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MATHEMATICAL MODELS AND COMPUTER INTERFACE DESIGNED FROM EXPERIMENTAL RESULTS OF BASIC PHYSICAL PROPERTIES OF EXTRUDED PVC TUBES LOADED WITH PALM KERNEL SHELL POWDER.

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KeyWords

Experimental results of basic physical properties of extruded PVC; Influence of palm kernel shell powder on the physical behavior of extruded PVC loaded; Mathematical models; Design and set up of a computer interface.

ABSTRACT

We have developed mathematical models and designed a simple and practical computer interface based on the experimental results obtained during the calculation of density, absorption, desorption of water and its vapour of PVC tubes extruded and loaded with 4.02%, 12.54%, 23.01%, 32.02%, 38.02% and 51.02% of micronized palm kernel shell powder respectively. Thus, we took the unloaded PVC tubes and the PVC tubes loaded with the shell powder extruded industrially in the past. We calculated their density, water absorption and desorption with their vapor using standard classical methods. We obtained the results that we exploited respectively, to study the influence of the shell powder on the physical behavior of the extruded PVC, to elaborate the mathematical models and to design a computer interface for the calculation of the basic physical parameters of the composite according to the dosage with the shell powder. We obtained that the interface is simple, fast, convenient and suitable for all operating systems. That interface will allow engineers and standard teams, businessmen and hardware stores to control their work, satisfy their customers, print and archive the data.

I - INTRODUCTION .

The shells of palm kernel are very little used in the oil palm, while the oil palm sector is booming in the world **[1, 2, 3, 4, 5].** Moreover, the plastic material is nowadays requested in several fields of the construction because of its prestigious performances. That's why we will find them in increasing quantity in the aeronautical, automotive, domestic constructions, buildings to approach only those **[6, 7, 8, 9]**. Synthetic polymer matrix composites are widely used because of their availability, relatively low cost and convenient processing technology **[10, 11, 12, 13, 14, 15].**

In the past, plastics were considered to be a danger to society because of their environmental pollution due to their non-degradability and non-recyclability **[13,16].** However, in the last few years, research work has been carried out to solve this problem and has shown that it is possible to recycle plastics, for example, in the production of paving stones and floor coverings in civil engineering, and in the production of petroleum products such as diesel oil in mechanical engineering. The use of ceramic and metallic reinforcements for the manufacture of parts with high mechanical resistance for delicate constructions such as aeronautics, naval, automotive, machine tools and many others **[12,13, 16, 17].**

Several works in the literature have shown that palm kernel shells are abundant in the world in general **[2, 6]** and the work of characterization and processing of palm kernel shells as load for the production of plastics has been carried out **[18]**, followed by the industrial production of PVCs tubes taking micronized palm kernel shell powders as loads at dosages ranging from 0% to 51% has been successfully experienced **[21].**

Several works in the use of vegetation as loader and reinforcement of synthetic polymers in the manufacture of plastics have already seen the light of day and several characterizations have been made with the aim of making this new material available to engineers **[13,16].** The appreciation of a new material requires a set of characterizations to enable the engineer to be interested in this plastic material in the design or realization of his constructions **[12, 14, 22].**

For this reason, having made a new plastic material with a polyvinyl chloride matrix with palm kernel shells as a load at different dosages, the worrying work today is to present the results of its different behaviors by carrying out a series of characterizations to allow engineers to evaluate the performance of this new material in order to integrate it into the works and constructions.
Thus, we will choose extruded PVC tubes loaded with 0%, 4.01%, 12.54%, 23.03%, 32.01%, 38.01% and 51. 02% of the shell powder **[21];** we will make physical characterizations of the density, absorption and desorption of water and its vapor that we will present the results that will allow us to study in turn the influence of the palm kernel shell powder on the PVC and the development of mathematical models for the calculation of these physical parameters of the new material **[23].**

Obtaining the above results will allow us to design a computer interface integrating the experimental results, which should help production and construction engineers, traders and hardware dealers, standard teams and businessmen to better assess the quality of PVC loaded with palm kernel shell powder that is available to them **[12,13,14].** An overview of the possibilities of using the performance of the material in construction will be discussed based on the results of the characterizations **[16,18].** This work is an important preface that will allow us to continue the work of characterization of PVCs tubes loaded with palm kernel shell powder in order to allow engineers and industrialists, to use this new material in construction in general, and researchers to expand the field of research work of the production of plastic materials using other synthetic polymers as matrix and the palm kernel shell powder as load and even as reinforcement **[8, 15, 25].**

II - MATERIALS AND EXPERIMENTAL METHODS.

II - 1 - MATERIALS

II - 1 - 1- MATERIALS OF THE STUDY:

The materials are PVC tubes which were industrially elaborated according to the methodology described in the work of Djomi and his team **[21].** They were elaborated in the company SOFAMAC (Société de Fabrication des Matériaux du Cameroun) located in SOA, city of Yaoundé in Cameroon **[26].** As a reminder, we used an industrial twin screw extruder for the extrusion. The extrusion was carried out continuously without interruption. The working conditions were the same. The dosages in terms of extrusion additive remained the same as when using calcium carbide as load. The only load used here is micronized palm kernel shell powder, the processing and characterization of which was described in the work of Djomi et al **[18].**
The raw PVC used was purchased from DANSUK & Cie **[27]** by SOFAMAC, one of the company's customers. The additives are those commonly used by SOFAMAC to satisfy the Cameroonian people in terms of plastic materials for construction for many years.
We produced the unfilled PVC pipes which we called F0, then we produced the PVCs tubes load with micronized palm kernel shell powder with the following percentages: 4.01% called F4.01, 12.54% which we called F12.54, 23.03% called F23.03, 32.01% called F32.01, 38.02% which we called F38.02 and 51.01% called F51.01.
The tubes were controlled by the team of the norms of the company in accordance with the respect of the laws that regulate the production of plastic materials in the companies of the production of plastic materials.
Fig. 1 shows the photographs of the tubes elaborated for each formulation. We point out hereafter that we will call each tube by the percentage of the dosage of palm kernel shell powder as shown in **fig. 1.**

Figure 1: Unloaded PVC tubes and PVC tubes loaded with micronized dura palm kernel shell powder.

From **Fig. 1**, we will say as a reminder **[21]** that:

- All tubes are perfectly round.
- The colors range from light gray for F0 to gray-black for F51.01, passing through gray and dark gray, confirming the presence of the purple color of the micronized palm nut shell powder load and the presence of carbon black from the extrusion additives.
- The surfaces range from smooth and shiny for the F0 tubes to rough for the F51.01 tubes confirming the presence of micronized palm kernel shell powder in the tubes.
- The diameters are exactly 82mm for the inner diameter and 90 for the outer diameter confirming the qualities of the dies and the seriousness of the company.

II - 1 - 2- EXPERIMENTAL EQUIPMENT.

- Mechanical saw :
- SMID RS32 automatic lathes from the company Trumel Nancy-Strasbourg-Besançon-France.
- Digital caliper at 1/100th.
- Distiller : standard
- Oven :

II – 2 - EXPERIMENTAL METHODS.

