EXPERIMENTAL THERMOCHEMICAL, PHYSICAL AND MECHANICAL CHARACTERIZATION OF THE UNIAXIAL COMPRESSION OF PVC TUBES LOADED WITH 12.54% AND 51.02% OFDURA PALMKERNEL SHELL POWDER

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ABSTRACT

We have carried out here a chemical, thermal, physical characterization and a study of the mechanical behavior to the tubular compression of the PVC tubes loaded with 0%, 12.54% and 51.02% of the dura palm kernel shell powder obtained by extrusion and give an approach on its use. To achieve these objectives, we took the unloaded PVC tubes then the PVC tubes loaded with 12.54% and 51. 02% of the extruded shell powder, which we characterized: thermally by ATG/DSC with a LENSEI apparatus to obtain TG and DSC, chemically by Fourier transform infrared analysis with a Thermo Scientific Nicolet iS5 IR spectrometer to obtain FTIR, physically with standard equipment according to standards to obtain density, then mechanically by uniaxial tubular compression with a machine of compression-flexion of mark controlab to obtain the bearing capacities, the resistances and the behavior of the tubes to the uniaxial tubular compression. We obtained: at elaborated, tubes of diameter (D=90mm and d=82mm) of color light gray, dark gray, dark black respectively for the PVC tubes unloaded and loaded to 12.54% and 51.02%. DSC thermograms of the tubes showed glass transition, combustion temperature, calcination temperature and ash onset temperature and TG thermograms, mass change on dehydration, dehydrochlorination, condensation and residual calcination sensitive. FTIR showed particular groupings of the presence of: lignin from palm kernel shells and chlorine from PVC in the tubes. The density of the tubes gave 1.42 g/cm3 for the unloaded PVC tubes, 1.38 g/cm3 for the loaded PVC tubes at 12.54% and 1.23g/cm3 for 51.02% justifying the low density of the hull powder in the tubes. The bearing capacity as well as the mechanical strength, the shortening and the compression behaviour of the tube allowed to say that the unloaded PVC tubes and those loaded at 12.54% have a tenacious and ductile behaviour while those loaded at 51.02% have a rigid, brittle and fragile behaviour. These results show that the palm kernel shell powders used as loads influence in a sensitive way the physical, thermal, chemical and mechanical properties allowing several fields like aeronautics, automobile, building, toys for entertainment and laboratory materials to be interested in its production.

KEYWORDS: PVC tubes loaded with palm kernel shell powder, ATG/DSC, FTIR, water absorption, mechanical behaviour under uniaxial tubular compression.

1. INTRODUCTION

Plastics are increasingly in demand by engineers at the expense of metallic materials. This is due to the multiple properties they offer in many areas of construction. According to the literature, their use is increasing in industries such as aerospace, automotive, shipbuilding, construction and many others (1). Plastics from synthetic polymers are widely used due to their availability and relatively low cost, but they have certain properties that need to be improved such as biodegradability. For several decades, work has been done on the use of vegetable loads to solve these problems, particularly in the form of reinforcements (2) (3).

The oil palm is a plant of the agricultural sector in full development and research on palm oil has now reached a very advanced level, although it is only a part of the tree. In order to participate in encouraging investors in this agricultural field, researchers are trying to find areas that can allow the use of other parts of the oil palm in society (4) (5)(6). In this sense, the palm kernel shells of the oil palm are concerned with the research of its use as a load or reinforcement in the production of plastics.

Palm kernel shells have been characterized for use as a load (4) and they have been tested for use in the industrial production of PVC tubes by extrusion with success (7). Several works in the elaboration of plastics using synthetic polymers with plant materials as load(reinforcement) have been carried out. However, the appreciation of a new material requires a set of characterizations to allow the engineer to be interested in this plastic material in the design or realization of constructions (8)(9).

It is for this reason that, the PVC tubes having been realized, the work presented here consists in proceeding to a set of characterization having to allow to evaluate the performances of the PVC loaded with the powder of palm kernel shells. Thus, we will choose extruded PVC tubes loaded with 0%, 12.54% and 51.02% of the shell powder to which we will make basic physical characterizations then, thermal and chemical characterizations, mechanical characterizations by uniaxial tubular compression. An overview of the possibilities of using the material in construction will be discussed according to the results of the characterizations carried out. This preliminary work will allow us to continue the work of characterization of PVC tubes filled with palm kernel shell powder in order to allow engineers and industrialists, the use of this new material in construction in general, and researchers to extend the field of work of the production of plastic materials by using other synthetic polymers as matrix and the palm kernel shell powder as load and even as reinforcement.

2 -MATERIALS AND EXPERIMENTAL METHODS.

2 - 1 MATERIALS.

Resin: the resin used is the PVC described in the work of Djomi el al (4) of the company DANSUK et Cie (10).

Load: the load used is micronized dura palm kernel shell powder.The shell powder is the one obtained according to the methodology described in the work described by Djomi et al in 2018 (4).

Additive :the additives are those described in the work of Djomi et al (4) (7).

2-2 MATERIALS.

2-2-1. THERMAL ANALYSIS.

Thermogravimetric and thermo differential analysis: we used a LINSEIS STA PT-1000 C thermal analyzer of type Platinum Evaluation V1.0.182, coupled to a computer and programmed for this purpose to perform thermogravimetric and thermo differential analyses. The thermal treatment of the apparatus goes from room temperature (20°C) to 1000°C. The heating rate varies between 1°C and 100°C. The crucible is in alumina oxide with a capacity of 150 mg and a control crucible in alumina. The mass of the powder to be characterized is between 20 and 25 mg. The mass of the load is between 100mg and 125mg. The initial heating temperature depends on the ambient temperature at the time of the measurement. The heating rate according to the literature is 10°/min. The computer plots the ATG/DSC thermograms and records the data. We carry out the analyses in the Laboratories of Physicochemistry of Materials of the Faculty of Sciences of the University of Yaounde 1, Cameroon.

2-2-2. CHEMICAL ANALYSIS.

Fourier transformed infrared analysis:

Fourier transform infrared (FT-IR) spectroscopy was performed using the Nicolet iS5 IR spectrometer. We recorded the IR spectra in ATR (attenuated total reflectance) mode on a germanium crystal(11). FTIR spectra are obtained from the data records and we can trace our data in two parts: from 4000-500 cm-1 and from 500-400 cm-1. The samples are primed solid as a fine powder. The test conditions and test ranges are governed by the standard detailed in the manufacturer's catalogue(11). This analysis was carried out at the Research Laboratory of Chemistry of Nuisances and Environmental Engineering (URCHINGE) University of Dschang-Cameroon.

