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INFLUENCE OF TEMPERATURE ON THEBIOCOMPATIBILITY AND MECHANICALBEHAVIOR OF A BIOSOURCED POLYMER

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ABSTRACT

This article is aiming to a continuous improvement of the quality of the materials by their bio-loading while contributing to contribute to the preservation of our ecological environment. In fact, industrial activity is based on the exploitation of the so-called non-renewable fossil who have so an expansion of technological progress. Indeed, certain criteria of performance of durable materials are closely dependent on those of preservation of the environment. With this in mind, we offer a design of new composite materials more efficient and sustainable industrialization by reinforcing polymers by loads of renewable resources.

In fact, this design will depend on the processing temperature and the dosage of the bio-loading of the basic material to ensure the biocompatibility of the new eco-composite and subsequently confirm its expected mechanical performance.

Keywords: Bio-loading, processing temperature, biocompatibility and eco-composite.
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1. INTRODUCTION

Natural polymers were the first materials used: wood and plant fibers, leather, tendons of animals, wool, etc. Polymers are used mainly for their flexibility, their ease of formatting, their lightness, their surface properties; their resistance to various chemical environments, their insulating, thermal and electrical properties. However, they are limited in temperature since their mechanical properties deteriorate as soon as the temperature rises and they are low in hardness, tensile strength (except the fibers) and erosion [1].

Considering the long-term effects of human actions on nature, the idea is to manufacture eco-composites from polymers as (soft PVC, PVC plasticized, PVC rigid) polyvinyl chloride, reinforced by naturally present loads or excerpts from biomass, or obtaining high-performance composite materials. This base material has the acronym PVC, contains much of chlorine (17% of the atoms, 57% of the mass) which is a mineral element and its production requires less oil [2-3].

As natural filler, the horn is a substance composed of keratin, which offers it protection, warmth, virility and vital force.

Living, the horn has certain moisture, tenderness, elasticity and can be easily transformed after drying and hardening.

It is ground, which makes it possible to obtain a powder material ready to use and in an industrial way. Indeed, this powder can be molded and injected into polymer materials: a second life for the horn and an alternative to plastic [4].

2. CHARACTERIZATION STRATEGY OF THE VIRGIN MATERIAL

2.1. Bio-loading assumptions

In the perspective of continuous improvement of composite materials by bio-loading, a first experiment of the virgin biological load implemented made it possible to verify the hypotheses put forward, to acquire positive classification criteria and exploit its mechanical characteristics such as the maximum stress at break, the relative deformation and the Young module of material in question[4].

This bio-load of animal origin comes in the form of regular thickness and generally smooth surface (Figure 1). It is thinner at its base than at its end. The lower part is rough surface and streaks at fairly regular intervals. While “dead”, this fabric is produced by the living. It is composed of sulfur-rich proteins, forming fibers. Once, it was proven to be a material of value to be subject of a lot of articles. In mythology, this symbolizes material abundance perpetual extravagance; it produces much from little [5].

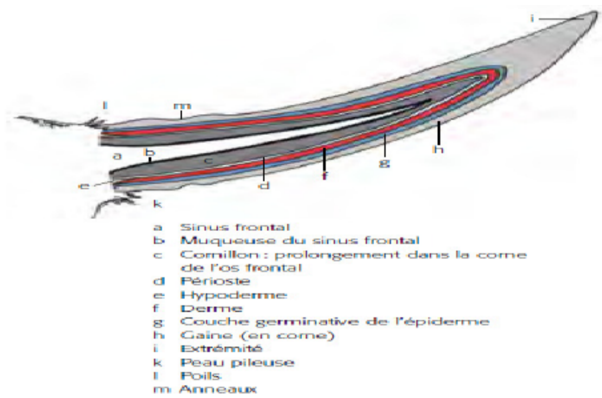


Figure 1 Longitudinal sections of the corne.

2.2. Analysis of the elastic behavior of the virgin material

The experimental study on biomaterial illustrated a variability of reactivity of material to the requests with extension under similar conditions of experiment during the tensile test [4].

These mechanical behaviors, characterized by the reversibility of the deformations during the suppression of the constraints, only appears for constraints lower than a limiting value, noted “Re”, which is called limit elastic. Nevertheless, beyond this limiting value, the permanent deformations are added to the elastic strain and/or well the rupture occurs. During the tensile tests on fibers, the ultimate constraint presents a relatively important dispersion. That comes owing to the fact that the rupture is related to the preexistent fiber orientation [4].