II - 2 – 1- DENSITY.

PREPARATION OF THE SPECIMENS.

The specimens are cut and straightened on an automatic sowing lathe equipped with longitudinal and transverse stops for length accuracy. The tubes are cut into lengths l=184mm. The external diameter D=90m, the internal diameter d=82m of the tubes are obtained by the die of the extruder. The length l=184mm is obtained by straightening. 10 specimens are provided per formulation.

Fig. 2: Length and mass measurements.

METHODOLOGY.

We measure the length Li and mass mi of each test piece. We apply the classical relation **(1)** to calculate from the density ρi of the tube specimens. The actual density ρ of the unloaded PVC and loaded PVC in the formulation is the average of the densities of the specimens obtained in each formulation followed by its standard deviation **[28, 29]**.

$$\rho_v = \frac{4m}{\pi L(D^2 - d^2)} \quad \left\{ \begin{array}{l} m_i = \text{mass of the specimens (g).} \\ D_e = \text{external diameter (cm).} \\ \text{Li = length of the tubes (cm).} \\ D_i = \text{internal diameter (cm).} \end{array} \right. \qquad (1)$$

II - 2 – 2 : PERMANENT HUMIDITY, ABSORPTION, DESORPTION OF WATER AND ITS VAPOR.

Plastic materials are used for various constructions. They can be exposed to conditions where the temperature variation can influence it. It is essential to know the behavior of materials in front of the humidity of the air and under variable atmospheric conditions **[24].**

The parameters studied are :

- ✓ the permanent humidity of the tubes ;
- ✓ water absorption ;
- ✓ water desorption;
- ✓ absorption of water vapour;

a) PREPARATION OF THE SPECIMENS.

The materials for each test are plates cut along the longitudinal direction of the tubes **fig. 3.** 8 plates per formulation are provided for each test **fig4.**

The tests are carried out under the same conditions of temperature, pressure and recording according to the standard **[30].**

Each plate is marked with a code corresponding to the material formulations and the tests to be carried out, and the mass of each specimen is weighed before the start of the experiment.

Fig. 3: Direction of sampling of the specimens.

b) EXPERIMENTAL METHOD

i. Measurement of Moisture content rate:

We prepare 6 specimens labeled by formulation. We record the initial mass mih of each one. We place the test specimens in the oven and set the temperature to 103°C. We let the specimens stay there for 72 hours. After this time, the specimens are put in a desiccator and weighed. The test tubes are put back in the oven and the weights are taken after every 4 hours until a mass is obtained that does not vary within 10-3g. The moisture content is calculated by the classical relation **(2) [28, 31].**

$$T_{ih} = \frac{m_{ih} - m_{is}}{m_{is}}$$ m_{ih} = wet mass (g); m_{is} = dry mass (g); T_{ih} = moisture content %. (2)

ii. *Measurement of the water absorption rate*

The initial masses m_{is} of each specimen are measured. We place the specimens in a ceramic cuvette containing distilled water. We place them in an oven with a temperature of 25 °C. The gain in mass of the specimens is recorded after 24 hours and noted m_{ia} . The samples are put back in the tank. We take readings every 6 hours so as not to observe the variation at 10-3g. We record the final mass which is the mass m_{ia} of the test tube. The water absorption rate T_{ia} of each test piece is calculated according to relationship **(3) [28, 31]** and The water absorption rate T_{ia} of each formulation is obtained by averaging the records of water absorption rates of the test pieces obtained for each formulation.

$$T_a = \frac{m_s}{m_a}$$ m_{ia} = absorbed mass (g); m_{is} = dry mass(g); T_{ia} = water absorption rate % (3)

iii. *Measurement of the water vapor absorption rate.*

The initial masses of each specimen m_s are measured. In a desiccator, we replace the desiccant with distilled water and place our test tubes on top. The whole is left at room temperature. After saturation of the desiccator with water vapor for 48 hours, we let our test tubes remain for 24 hours and we take the masses $\mathrm{m_v}$. The specimens are reintroduced into the desiccator and the masses are measured after every 6 hours until there is no more mass variation at 10-3g. The water vapor absorption rate of each test piece is calculated according to relationship **(4)** and the water vapor absorption rate $\mathrm{T_v}$ of each formulation is obtained by averaging the records of the different water vapor absorption rates of the test pieces obtained per formulation **[28, 31].**

$$T_v = \frac{m_s}{m_v}$$ m_v = masse absorbée (g); m_s = masse sèche (g); T_v = taux d'absoption de vapeur d'eau %. (4)

iv. *Measurement of water desorption rate.*

The initial masses of each specimen m_d are measured. In a desiccator, we replace the desiccant with a wire mesh and arrange our specimens on top. The whole is left at room temperature, i.e. 25°C at the time of the experiment. After dehydrating the test tubes for 48 hours, we let our test tubes stay for 24 hours and we take the masses m_s . The specimens are reintroduced into the desiccator and the masses are measured after every 6hours until there is no more mass change at 10-3g. The water desorption rate of each test piece is calculated according to the classical relation **(5)** and The water desorption rate T_d of each formulation is obtained by the mean and standard deviation of the water desorption rate records of the test pieces of the formulation **[28, 31].**

$$T_d = \frac{m_s}{m_d}$$ m_d = absorbed mass (g); m_s = dry mass (g); T_d = water vapor absorption rate %. (5)

III - RESULTS AND DISCUSSIONS

III - 1 - RESULT OF THE PREPARATION OF THE SPECIMENS :

III - 1 - 1 - FOR THE CALCULATION OF THE DENSITY.

We have obtained for the specimens intended for the measurement of the density. Thus, we obtain that the diameters of the tubes are the same for all the specimens and for all the formulations.
We prepared 10 test tubes per formulation in order to have a good readability in the standard deviations of the records. The lengths are variable according to the machining, which explains the variability of the masses.

III - 1 - 2 - For the calculation of the absorption and desorption of water and its vapor.

Fig. 4 below shows the results of the specimens for the measurement of different rates of moisture, absorption and desorption of water and its steam. The test specimens were taken according to the explanations given in the material and experimental method section (see **fig. 3**). These are rectangular plates taken along the longitudinal direction of the tubes, since the dimensions and curvatures do not impact on the results to be obtained.

Fig 4: Presentation of the specimens for the measurement of the rate of moisture, absorption and desorption of water and its vapor.

III – 2 - Results of the characterizations:

III - 2 – 1- Results of the calculation of the density.

i. ***Results of the density and standard deviations of the tubes by formulation***.

Results of the measurements of the specimens for each formulation.