Balance: it is a digital balance branded SEDITECH, accuracy 1/1000th.

2-3 EXPERIMENTAL METHODS.

2-3-1. Extrusion.

The extrusion technique was described in the article "Industrial elaboration by extrusion of PVC tubes loaded with micronized dura palm kernel shell powder" (7).

2-3-2. Physical characterization of extruded PVC tubes.

We studied: the density of the tubes, the humidity rate and the water absorption rate.

2-3-3. Density.

The test tubes are of external diameter **De**=90m, internal diameter Di=82m, length **Li**=184mm. 6 tests tubes are provided per formulation.We measure the length **Li** and the mass mi of each specimen. We apply the classical relation (1) of the calculation of the density of the tubes. We obtain the density**ϱi** of each specimen in the formulation. The actual density ϱ is the average of the 6 densities of the specimens obtained in each formulation.

$$\varrho_v = \frac{4m_i}{\pi L_i({D_e}^2 - {d_i}^2)} \quad (1)$$

- $\mathbf{m_i}$ = mass of the specimens (g).
- D_e = external diameter(cm).
- Li = length of the tubes (cm).
- D_i = internal diameter (cm).

2-3-4. Moisture content measurement:

The test specimens for each test are plates taken along the longitudinal direction of the tubes. 6 specimens are provided per formulation. The tests are carried out under the same conditions of temperature, pressure and recording according to the standard. We apply the classical relation (2) for the calculation of the moisture content of the plates.

$$T_{ih} = \frac{m_{ih} - m_{is}}{m_{is}} \quad (2)$$

- m_{ih} = wet mass .
- m_{is} = dry mass.
- T_{ih} = moisture content.

2-3-5. Measurement of water absorption rate:

The test specimens for each of the tests are plates cut along the longitudinal direction of the tubes. 6 specimens are provided per formulation. The tests are carried out under the same conditions of temperature, pressure and recording according to the standard. We apply the classical relation (3) for the calculation of the water absorption rate.

$$T_a = \frac{m_s}{m_a} \quad (3)$$

- m_{ia} = absorbed mass.
- m_{is} = dry mass.
- T_{ia} = water absorption rate.

3- RESULTS AND DISCUSSION.

3-1 Extrusion result:

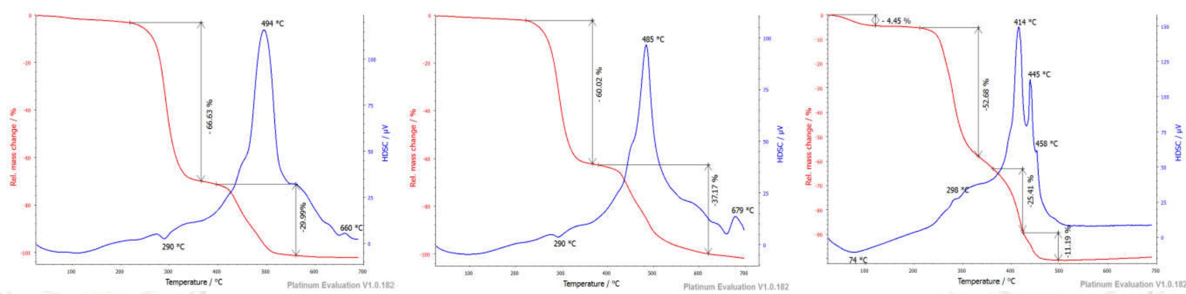
figure (a) **figure (b)** **figure (c)**

Figure 1:Extruded PVC tubes loaded with 0%, 12.54%, 51.2% of palm kernel shell powder.

We have elaborated unloaded PVC tubesfigure (a), PVC tubes loaded with 12.54%figure (b) and 51.02% figure (c)of palm kernel shell powder. The tubes are perfectly round and of different colors, of external diameter 90 and internal diameter 82 as presented in the figure 1. We cut the tubes from the factory to the laboratory to proceed to the analysis and characterization. Then, we found during the development that the extrusion of F0 and F12.54 is perfect but that of the formulation F51.02 was a little difficult because of the amount of load in the resin too high and it was necessary to adjust the temperature in order to obtain a tube accepted by the standard team of the company. Referring to the literature, several works in high load composite reinforcement have experienced the same difficulties (2) (3) (12).

3-2.Thermal characterization of extruded PVC tubes results.

3-2-1. Thermogravimetric and differential analyses.



0% **12.54%** **51.02%**

Figure 2 : TG/DSC thermogram of the elaborated tubes : from right to left : F0 ; F12.54 ; F51.02.

Figure 2 respectively the TG and DCS thermograms of unloaded PVC tubes and loaded PVC tubes at 12.54 and 51.02 present both the temperature at which the TG thermogram meets the DCS thermogram for the 3 formulations performed. We obtain that for the unloaded PVC tubes, the TG meets the DSC at the temperature of 425°C i.e. 4000s after the beginning of the heat, whereas the TG and the DSC of the loaded tubes at 12.54 and 51.02 meet respectively at the temperature of 438°C and 374°C i.e. 4130s and 3520s of heat. In addition, by observing both the TG and the DSC of all the tubes, we observe that the addition of the shell powder load in the PVC tends to create a rapid degradation of the tubes when it rises in temperature; but the powder load being enveloped by the PVC does not calcine continuously and at a certain temperature at 445°C, the powder reabsorbs heat before turning to ashes. This phenomenon is justified by the thermogravimetric and differential analysis of palm kernel shell powder, which shows that the shell powder absorbs heat continuously by decreasing its mass and maintains this heat for a long time before burning (4).

3-2-2. Results of thermogravimetric analysis of the PVC tubes produced.

TG thermogram.

We have 3 materials whose load in palm kernel shell makes the difference. The behavior of all materials to temperature increase remains the same from unloaded PVC to loaded PVC with 12.54% and 51.02% of palm kernel shell.

