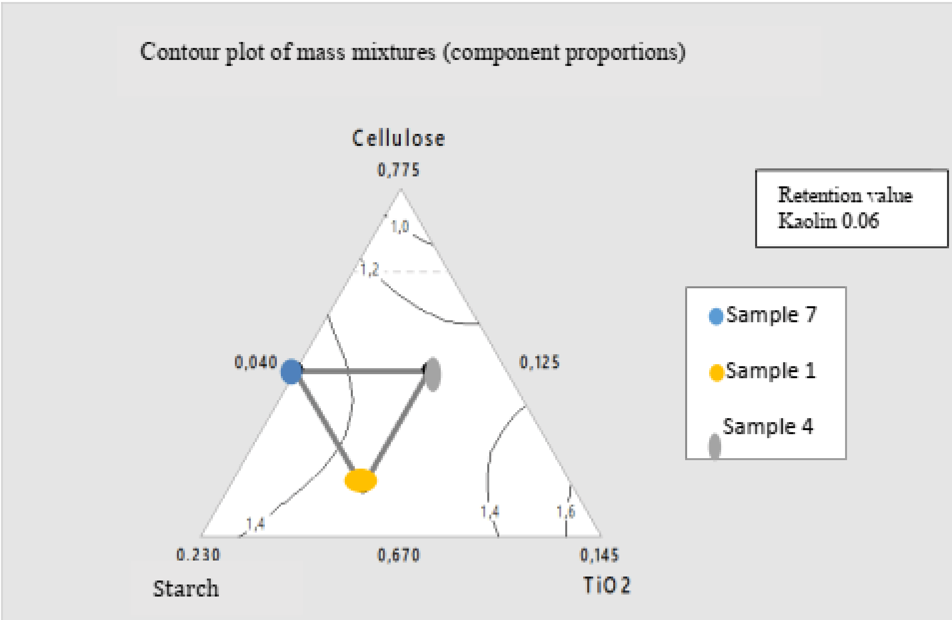

Fig. 9: Mass outline

b) Water content

The simplified model is used to draw the curves of equal mass value in the field of study (**figure 10**).

It can be seen that the objective of obtaining a water content of between 5 and 10% is achieved in a very small part of the study area.

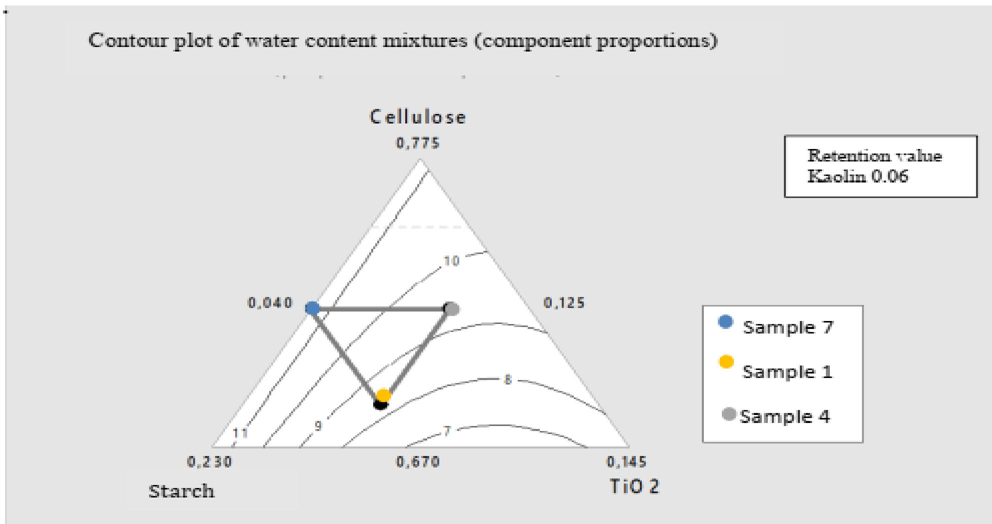

Fig. 10: Water content outline

c) Conclusion of the study

As the two objectives must be simultaneously achieved, we have superimposed Figures 9 and 10 and eliminated the forbidden regions to obtain the set of mixtures that satisfy our objectives (**Figure 11**).

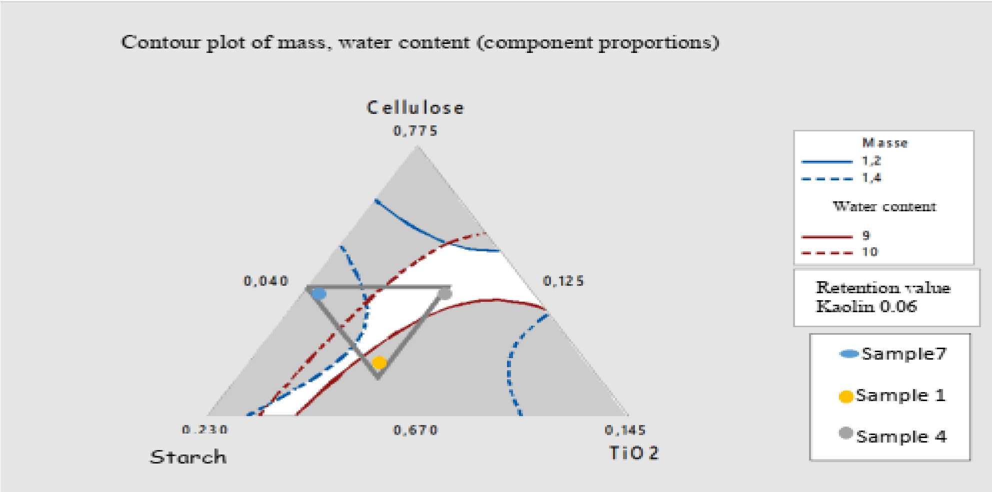

Fig. 11: Outline of the specification area respecting the two responses

On this graph (**figure 11**), it is clear that in this zone, the residuals are not significant. The zone is therefore well described by the models and consequently, it can be assumed that this zone corresponds to an optimal zone for the combined responses.

The different constituents do not influence the two responses in the same way. To account for the actions to be undertaken, we have drawn up table 9 which indicates the direction of variation of the response when the content of constituent increases.

- The mass
  The model predicts a mass of 1.30g, while the measurements gave an average value of 1.26g; i.e. 0.04g less mass point.
- Water content
  The model predicts a water content of 9.32%, while the measurements gave an average value of 9.30g; i.e. a difference of 0.02%.

These values are sufficiently close to the mean value of the responses measured, so our model is validated.

IV. CONCLUSION

The present work focused on the extraction and formulation of a paper from cellulose extracted from water hyacinth.

The aim was to develop models for the optimization of the formulation of a paper from cellulose extracted from water hyacinth. This formulation depends on the cellulose-starch-TiO2-Kaolin mixture. It was necessary to determine the right proportions to obtain a better formulation. As modelling schemes offer a large field of action in relation to the domain exploited, it became clear that the one that concerned us was the mixing schemes.

The identification of constraints and boundary values allowed us to draw up an experience matrix, from which we were able to determine the coefficients of the models as a function of mass and moisture content. The Cox diagrams obtained show that the addition of cellulose increases the moisture content and mass, while the amount of TiO2 decreases with the moisture content and mass.

The tests carried out allowed us to understand the role played by each of the constituents. However, the statistical tests allowed us to validate the model on the one hand and to define the optimal zone on the other hand. With these satisfactory results, we can now predict the mass and moisture content of a paper.

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