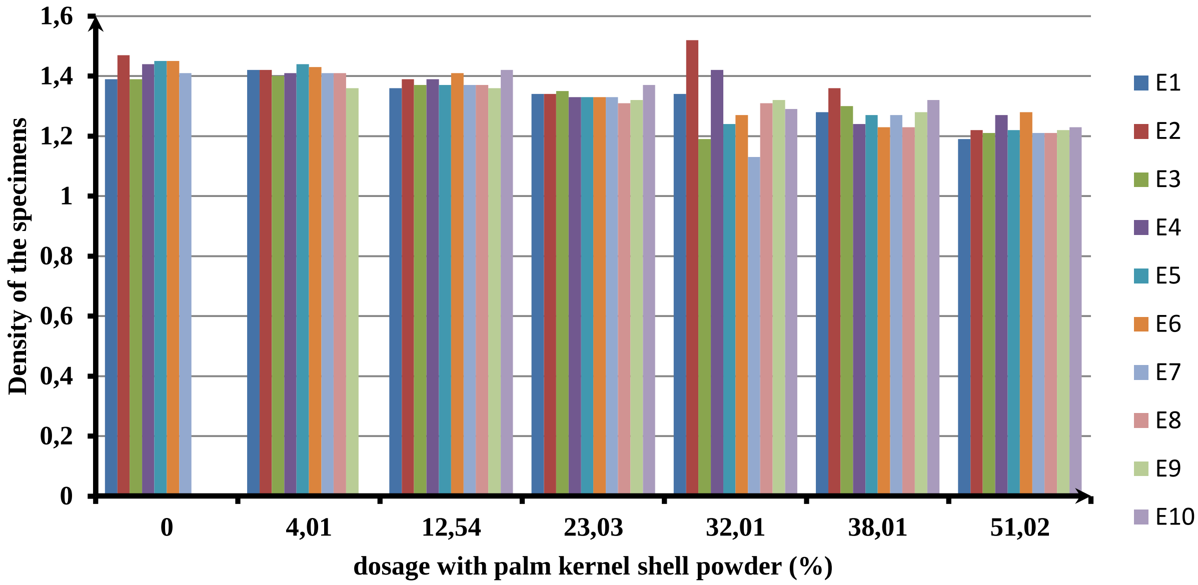

Fig. 5: Results of the measurements of the specimens.

Polymers have a relatively low density, which makes the plastic material quite light compared to metallic materials **[32, 33].** This physical behavior makes plastic material suitable for many constructions, especially aeronautics and automotive. Thus, the load of palm kernel shell powder is lighter than raw PVC **[18].**

We have made PVC and PVC tubes load with palm kernel shell powder. We cut and measured the density of 10 specimens of these tubes per formulation. We have recorded the results in **Fig. 5.** We note that there is not enough dispersion in the results obtained on the different specimens per formulation. Thus, Fig. 5 shows that the value of the standard deviation of the records for each formulation is low. These values of standard deviation allow us to adopt well the average values of the results obtained in each formulation as the density of PVC. **Table 1** shows the standard deviations of the density obtained.

Table 1: Standard deviation of density measurements by formulation.

Formulations	F0	F4.01	F12.54	F23.03	F32.01	F38.01	F51.02
Standard deviation	0,032	0,023	0,021	0,016	0,111	0,041	0,028

From **Table 1** we see that the standard deviations obtained for the measurement of the densities of the tubes are quite good. However, we can see in **Fig. 5** that there was a slight dispersion in the formulation F32.01. But the calculation of the standard deviation shows that this dispersion is negligible compared to the density of the material.

ii. Results of the average density by formulation.

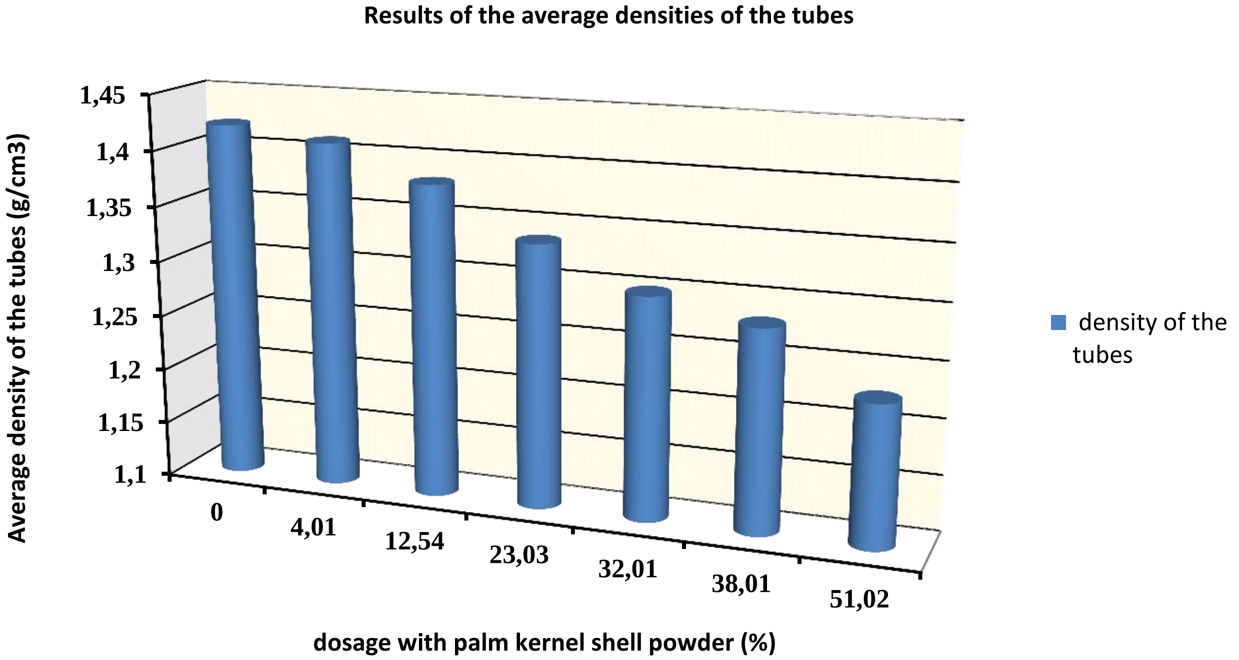

Fig. 6: Results of the average densities of the tubes.

From **Fig. 6**, we obtain that the density of unfilled PVC F0 is 1.426g/cm 3 that of F4.01 is 1.411 g/cm 3 for PVC F12.54 is 1.381 g/cm 3; for PVC F23. 03 is, 1.335 g/cm 3; for PVC F32.01 is 1.303 g/cm 3; for PVC F38.01 is 1.278 g/cm 3 and finally, PVC F51.02 has a density of 1.226 g/cm 3.
We obtained in **Table 1** that the values of the densities that we represent here are derived from the average of the measurements of the densities of several specimens, which led us to calculate the values of the standard deviations for each formulation.
Thus, the densities of the PVCs thus obtained can be written as in **Table 2.**

Table 2: density measurements by formulation.