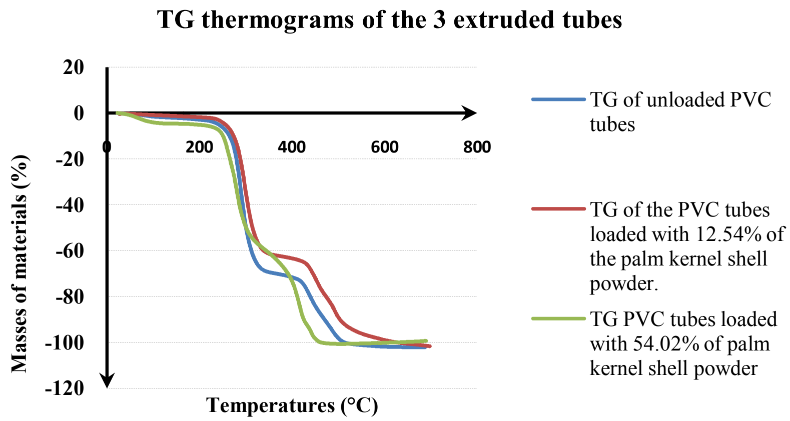


Figure 3: TG thermogram of the 3 extruded tubes.

The TG thermograms in Figure 3 of all the elaborated tubes show that when subjected to a temperature rise, they first absorb heat observable on the DSC Figure 6 by gradually decreasing its mass. This is the departure of free water commonly called water of hydration or moisture of materials.

This phenomenon is noticeable for the formulations F12.54 and F51.02 because of the presence of free water contained in the shell powder. The increase in temperature causes a slow and progressive absorption of heat by gradually decreasing its mass until a temperature close to 200°C. It is the bound water commonly called hemicellulose of the hull powder that goes away. By observing the TG of the 3 materials, we notice that after the departure of the free water, the mass of the 3 materials does not vary in a sensitive way because the raw PVC does not have hemicellulose and that of the shell powder is very small and consequently negligible.

After this departure of the cellulose from the shells, we observe a brutal decrease in the mass of the 3 materials up to a temperature close to 360°C characterizing the dehydrocloruration of the PVC, thus facilitating the degradation of the cellulose of the shell powder, particularly observable for the tubes loaded to 12.54% and 51.02%. Beyond the temperature which makes the cellulose leave and provoke the dehydrocloruration of the PVC, a brutal rise of the materials calcines the bodies and transforms the bodies into vapor and gases which are released. The end of the release of these gases presents a strong disappearance of the mass of the materials.

During the passage to the state of ash, certain crystals which have volatilized return to the crucible and are consumed for the second time, thus creating the phenomenon of relaxation produced in the vicinity of 550°C for F0 and F12.54 and 437°C for F51.02. This is the recombustion of the PVC crystals and their load which had not been able to calcine completely, absorb heat to become total ash. Figure 11 below shows the results of the TG thermograms of the 3 materials, i.e. the phase change temperature with the consequent mass losses.

3-2-3. Results of thermogravimetric analysis.

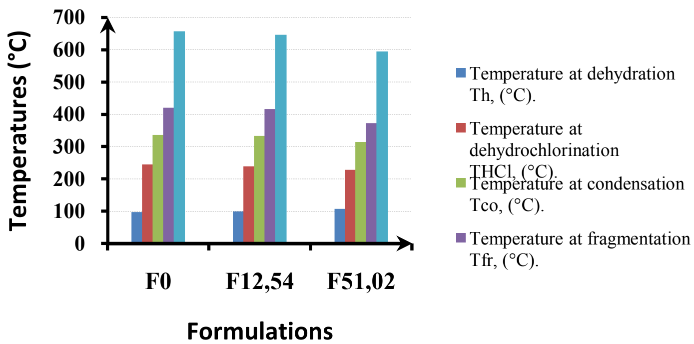


Figure 4: Phase transition temperatures of the tubes at TGA.

We obtain from Figure 22 that:

The unloaded tubes F0 have a dehydration phase transition temperature of 96.71°C, a dehydroclorination phase temperature of 244.71°C, a condensation phase temperature of 355.71°C, a fragmentation phase temperature of 420.71°C and a residual calcination temperature of 657.71°C.Similarly, the tubes loaded with 12.54% palm kernel shell powder have a dehydration phase transition temperature of 99.58°C, a dehydroclorination phase temperature of 238.58°C, a condensation phase temperature of 333.58°C, a fragmentation phase temperature of 416.58°C and a residual calcination temperature of 646.58°C.Finally, the tubes loaded with 51.02% palm kernel shell powder have a dehydration phase transition temperature of 107.56°C, a dehydroclorination phase temperature of 227.56°C, a condensation phase temperature of 314°C, a fragmentation phase temperature of 372.56°C and a residual calcination temperature of 594.56°C.

3-2-4. Mass loss at degradation phase transition temperatures.

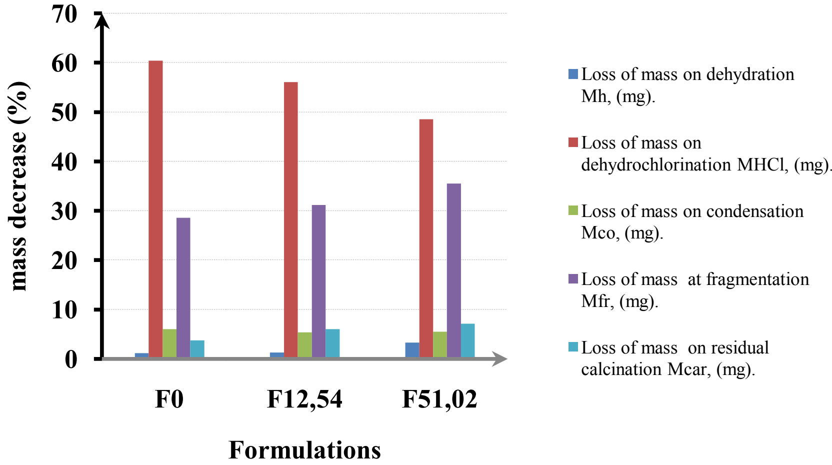


Figure 5: mass loss at degradation phase transition temperatures.

Figure 5 shows the mass losses during the transition from one phase to another. We obtain that,

The unloaded F0 tubes have a mass decrease when passing the dehydration phase transition temperature of 1.16%, a mass decrease when passing the dehydroclorination phase temperature of 60.41%, a mass decrease when passing the condensation phase temperature of 6.050%, a fragmentation phase temperature of 28.60% and a mass decrease when passing the residual calcination temperature of 3.76%.Similarly, the tubes loaded with 12.54% palm kernel shell powder have a mass decrease when passing the dehydration phase transition temperature of 1.31%, a mass decrease when passing the dehydroclorination phase temperature of 56.03%, a decrease in mass when passing the condensation phase temperature of 5.39%, a fragmentation phase temperature of 31.20% and a decrease in mass when passing the residual calcination temperature of 6.05%.Finally, the tubes loaded with 51.02% of palm kernel shell powder have a mass decrease when passing the dehydration phase transition temperature of 3.27%, a mass decrease when passing the dehydroclorination phase temperature of 48.54%, a decrease in mass when passing the condensation phase temperature of 5.51%, a fragmentation phase temperature of 35.50% and a decrease in mass when passing the residual calcination temperature of 7.15%.