Formulations	F0	F4.01	F12.54	F23.03	F32.01	F38.01	F51.02
Densities	1.426 ±0,032	1.411 ±0,023	1,381 ±0,021	1.335 ±0,016	1,303 ±0,111	1,278 ±0,041	1.226 ±0,035

According to **Table 2**, we will write the density of the tubes for each formulation as follows: F0 tubes have 1.426 ±0,032 g/cm 3 ; F4.01 have 1.411 ±0,023 g/cm 3 ; F12. 54 have 1.381 ±0.021 g/cm 3; F23.03 have 1.335 ±0.016 g/cm 3; F32.01 have 1.303 ±0.111 g/cm 3; F38.01 have 1.278 ±0.041 g/cm 3 and F51.02 have 1.226 ±0.035 g/cm 3.
To summarize, the density of the unloaded extruded PVCs to the extruded PVCs loaded with palm kernel shell powder, i.e., from F0 to F51.02 formulations with the assumptions of extrusion is between :

$$1.226 \pm 0.035 g/cm3 < \rho < 1.426 \pm 0.032\ g/cm3$$

This value gives advantages to the plastic material to be used without fear in several fields of construction in a varied way. These results are observable in the literature especially when the composite is reinforced with plant loads **[12, 13, 34, 35].**
Behavior of PVC and PVC loaded with palm kernel shell powder facing density.
We developed the PVC tubes in the study and used the appropriate standards to characterize them. We obtained the results in **Tables 2** and **3** and **Fig. 5** and **6.** We now present scientifically that the palm kernel shell powder has a significant influence on the behavior of PVC. The principle is to analyze the results of the characterizations and to determine the influence of the palm kernel shell powder on the PVC tubes and then to develop mathematical models which link the properties to their dosage **[12, 34].**

iii. Influence of palm kernel shell powder on extruded PVC tubes.

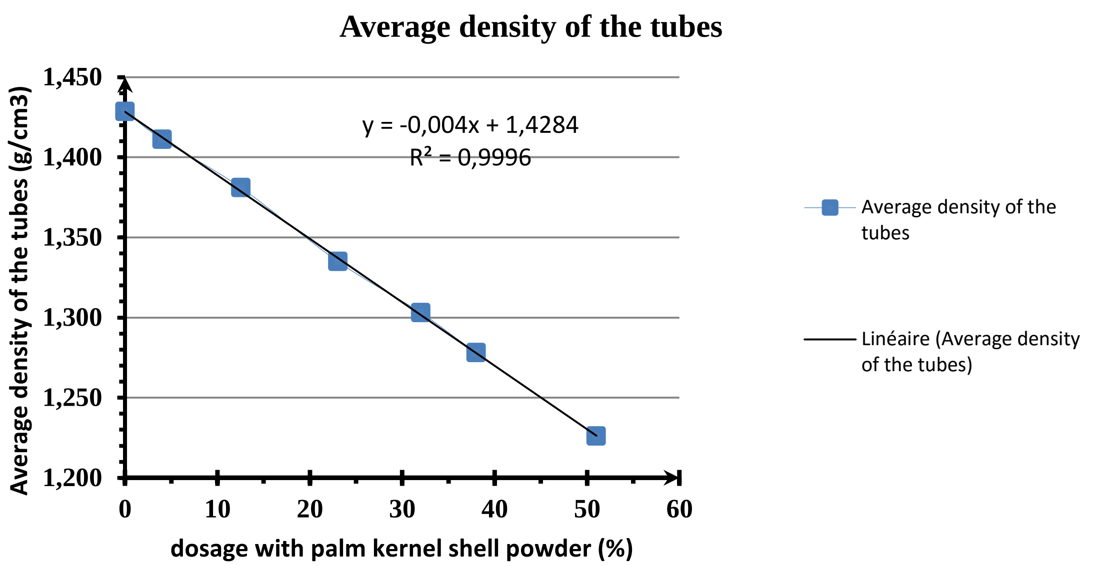

Fig. 7: Influence of the shell powder on the density of the PVC tubes.

By scientific interpretation of **Fig. 7**, we obtain that the results of the density measurements decrease with the loading rate of the hull powder. By statistical interpolation, we obtain that the regression of the results shows a linear trend line. The arrangements of the results show that all the representative points of the densities of the studied formulations are either on the line or very close to the line **[36].**

iv. The mathematical model for the calculation of the density

Table 3: Mathematical models for the calculation of the density of PVC tubes.

Propriétés	Modèles mathématiques	type	Corrélation
density of PVC tubes (ρ)	y = -0,004x + 1,4284	Linéaire	R^2 = 0,9996

Interpreting **Fig. 7**, we obtain **Table 3**, which is The mathematical equation that allows the calculation of the density of PVC loaded with shell powder **[37]** and is the result of interpolation of the points representative of the density for each formulation of extruded pipes. We obtain that it is y = -0.004x + 1.4284. The correlation of the records R^2 = 0.9996. We observe a very slight dispersion at the level of F12.54 and F32.01. Perhaps this is due to the disturbances during the recordings **[38, 39]** and, the regression R^2 = 0.9996 is very close to 1 allowing the mathematical model y = -0.004x + 1.4284 obtained to be reliable for the calculation of the density of the PVC when they are loaded with the powder of palm kernel shells.

III - 2 – 2- RESULTS OF MOISTURE CONTENT, ABSORPTION, DESORPTION OF WATER AND ITS VAPOR

i. Results of moisture content, absorption, desorption of water and its vapor.