3-2-5. Results of Differential thermal analysis of the PVC tubes produced.

DSC thermogram.

Figure 6 below shows the DSC thermograms of unloaded extruded PVC tubes, and extruded PVC tubes loaded with palm kernel shell powder.

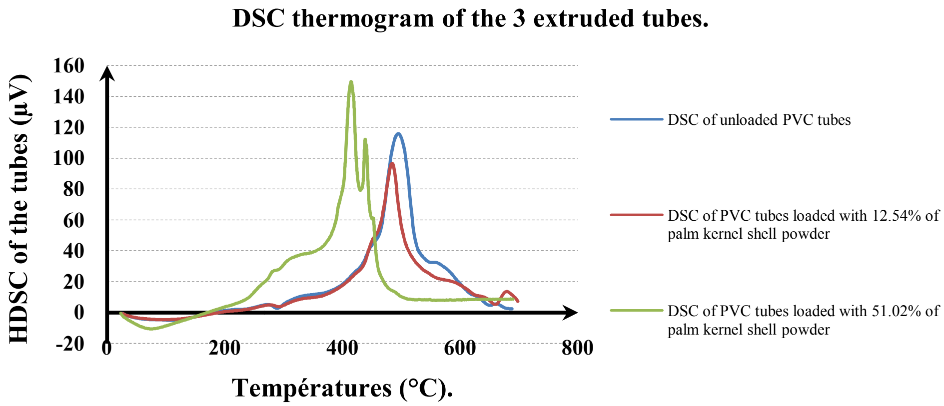


Figure 6: DSC thermogram of the 3 extruded tubes.

The DSC thermograms in figure 6 of all the elaborated tubes show that when they are subjected to a temperature rise, they first absorb heat up to its glass transition temperature (Tg). The consequence of this heat absorption is a progressive decrease of the mass observable in the TG figure 9. This is the departure of free water commonly called water of hydration. The increase in temperature causes a slow and progressive absorption of heat (≈6µv) up to its melting temperature this observable for unloaded tubes and 12.54% loaded tubes. Similarly, for the tubes loaded with 51.02% hull powder, we observe a large and sudden heat absorption (≈25µv) this impacting the mass of the material causing the departure of the hemicellulose and cellulose contained in the hulls and observable at the TG. The following rise in temperature then causes the material to dissociate into crystals which releases a large amount of heat in the vicinity of 100µv for the F0 and F12.54 tubes, then in the vicinity of 150µv for the F51.02 causing the material to burn in the vicinity of 413°C. During the transition to the ash state, a phenomenon known as the relaxation phenomenon occurs in the vicinity of 550°C for the F0 and F12.54 tubes, then 437°C for the F51.02 tubes. This is the recombustion of the PVC crystals and their load, which have not been able to calcine completely, and which absorb heat to become the total ash.

3-2-6. Results of the differential thermal analysis.

Figure 7 below shows the DSC thermogram results of all PVCs and extruded PVCs loaded with palm kernel shell powder.

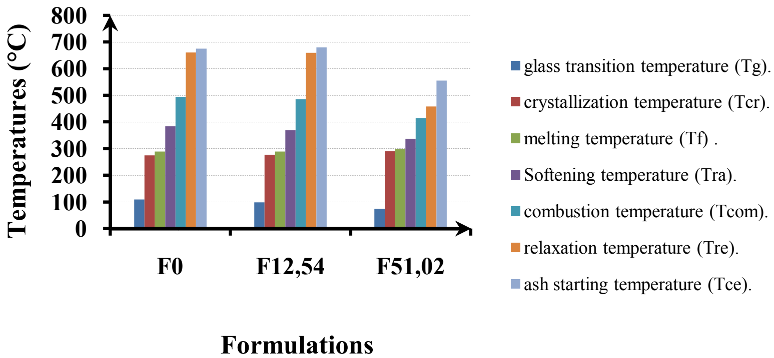


Figure 7: Phase transition temperatures of tube decomposition.

From the thermograms of the thermo differential analyses in figure 7, we obtain that: The glass transition temperature (Tg) of the unloaded PVC tubes is Tg=108.78°C, that of the 12.54% loaded PVC tubes is Tg=98.58°C and 51.02% of the shell powder is Tg=76.56°C.The thermal combustion temperature (Tc) of the unloaded PVC tubes is Tc=494.71°C, that of the 12.54% loaded PVC tubes is Tc=485.58°C and that of the 51.02% loaded PVC tubes with palm kernel shell powder is Tc=414.56°C. The starting temperature of the ash (Tce) of the unloaded PVC is Tce=475.71°C, that of the PVC tubes loaded with 12.54% is Tce=659.58°C and that of the PVC tubes loaded with 51.02% palm kernel shell powder is Tce=555.56°C.

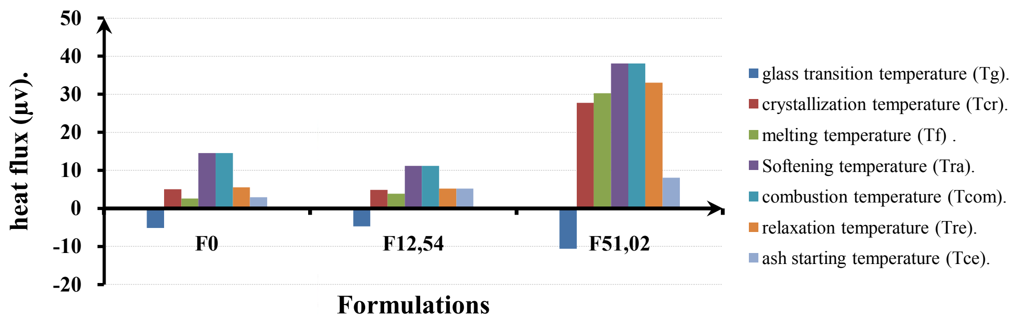


Figure 8: Heat absorbed at the phase transition temperatures of the decomposition of the tubes.

From figure 8, we obtain that, at the time of the glass transition, the tubes of mixture have already absorbed respectively -5.129µv, -4.67µv, -10.603µv. This justifies that the more there is of shell powder, the more the tube absorbs heat. Thus, at crystallization, the tubes give off heat up to 5.028 µv, 4.906 µv, 27.699 µv. This absorbed heat causes the tube to soften and thus the tube enters into fusion by absorbing a respective heat of 14.57 µv, 11.209 µv, 38.0 µv for. This increasing amount of heat forces the tube to burn around Tc=494.71°C, Tc=485.58°C,Tc=414.56°C. This burning makes so that in the flame, there are residues that cannot be consumed and become totally the flame. The temperature being in increase, the PVC absorbs even more heat in the vicinity of 5.515 µv, 5.18 µv, 33.012 µv so that all the PVC powder thus raised in temperature becomes totally the ash in the vicinity of Tce=475. 71°C, Tce=659.58°C, Tce=555.56°C. After this temperature, the remaining powder can no longer absorb heat and only release 2.90 µv, 5.204 µv, 8.039 µv respectively.

3-3 Chemical characterization of extruded PVC tubes results.

3-3-1. Results of the FTIR.

The spectra in the figure below show the results of the FTIR analysis of the extruded PVC loaded with palm kernel shell powder.

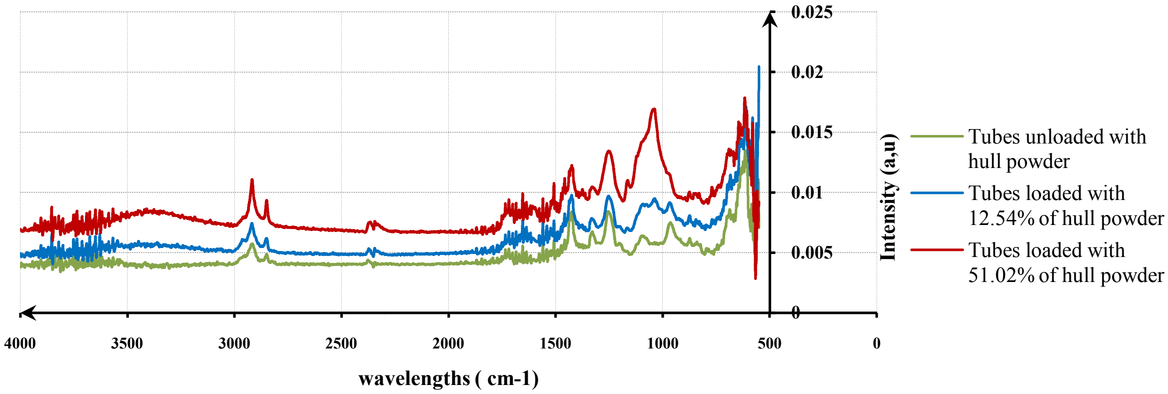


Figure 9:Results of the infrared-FT analyses of the elaborated tubes.

Figure 9 shows the FTIR spectra of the unloaded PVC tubes and the PVC tubes loaded with 12.54% and 51.02% of the palm kernel shell powder. We observe a series of background noises at wavelengths near 600Cm-1 and above 3500Cm-1. These noises come from the nature of the analysis and, when an element is far from the surface of the analysis, many electrons emitted will undergo inelastic shocks on their trajectories thus losing kinetic energy to come to constitute the background of the spectrum. These noises are present in all materials as well as unloaded PVC and loaded PVC of palm kernel shell powder.

We observe peaks characterizing the presence of PVC in all spectra. The most striking peaks are present at wavelengths around 800 cm-1 representing the -C-Cl groups, then 1100 cm-1 representing the - C-O groups present in the PVC.

On the other hand, peaks characteristic of the presence of palm kernel shell powder are present in the spectra at formulations of 12.54% and 51.02% but absent in the spectra of the 0% shell powder formulation. The most striking are at wavelengths near 3300cm-1 representing the -O-H groups, showing the presence of cellulose from the hull powder, and then near 2700 cm-1 representing the -C-H groups, showing the presence of lignin from the hull powder.

3-3-2. Fourier transforms infrared (FTIR) results of extruded PVC.

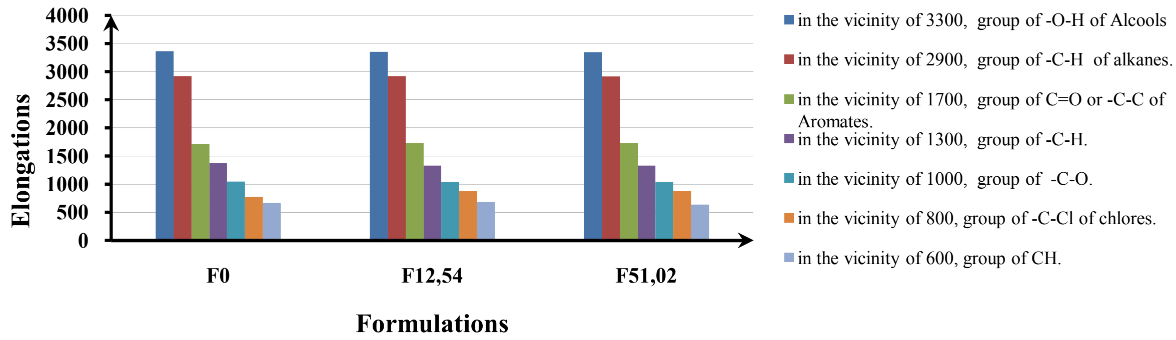


Figure: 10: Results of the fourier transform infrared analysis of the elaborated tubes.

We obtain from figure 10 that:

For unloaded PVC, the peaks characterizing the -O-H groups of alcohols are exactly at elongations of 3363.2 Cm-1, those of the -C-H groups of alkanes are at elongations of 2919.64 Cm-1, those of the -C-H or -C-C groups of aromatics are at elongations of 1718.06 Cm-1, those of the -C-H groups are at elongations of 1374.63 Cm-1, those of the -C-O groups are at elongations of 1044.64 Cm-1. Those of the -C-Cl groups are at elongations of 770.68 Cm-1, those of the CH groups are at elongations of 665.66 Cm-1.

At the same time, for the PVC tubes loaded af 12.54%, the peaks characterizing the -O-H groups of alcohols are at elongations of 3351.3 Cm-1, those of the -C-H groups of alkanes are at elongations of 2918. 33 Cm-1, those of the -C-H or -C-C groups of aromatics are at elongations of 1731.17 Cm-1, those of the -C-H groups are at elongations of 1331.8 Cm-1, those of the -C-O groups are at elongations of 1037.53 Cm-1. Those of the -C-Cl groups are at elongations of 874.18 Cm-1, those of the CH groups are at elongations of 683.3 Cm-1.