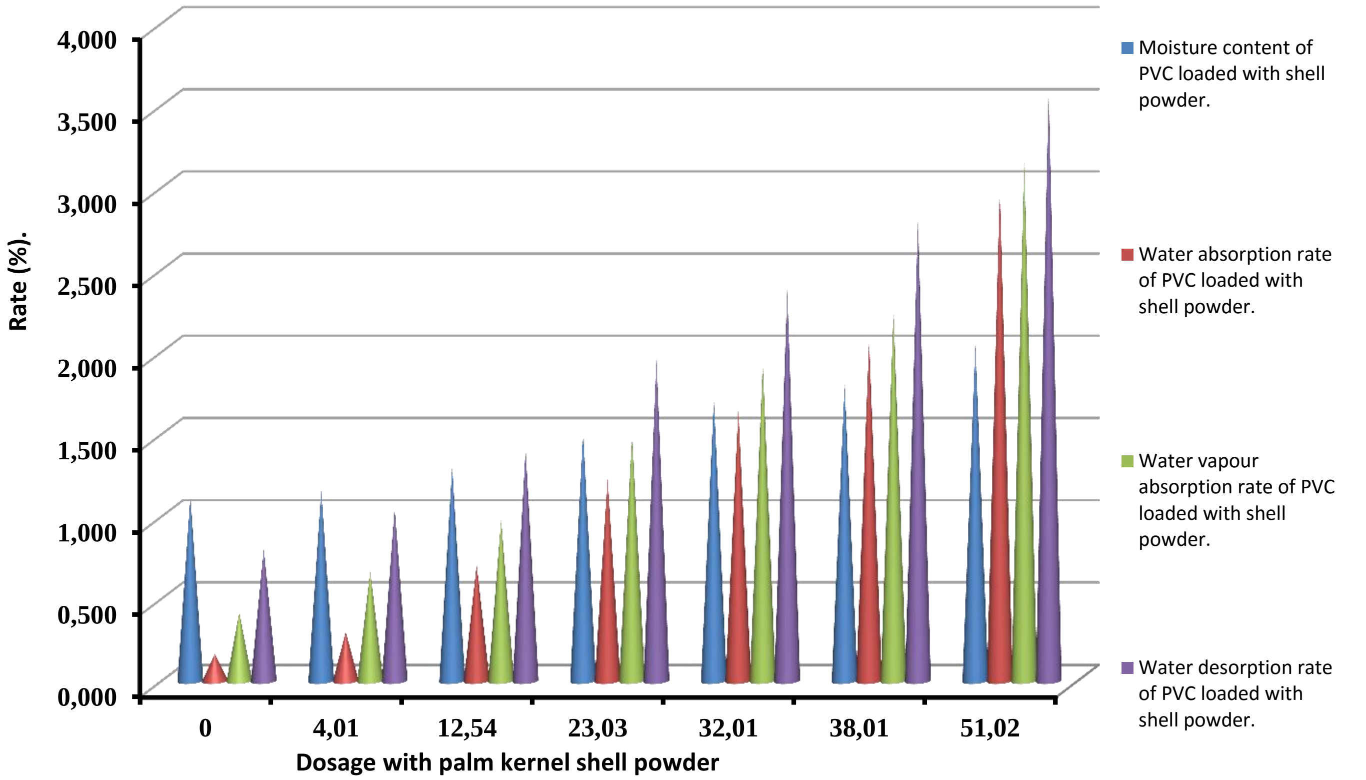

Fig. 8: Results of moisture content, absorption, desorption of water and its vapor.

We obtain from **Fig. 8** therefore from the laboratory tests that :
Unload PVCs have a moisture content of 1.120%, a water absorption rate of 0.165%, a water vapor absorption rate of 0.417% and a water desorption rate of 0.802% **[16, 32]**.
For PVCs loaded with palm kernel shell powder,

- F4.01 has a moisture content of 1.159%, a water absorption rate of 0.299%, a water vapor absorption rate of 0.666% and a water desorption rate of 1.052%.
- F12.54 has a moisture content of 1.303%, a water absorption rate of 0.708%, a water vapor absorption rate of 0.980% and a water desorption rate of 1.406%.
- F23.03 has a moisture content of 1.509%, a water absorption rate of 1.227%, a water vapor absorption rate of 1.499% and a water desorption rate of 1.953%.
- F32.01 has a moisture content of 1.709%, a water absorption rate of 1.649%, a water vapor absorption rate of 1.935% and a water desorption rate of 2.377%.
- F38.01 has a moisture content of 1.803%, a water absorption rate of 2.075%, a water vapor absorption rate of 2.249% and a water desorption rate of 2.800%.
- F51.02 has a moisture content of 2.043%, a water absorption rate of 2.996%, a water vapor absorption rate of 3.152% and a water desorption rate of 3.592%.

ii. Behavior of the materials to the absorption and desorption of water and its vapor.

Fig. 8 shows the results obtained from the tests of dehumidification, absorption and desorption of water and its vapor **[38].** We have recorded 3 cases of behavior of the material namely:
cases 1: material with very low moisture content. These materials are those that resist well both the absorption of water and its vapor. During the laboratory tests, we observed that these materials have a loading rate with palm kernel shell powder lower than 20%. This is the case of F0, F4.01, F12.54.
cases 2: materials with average moisture content. These materials are those that do not resist very well to both the absorption of water and its vapor, desorb but very slowly that is to say do not dry also very quickly. During laboratory tests, we observed that these materials have a loading rate with palm kernel shell powder lower than 20%. This is the case of F23.03, F32.01.
cases 3: material with high moisture content. These materials are those that do not resist both the absorption of water and its vapor but also desorb quickly that is to say also dry very quickly. During laboratory tests, we observed that these materials have a loading rate with palm kernel shell powder higher than 40%. This is the case of F38.01, F51.02. Let us note in passing that the dosage of F38.01 has a dosage very close to 40%, which assimilates its behavior to that of a material with a high loading rate.

iii. Influence of shell powder on the moisture content, absorption, desorption and water vapour absorption of PVC.

We developed the PVC pipes for the study and used the appropriate standards to characterize them. We obtained the results in fig. 8. We present scientifically in **fig. 9**, the influence of palm kernel shell powder on the behavior of PVC. The principle consists in analyzing the results of the characterizations and determining on a graph the influence of the palm kernel shell powder on the PVCs **[31, 34]** and then developing mathematical models that link the properties to their dosage.

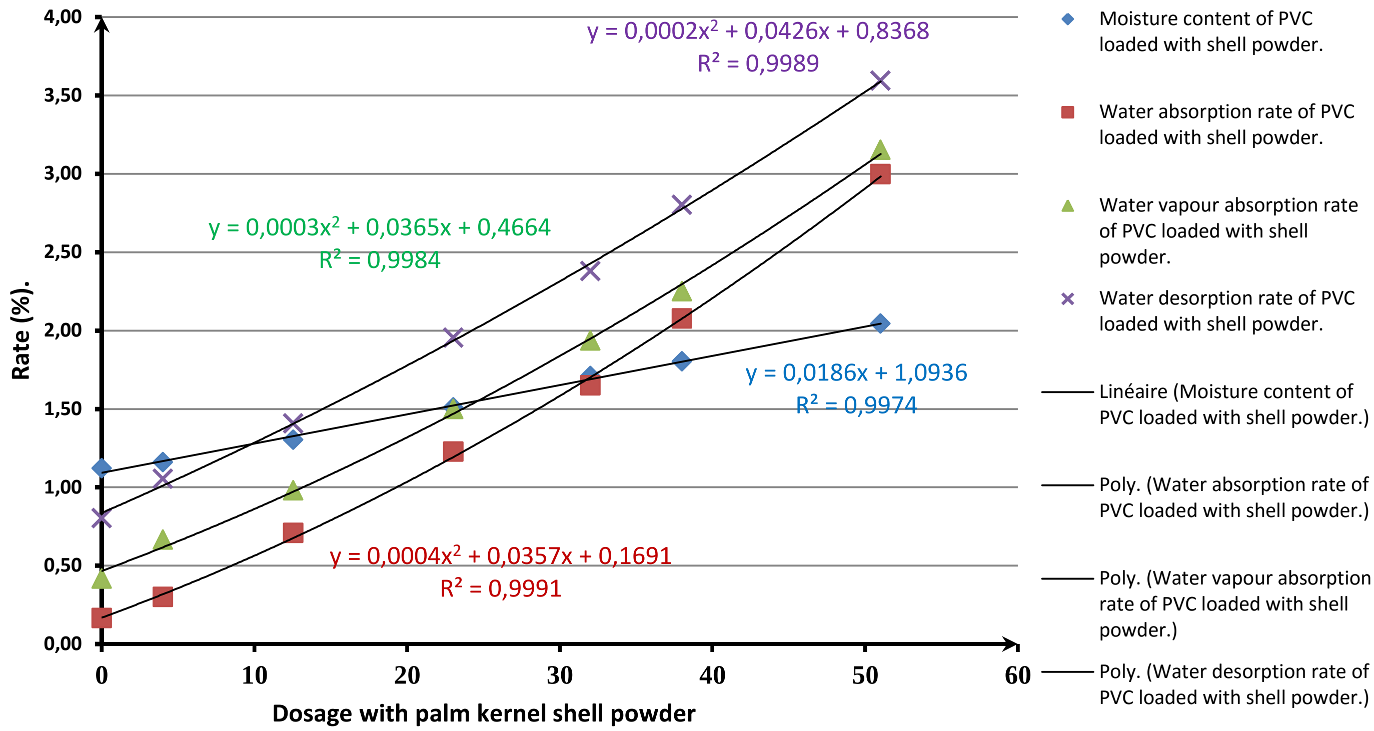

Fig. 9: Influence of hull powder on moisture, absorption, desorption of water and its vapor.

Fig. 9 shows the results of the Influence of palm kernel shell powder on the moisture content rate, absorption rate, water desorption rate and its vapor of extruded PVCs from formulation F0 to formulation F51.02.
By scientific interpretation of **Fig. 9**, we obtain that the results of the measurements of moisture content, absorption rate, desorption rate of water and its vapor increase with the loading rate of the shell powder. By statistical interpolation, we obtain that the regression of the results presents a linear trend line for the rate of humidity and polynomial for the rate of absorption of water and its vapor. The arrangements of the representative points of the results show that all the rates of all the studied formulations are either on the line or very close to the line. We notice some small dispersions like at the points F12.54 and F32.01 for the rate of moisture and the rate of water absorption, at the points F0, F4.01, F38.01 for the rate of water vapour absorption and at the points F4.01 and F32.01 for the rate of water desorption. Certainly this may be due to the dispersions obtained during the recordings during the tests.

iv. Mathematical models of the calculation of the absorptivimetry of the developed tubes

Table 4: Mathematical models for the calculation of the absorptivimetry of the elaborated tubes.

Properties	Mathematical models	type	Correlation
Moisture content rate	y = 0,0186x + 1,0936	linear	R^2 = 0,9974
Water absorption rate	y = 0.0004x2 + 0.0357x + 0.1691	Polynomial	R^2 = 0,9991
Water desorption rate	y = 0.0002x2 + 0.0426x + 0.8368	Polynomial	R^2 = 0,9989
Water vapor absorption rate	y = 0.0003x2 + 0.0365x + 0.4664	Polynomial	R^2 = 0,9984

Interpreting **Fig. 9**, we obtain **Table 4,** which is the set of mathematical equations that allow us to calculate the rates of moisture, absorption and desorption of water and its vapor of the PVCs loaded with the shell powder **[27].** These equations are the result of the interpolation of the representative points of the different properties recorded during the laboratory tests for each formulation of the extruded tubes **[32].** We obtained that the equation that allows the calculation of moisture content is y = 0.0186x + 1.0936 with a correlation of records R^2 = 0.9974, That which allows the calculation of the rate of water absorption y = 0.0004x2 + 0.0357x + 0.1691 and its steam is y = 0.0003x2 + 0.0365x + 0.4664 and For y = 0.0002x2 + 0.0426x + 0.8368 That of water desorption. The regression coefficients (R^2) are between R^2=0.9984 and R^2=0.9991 reassuring the quality and reliability of the mathematical models obtained for the calculation of the properties of PVC when loaded with palm kernel shell powder.

III - 3 : Computer interface for the calculation of physical properties of PVC loaded with palm kernel shell powder.

i. Materials for the design of the interface.

- Equations obtained from the calculation of the material properties see **table 4.**

Table 5: Mathematical equations supporting the design of the interface.

Physical properties	**Mathematical models**
Density	y = -0.004x + 1.4284
Moisture content	y = 0.0186x + 1.0936
Water absorption rate	y = 0.0004x2 + 0.0357x + 0.1691
Water desorption rate	y = 0.0002x2 + 0.0426x + 0.8368
Water vapor absorption rate	y = 0.0003x2 + 0.0365x + 0.4664

- JAVA development environment (net Beans IDE 8.0.2 with java ver 1.8.0_181)
- Java FX Scenebuilder 1.0

ii. Result of the designed interface.

We get a software in the compressed folder winrar **fig. 10.**

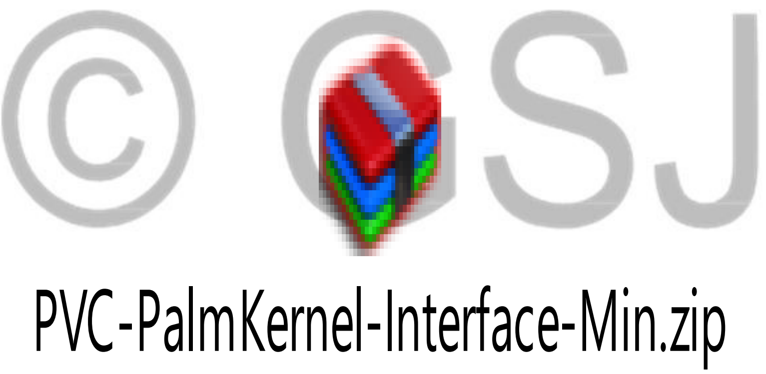

fig. 10: Compressed folder

iii. Methodology of the installation of the software:

- Extract the compressed folder fig. 10 by double clicking on the software.
- Enter the folder and double click on the PVC-PalmKernel-Interface folder type.
- Enter the folder and double click on the executable file PVC-PalmKernel-Interface.exe of type application.
- The interface fig. 11 is displayed and ready to be used.