Finally, for the PVC tubes loaded af 12.54%, the peaks characterizing the -O-H groups of alcohols are at elongations of 3345.61 Cm-1, those of the -C-H groups of alkanes are at elongations of 2917. 56 Cm-1, those of the groups of -C-H or -C-C of the aromatics are with elongations of 1734.32 Cm-1, those of the groups of -C-H are with elongations of 1329.67 Cm-1, those of the groups of -C-O are with elongations of 1038.72 Cm-1. Those of the groups of -C-Cl are at elongations of 875.01 Cm-1, those of the groups of CH are at elongations of 638.083 Cm-1.

3-4 Results of physical characterizations of extruded PVC tubes.

3-4-1. Results of the water absorption of the elaborated tubes.

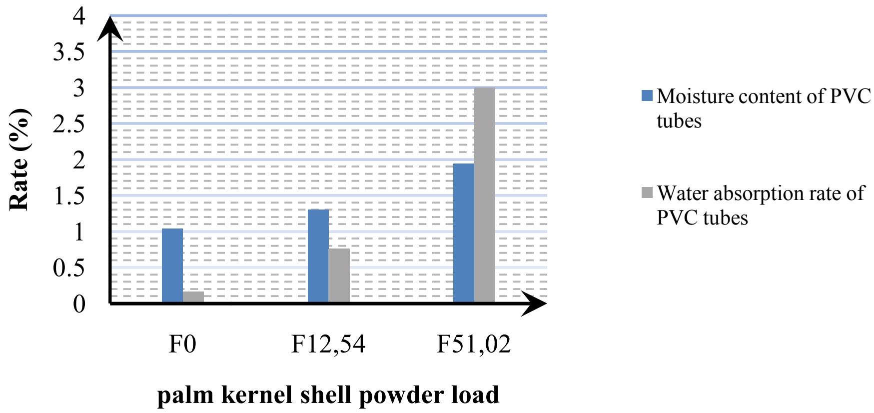


Figure 11: Absorbance results of the elaborated tubes.

The results recorded in Figure 11 show that:

- The unloaded F0 PVCs in the elaborated formulation have a relative moisture content of 1.04 and water absorption 0.165.
- Similarly, 12.54% filled PVCs have a moisture content of 1.303% and water absorption of 0.758%.
- PVC loaded 51.02% have a respective rate of 1.943% for moisture content and 2.996% for water absorption.

All these results show that palm kernel shell powder has a considerable influence on the climate behavior. Water is rapidly absorbed by palm kernel shell powder, hence the high results at 51.02% formulations.

3-4-2. Results of the density of the elaborated tubes.

Table 1: Density of PVC tubes loaded with palm kernel shell powder.

Formulations	F0	F12.54	F51.02	units.
Density of PVC tubes loaded with palm kernel shell powder.	1.42±0.021	1.38 ±0.015	1.23 ±0.035	g/cm^3

We say from Table 1 that the density of unloaded PVC tubes F0 is 1.42 ±0.021 g/cm3, that of PVC loaded with palm kernel shell powder at formulations F12.54 is 1.38 ±0.015 g/cm3 and that of F51.02 is 1.23 ±0.035 g/cm3 conforming to the standards with the assumptions of extrusion set out in the paragraph materials and experimental methods.

3-5 Results of the mechanical characterizationsof extruded PVC tubes.

Results of uniaxial tube compression.

The tubes are used not only for piping, but also for its bearing capacity. The need to determine the parameters for this use is important. The principle consists in exerting a force parallel to the axis of the tube in order to compress it. We worked according to the standard NFT 51-101, here we determine the results of the forces as a function of the decrease in length, compressive strength as a function of short.

3-5-1. Compressive forces as a function of length decrease.

Curve of forces as a function of length decrease.

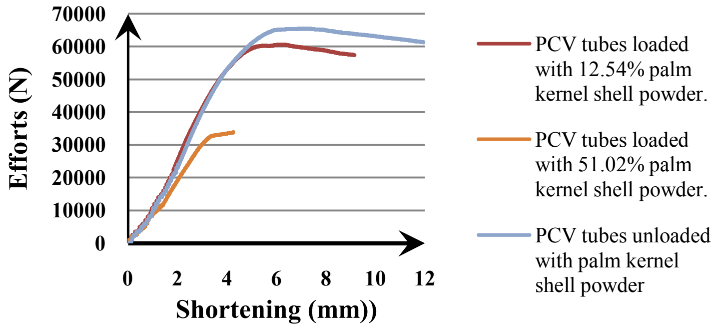


Figure 12: Compressive stress curve of elaborated tubes as a function of length decrease.

We observed the specimens during practical loading and the pattern of length decrease under compressive forces. We obtained the records of the efforts according to the decreases in length of the specimens. We have analyzed the results of the broken specimens. We have obtained the average curves at failure in figure 12 above. We say with certainty that:

For materials F0 and F12.54, the length of the specimen decreases proportionally with the forces applied to them up to a limit force, this is the maximum force (Fm) commonly called the bearing capacity of the tube that they can support. Following the solicitation, the length of the specimen decreases, but the applied forces also decrease and we see that the tube is in its zone of stricture and we observe an increase in diameter until its total splitting, which leads us to record a force (Fr) at the time of failure and ΔLu which is the maximum decrease in length of the tubes to uniaxial compression.

For the materials the tubes of formulation F51.02, the materials in their solicitation, the length of the specimen decreases proportionally with the efforts that are applied to them until a limit effort (Fm) commonly called bearing capacity of the tube. Following the stress, we observe an abrupt rupture without any noticeable diametrical deformation of the tubes. Thus, these tubes do not have a considerable stress zone.

The results and the behavior of the tubes in their compressive solicitations are given in the following figures13, 14,15.

3-5-2. Results of the uniaxial compression forces as a function of length reduction of the elaborated tubes.

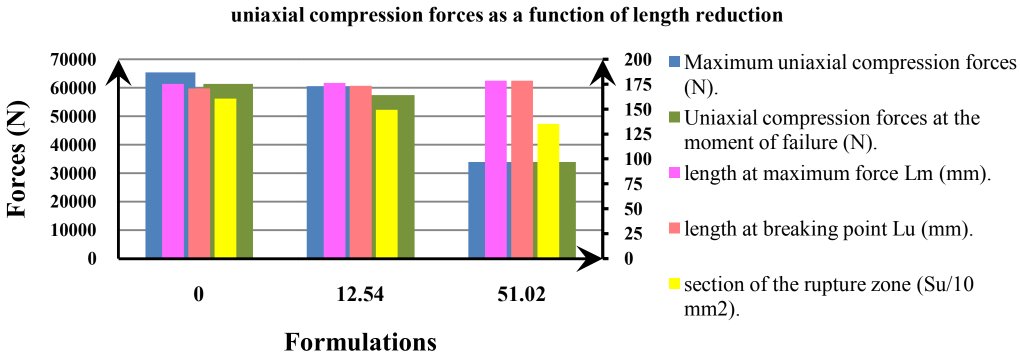


Figure 13: Results of the uniaxial compression forces.

We obtain from Figure 13 that:

The maximum force that the unloaded PVCs (F0) can withstand is Fm=65431N, that of F12.54 is Fm=60540N and that of F51.02 is Fm=33901N. Similarly, the stress that the tubes can have at the moment when the breakage occurs is for unloaded PVCs F0 Fu= 61300N, those of PVCs loaded with palm kernel shell powder at formulations F12.54, Fu=59850N and F51.02 Fu=33901N. Then in the zone of stricture, we observe a large increase in diameter for F0, and F12.54 and almost no increase for F51.02 with bursting at failure.

Finally, at the end of the rupture, we obtain a decrease in length corresponding to 11.963 mm for the unloaded tubes, to 9.154 mm for the tubes loaded to 12.54% and to 4.258 mm for the tubes loaded to 51.02%.

3-5-3. Uniaxial tubular compressive strength of elaborated tubes.

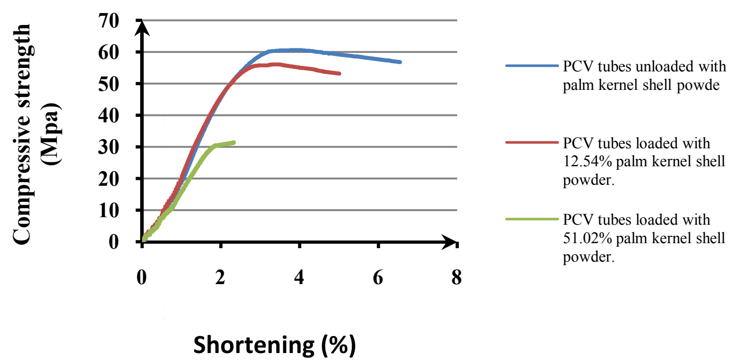


Figure 14: Conventional uniaxial tubular compression curves of tubes.

We obtain from figure 14 that when a force is exerted on all the tubes, they compress progressively and proportionally to the resistance to which they are subjected up to a limit which is the mechanical resistance Rm of the tube. At this point, the tube deforms by shortening by a value Rc% which is the shortening at a limit of the mechanical strength of the tubes. We note that at this strength, the release of the force does not damage the tube. On the other hand, the continuation of the solicitation shows that, the tube breaks by bursting without very appreciable increase in diameter as in the case of F51.02 and, others rather crush considerably before breaking, it is the case of F12.54, and of F0 by increasing diameters in a very perceptible way.

3-5-4. Results of the uniaxial tubular compression strength of elaborated tubes.

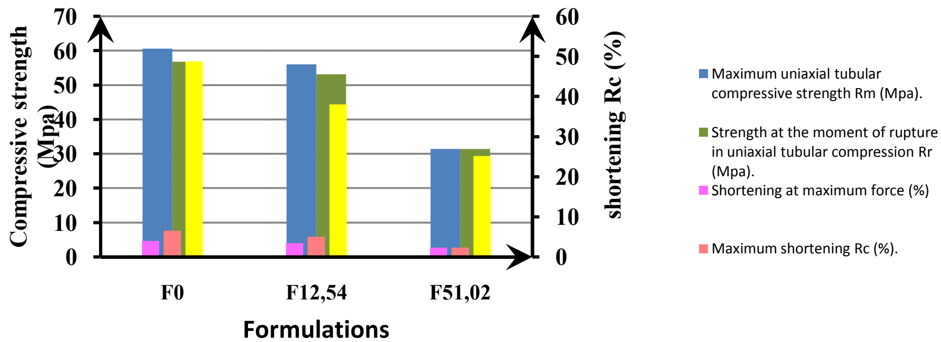


Figure 15: Results of the uniaxial tubular compression strength of elaborated tubes.

We have analyzed the records and the conventional uniaxial compression curves. We obtained that the mechanical strength of the unloaded PVC F0 is Rm =60.575Mpa at the time when those of the PVC loaded with palm kernel shell powder is Rm= 56.047MPa for F12.54 and Rm = 31.385MPa. Similarly, the breaking strength of the unloaded PVC is Rr=55.751Mpa, while that of the shell powder loaded PVC is Rr=53.170Mpa for F12.54 and Rr=31.385Mpa for F51.02.

The unloaded PVC tubes F0 shorten longitudinally by Rc%=6.55 at break while the loaded PVC tubes shorten longitudinally by Rc%=5.84 for F12.54 and Rc%=2.33 for F51.02.

The consequence of the modification of the mechanical resistance and then of the elongation per cent (%) impacts directly on the stricture of the material. Thus, we obtain that the unloaded PVC F0 increases in diameter (ultimate section Su) so as to obtain the striction Z= 20.14% and that the loaded PVC vary from Z= 15.62% for F12.54 and Z= 0.47% for F51.02.

3-5-5. Behavior of elaborated tubes to uniaxial tubular compression.

We obtain 3 zones of compression deformation, but the zone of elastic deformation and the zone of permanent deformation are confused. This observation is common for all plastic materials according to the literature (15). For the zone of stricture, we observe 2 cases of the deformation. The F51.02 formulations fail immediately after the maximum load and do not show a noticeable failure section. The initial section is approximately the same as the failure section. For formulations F0 and F12.54, the tubes shorten and the stresses gradually reduce. The tubes increase considerably in diameter before failure justifying the results obtained at the stricture (Z) and the lengths reduce sensitively at failure (16). These observations allowed us to summarize Table 2 representing the characteristic uniaxial tube compression parameters of the elaborated tubes.

Table 2: characteristic properties of uniaxial tubular compression of elaborated tubes.