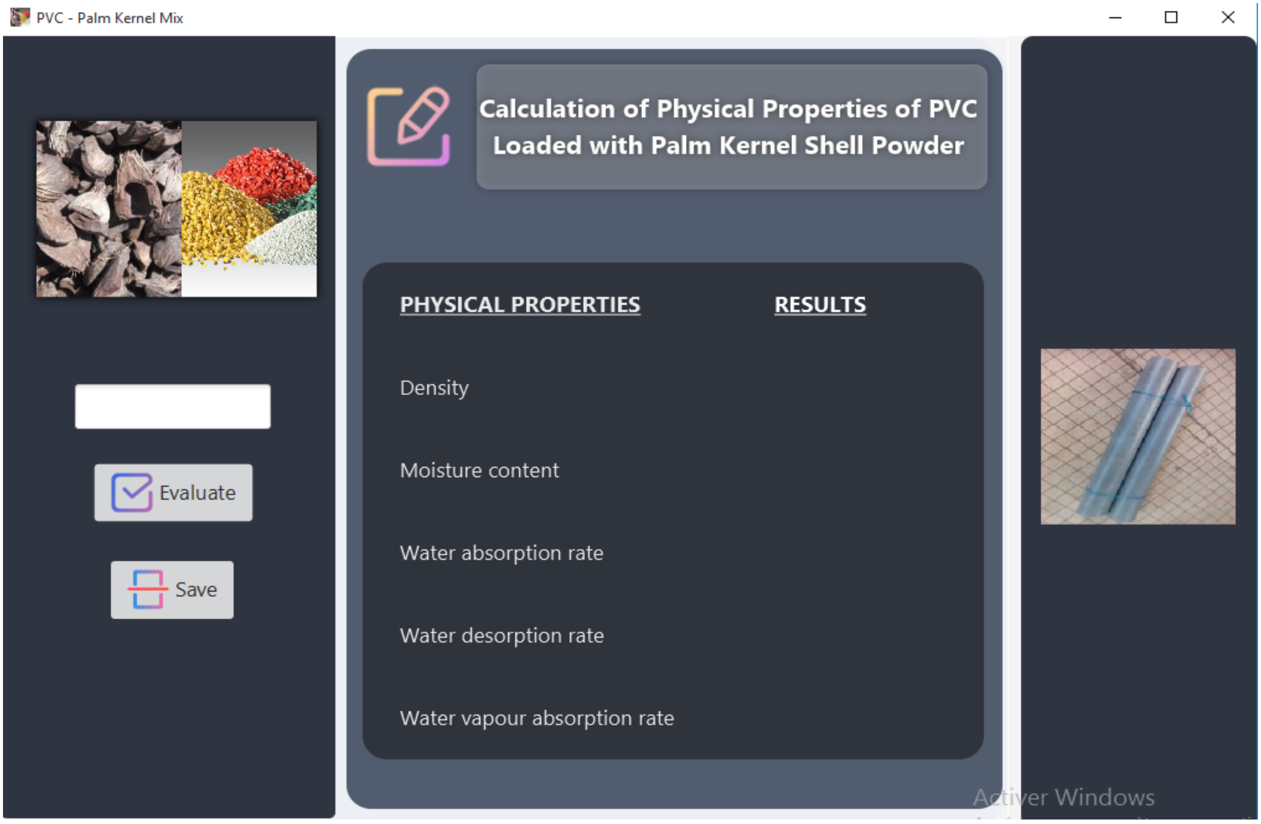

Fig. 11: Result of the interface designed.

iv. Using the interface

- Enter the dosage nown to get the properties;
- Example of application **fig. 12**
- Data : we want to have the properties of a PVC with 41.86% as load with palm kernel shell powder. We obtain the results on the interface **fig. 12.**

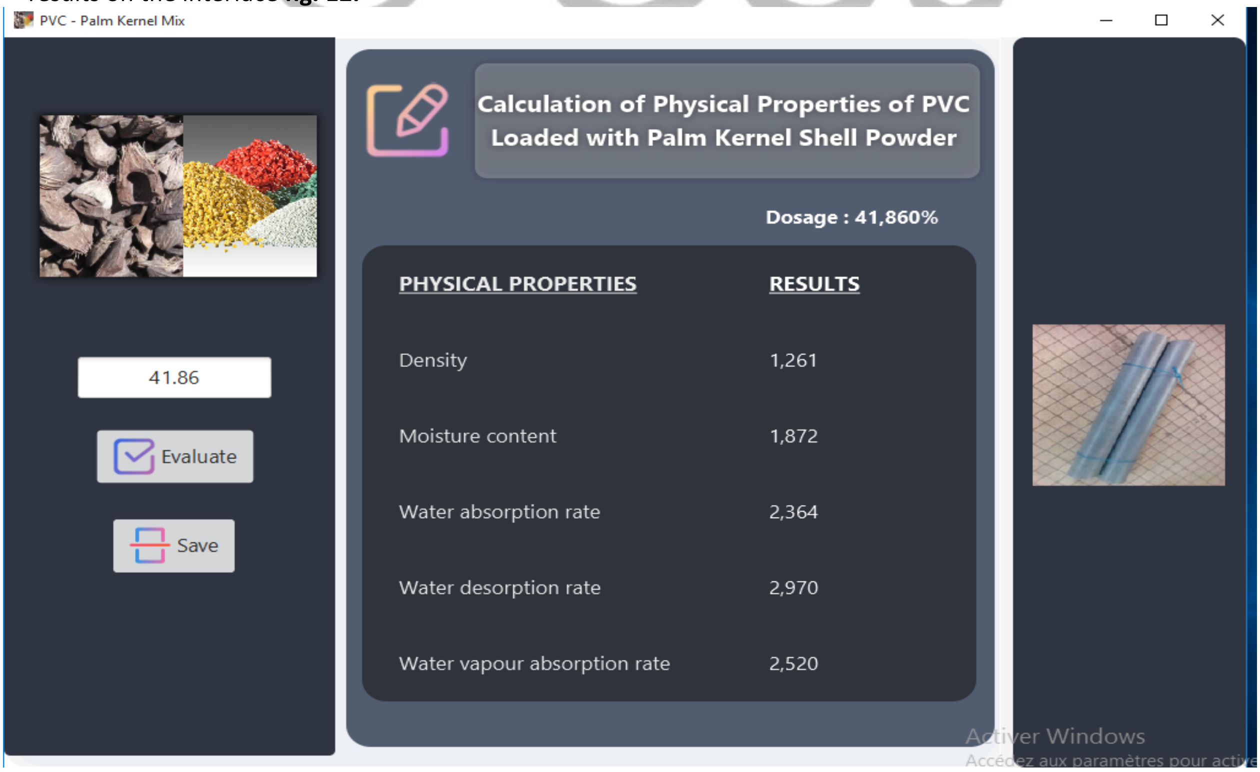

Fig. 12: interface of the result of the properties of a PVC loaded with 41.86% of the shell powder.

IV- GENERAL DISCUSSION AND SPECIFIC OBSERVATIONS.

Polymers have a relatively low density, i.e. 1.38 to 1.44 g/cm3 for PVC, 0.9 g/cm3 for PE, 1.15 g/cm3 for PA6-6, 1.2 g/cm3 **[12, 30,36]** which makes plastic light compared to metallic materials (7.8 g/cm3 for steel, 2.4 g/cm3 for aluminum) **[30,36].** This physical behavior makes the plastic material very solicited in several sectors of activity such as in the mechanical manufacturing and leisure works, metrology and automotive, robotics and design and quality materials, biotechnology and biomedical, automation and aeronautics, energetics and buildings (ceilings, decoration)...etc. **[7, 23].**

Palm kernel shell powder is lighter than PVC **[18]** and much lighter than calcium carbide **[7, 34].** These characteristics therefore make the resulting plastic a sufficiently light material. The results of **Tables 2** and **3** and **Fig. 5** show that the density of the composite obtained from palm kernel shell powder as filler or reinforcement is much lower than that obtained from pure PVC and even from PVC loaded with calcium carbide and then reinforced with vegetable loads **[12, 13].**

The peculiarity of our results lies in the fact that we use only palm kernel shell powder as load **[21,25]** while several researches combine calcium carbide as load and plants as reinforcements **[12, 13]** hence the smaller density (ρ=1.227 to 1.445g/cm3) **fig. 6** and **table 2.**

The densities of ρ=1.227 to 1.445g/cm3 show that palm kernel shell powder significantly influences the mass of PVCs. Similar results are obtained in plant fibers namely wood, hemp, date palm, flax, sisal, ramie, fair, hemp, esparto fibers **[9, 13, 34].** Now these fibers are widely used in the construction of aircraft and automotive see building, it is clear that our materials for the same reasons are also likely to be used in the same conditions and much more.