Properties	F0	F12.54	F51.02	units
Maximum force or bearing capacity (Fm)	65431	60540	33901	N
Maximum strength (Rm)	60.575	56.047	31.385	MPa
Shortening per cent (A%).	6.55	5.01	2.33	%
Strictness coefficient (Z)	20.14	11.60	0.47	%
Behavior	Elastic	Elastic	Rigid	/
	Ductile	Ductile	Fragile	/

We obtain from Table 2 that, with the parameters of elaborated,
The PVC tubes unloaded with palm kernel shell powder are tough and ductile with a load bearing capacity of 65431N, a mechanical resistance to tubular compression of 60.57Mpa, a longitudinal shortening of 6.55% and a coefficient of striction of 20.14%.Similarly, the PVC tubes loaded with 12.54% of palm kernel shell powder are tough and ductile with a bearing capacity of 60540N, a tubular compressive strength of 56.04Mpa, a longitudinal shortening of 5.01% and a striction coefficient of 11.60%.Finally, the PVC tubes loaded with 51.02% of palm kernel shell powder are rigid and fragile with a bearing capacity of 33901N, a tubular compressive strength of 31.385Mpa, a longitudinal shortening of 2.33% and a coefficient of stricture of 0.47%.

3-6 Discussions and recommendations.

The DSC results obtained on the samples with high load percentage give very close results to the Tg and Tce. This glass transition value (Tg) obtained shows the effectiveness of the temperature resistance of PVC/shell powder.Thepresence of shell powder with high percentage of load presents a good degradation of the material at the end of life (17) (2) (18).

Indeed, the absorption and water content results show that the plastic material from PVC with the shell powder load has high water content and water absorption rate. Water is present in the material all the time and especially when it rains. According to the literature (2) (3), when a body absorbs enough water, it also degrades quickly. This gives an advantage to the plastic material when it is at the end of its life to degrade quickly which solves the problem of environmental pollution by plastic waste. Secondly, we get results from the density that the plastic material loaded with the shell powder is very light due to the very low density of the shell powder (4). These materials obtained from these loads have an advantage in several fields such as aerospace, automotive, construction where the weight of the device is called to be low to take advantage of its total mass to ensure a set of satisfaction to its user. Finally, the results of uniaxial tubular compression of the elaborated tubes give the characteristic parameters of the sensitive tubular compression. According to the literature (1), (9), PVC tubes are used for water pipes. But the results of uniaxial tubular compression of forces as a function of length, compressive strength as a function of shortening show that these tubes may be suitable for exploitation of its load-bearing capacity (9). (13). (19). The F0, F12.54 tubes are ductile, elastic and strong. In addition, they can undergo deformations of small deformation angles and large bending diameter. The tubes exhibit shrinkage before failure. These tubes can undergo deformation if they are elevated in temperature. F51.02 materials are stiff and brittle. They are not resistant. Therefore, for its use, it is necessary to obtain the final shapes during elaboration. No buckling is possible. This behavior is found in the ATG and DSC where the glass transition temperature decreases with the loading rate. So does the density, water absorption.

Recommendations:

Going through the observations obtained in the above characterizations, we obtain that the palm kernel shell powder as a load in the elaborated plastic material offers advantages as:

In the environmental pollution, from the point of view of its thermal behavior, water absorption power and the presence of cellulose and lignin of the shell powder contained in the elaborated material, the plastic material obtained will be very quickly degraded when it is at the end of its life. This gives a great advantage to further research on the use of palm hull powder as a load for synthetic polymers in general.

In the automotive industry, with such a low density, increasing the hull powder load makes the vehicle as light as possible and reduces fuel consumption, which directly leads to the reduction of greenhouse gas emissions in the atmosphere. This material can be used in many parts of the vehicle, such as the roof, interior doors, front and rear bumpers, embellishments, especially due to the results of its compressive strength, and why not think of the rims loaded with powdered shells and reinforced with fibers.

4- CONCLUSION.

In recent years, new plastic materials have been created in the research world. The validation of a material goes through a series of characterizations that allow it to find an application in the industry. For this reason, the work presented here consisted in taking the powders of palm kernel shells dura micronized, mixing them with PVC with its additives of extrusion to produce the PVC tubes with formulations of 0%, 12.54% and 51.02%. We have researched the thermal, chemical, basic physical and mechanical characteristics of uniaxial tube compression of the tubes before giving an application approach. We obtained for the extrusion, tubes of external diameter 90 mm and internal diameter 82 mm, perfectly round, from smooth shiny to dark black. For the thermal characteristics, the glass transition of the tubes is 108.71°C, 98.58, 74.56°C and the combustion temperature is 494.71°C, 485. 58, 414.56°C at DSC, the mass loss during dehydration is 1.176%, 1.315%, 3.32%%, the residual calcine is 3.761%, 6.053%, 7.154% at TG this for the formulations F0, F12.54, F51.02

respectively For the chemical characteristics of the tubes, the peaks characterizing the presence of PVC in the tubes obtained is sensitive to peaks at wavelengths in the vicinity of 800 cm-1 representing -C-Cl groups namely 770.68 cm-1, 874.8 cm-1, 875.01 cm-1, and at 1100cm-1 representing - C-O groups ranging from 1044. cm-1, 1037.53 cm-1, 1038.72 cm-1, the peaks characterizing the presence of palm hull powder in the obtained tubes is sensitive to peaks at wavelengths in the vicinity of 3300cm-1 representing -O-H groups ranging from 3363.20 cm-1, 3351.03 cm-1, 3451.22 cm-1 of cellulose, then in the vicinity of 2900 cm-1 representing -C-H groups namely 2910.06 cm-1, 2918.33 cm-1, 2917.56 cm-1 of the lignin of the hull powder, respectively for the formulation F0, F12.54, F51.02. For the physical characteristics of the tubes, the densities of 1.429g/cm3, 1.38 g/cm3, and 1.23 g/cm3, with moisture content of 1.040%, 1.303%1.943%, the water absorption rate of 0.165%, 0.758%, 2.996% were obtained for formulation F0, F12.54, F51.02. For the uniaxial tubular compression mechanical characteristics, the load capacities of 65431N, 60540N, 3390N, the uniaxial tubular compression mechanical strengths of 60.57Mpa, 56.04Mpa, 31.38Mpa respectively for formulations F0, F12. 54, F51.02 and the elastic, tough, ductile behaviors for unloaded tubes and 12.51% loaded PVC tubes then rigid, brittle for 51.02% loaded tubes were obtained. These results show that the PVC tubes loaded with shell powder constitute a new plastic material which deserves to be studied particularly for the fields of activity such as aeronautics, automobile, construction, toys for entertainment and laboratory materials.

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