Finally, looking at **Table 3** and **Fig. 7** we agree that the results are consistent and **Table 1** shows the standard deviations as tight, justifying that the errors in the elaboration of the material and in the characterization of the mass density reassure the quality of work done.

The equation of **fig. 7** and **Table 3**, proves that, for the management of the volumic masses the plastic materials loaded with the powder of shells of palm kernel it would be in conformity for the design and the elaboration of a computer interface that can help the engineers, the technicians, the teams of norms, the hardware dealers, the traders and even the investors in this field to alleviate the habitual calculations

Plastic materials are used for various constructions. They can be exposed to conditions where the temperature variation can influence it. It is essential to know the behavior of the materials in front of the humidity of the air and under variable atmospheric conditions.

Thus, we have coupled the work of calculating the density, the research of the behavior of materials to the humidity of the air and the absorption, desorption and absorption of water and its vapor. **Fig. 8** and **9** show that palm kernel shell powder has a considerable influence on the thermal behavior of PVCs in relation to humidity and climate variations. Water is rapidly absorbed by palm kernel shell powder **[14],** hence the high results at F38.01 and F51.02% formulations. In addition, thermal analyses of the shells **[14]** showed that the structure of the shell powder does not degrade until it is formed with the polymers **[14].** This behavior is reflected in the values of moisture content, water absorption and water vapor absorption. In addition, the desorption results show that PVCs loaded with shell powder do not rapidly evacuate stored water. This is a great advantage because a body that easily absorbs water and releases it very slowly is exposed to rapid decomposition of its structure and will degrade rapidly. This thermal behavior of palm kernel shell powder gives this powder an advantage to be considered for use as a load for polymers. When comparing the results obtained with those of work done in plant loads such as Fatima on Alfa fibers, Sbiai on date palm fibers, Mkacher on the degradation of electrical PVC gains, the observations remain similar **[14, 31, 36].**

We have represented the trend lines linking the results obtained from these tests in a reference frame and we have observed dispersions in some measurements particularly in the rate of water desorption (F4.01, F32.01) and water vapor absorption (F12.54, F23.03). We wrote the mathematical models of the trend line obtained by extrapolation of the points in the figure, then we calculated the correlation coefficients of the measurements and we obtained that they are between R^2 = 0.9974 and R^2 = 0.9991 **[31].** The values of the regression coefficient show, in spite of some dispersions, that the results remain within acceptable error tolerances. These dispersions can be due to disturbances during the control of the recordings or to the formulations of the shaping. Thus, the mathematical models for the calculation of moisture, absorption, desorption of water and its vapour from PVC loaded with shell powder can be written as shown in **Table 4.**

To summarize then, as observed in the discussion at the level of the results of the equation of the density, the equations of **fig. 9** and **table 4**, prove that, for the management of the humidities, absorptions, desorptions of water and its vapor, the plastic materials loaded with palm kernel shell powder would be suitable for the design and development of a computer interface that can help engineers, technicians, standards teams, hardware dealers, traders and even investors in this field to alleviate the usual calculations. For this reason, more and more researchers are setting up algorithms for the management of complex problems to limit the link to intellectual fatigue to humans **[31, 33].**

From these behaviors of the tubes and going through the kinetics of biodegradability of plastic materials carried out by Jbilou in 2011 in his thesis on "the evaluation of the kinetics of biodegradability composites ", then that of Ines Mkacher in the causes of aging of electric cable sheaths, we get that, PVC loaded with more than 30% of the powder of palm kernel shells are exposed to accelerated degradation at the end of life. Several works in vegetable fillers have obtained similar results as Winkler on "Mechanism of polyvinyl chloride degradation and stabilization". On this same cause, several works have shown that this particularity that have the vegetable loads to absorb quickly the water and its vapor while desorbing slowly finds its application in the sectors of activity where the materials are used for periodic purposes as the automobile construction, the household appliances, the clothing, the toys, the materials for the civil engineering **[12, 14, 35].**

For the computer interface then, According to the results obtained in the works visited in several journals, This graphical user interface (GUI) was made to meet the need for an interactive tool to quickly calculate the properties of our composite, depending on the dosage. This interface has been an inspiration of several works combining materials, applied mathematics and

applied computer science. The following essential features such as user-friendliness and ease of use, useful feedback provided to the user, almost zero calculation errors and saving of perfect results have been the product of a thorough research on several works, some of which we will mention in passing **[14, 24].**
This preliminary work gives the possibility for the future to integrate an additional option allowing to calculate the range of dosage with palm kernel shell powder, although we have rather the calculated values of the material properties by the structural engineer. This will be a help for the engineers of the design offices to limit the time of work and the dispersions in the searches of the material that it is necessary to face the results that we have. Also, the weight of the software designed accordingly allows the engineer to install it on his cell phone without occupying enough disk space, thus allowing him to work quietly even during a trip (time savings).
We stop these observations by saying for the interface that, we will put in the future an interface integrating all the properties (physical, thermal, chemical, mechanical...etc), however when their results will be validated by the reading and the observations of you the pairs of the toys.

V - CONCLUSION GÉNÉRALE

We have in the past obtained that palm kernel shells are in abundance in the world today. In the past, we have obtained that palm kernel shells can be used as load for the production of plastic materials and we have finally obtained by industrial extrusion the PVC tubes loaded with palm kernel shells powder at dosages of 0%, 4.01%, 12.54%, 23.03%, 32.02%, 38.01%, 51.02% of palm kernel shells powder. Today, the research of characterization in order to make the new material useful to engineers is the major concern of the research on this new material.
For this reason, we have taken the already extruded tubes to all the above formulations, we have used the standard methods to obtain the experimental results of the densities, water and vapor absorption and desorption of these PVCs. We represented the distribution of the points representing these experimental results on a figure to obtain the influence of the palm kernel shell powder on the PVCs and by extrapolation, we elaborated the mathematical models allowing to establish the behavior laws of all the tubes. These models thus obtained helped us to conceive and to increment a simple computer interface effective and pleasant to allow the engineers and technicians, the traders and hardware dealers, the teams of the standards and the controllers of the building sites, to calculate these physical properties when one knows the dosage with the powder of shells of palm kernel.

VI - Declaration of competing interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

VII - Additional information :

No additional information is available.

VIII - References

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