This mechanical behavior has recorded that biomaterial have significant Young module being able to play an interesting role in the improvement of the performances after the organic-loading of the composites [6].

This study showed that variation of mechanical qualities of the biomaterials respond to the direction of fibers of material: Different behavior in all the directions. It is a material with anisotropic behavior. This behavior is considered to be favorable to a exploitation o of the organic-load of animal origin for the innovation of certain composite materials [4-7].

In terms of sustainable development, two principal approaches will be developed in this research future outlook: The development of the recycling of the animal bodies at the end of the lifetime thanks to the improvement of the performances of identification and the development of materials organic-charged with renewable resources starting from organic biomasses [8-9].

3. APPROACH TO EXPERIMENTING THE ECO-MATERIAL

The use of materials leads to define the qualitative properties that are expected of them. To measure these properties, it is necessary to carry out test the behavior of a metal under conventional conditions close to practical situations. Most often, a material is selected for its mechanical properties under the conditions of use provided: elastic deformation ("elasticity") or plastic without breaking ("ductility"), resistance to penetration ("hardness"), Shock ("tenacity") or fatigue ("endurance").

3.1. Implementation of bio-industrialization

The use of bio-sourced materials contributes considerably to the preservation of natural resources. This is the reason why it is encouraged when renovating materials [9-10].

A bio-sourced product does not suggest that it is 100% derived from a biomass. In order to benefit from the advantages of each constituent. It is very common to generate products mixing several origins (fossil, mineral, vegetable or animal) [6].

For an industrialist, there are three main motivations which are taken into consideration in the choice of a specific material depends: optimizing its costs and varying its supply so as to stay always competitive in the event of market fluctuations; obtaining new functionalities and properties; diminishing the negative impact of its environmental footprint [11].

3.1.1. Basic Composite

Among the basic materials chosen for the perspective characterization, polyvinyl chloride (PVC) which can be found in two type states: Flexible or rigid [12].

Table 1 Mechanical Properties of PVC

Properties	Units	Rigid PVC	Soft PVC
Stress at break Elongation at break Flexural strength Traction Module Bending module Shore D hardness	MPa % MPa MPa MPa	50	10-20
Elongation at break	% % MPa MPa MPa	10-50	200 à 500
Flexural strength	MPa % MPa MPa MPa	70-80	-
Traction Module	MPa % MPa MPa MPa	2 400	-
Bending module	MPa % MPa MPa MPa	2 000	-
Shore D hardness		70-80	20-40

Table 2 Electrical properties of PVC

Properties	units	Rigid PVC	Soft PVC
Cross-sectional resistivity	Ω.cm%	1016	1011
Relative permissivity (from 50 Hz to 105Hz)	-	3,4	3 to 5
Dielectric loss factor (from 50 Hz to 104 Hz)	-	70 to 10-4	0,1 to 0,15

The main advantages of PVC are: highly economical; decent chemical resistance and intrinsically flame retarded.

As for the flexible PVC type: Soft and transparent and the Rigid PVC type: good mechanical strength; transparency and relatively good UV resistance.

While the main disadvantages of PVC are: delicate transformation which can cause a quick degradation of the material; limited chemical resistance to solvents; discoloration at high UV exposures and limited temperature resistance [13].

3.1.2. Compactness study of mixtures

The development of a new polymeric material can be accomplished following one of the two strategies: on the one hand, to conceive and synthesize a new molecule with the desired performances; On the other hand, associating the advantages of existing polymers to design a material displaying a synergy of properties. The first strategy is not necessarily the most followed. As a matter of fact, many of the conventional or technical polymers we use were synthesized before the 1980s [14]. The development of a new polymer, its synthesis at the industrial level and the development of appropriate transformation processes are long and difficult steps to undertake. The second method consists in mixing or associating polymers known for their ability to combine their properties. In an industrial application, it is indeed the compatibility that will be a determining criterion, since we will seek to match the properties of a material - possibly multiphase - and specification, without necessarily having to worry about morphology [15]. When two polymers of different nature are miscible, a homogeneous mixture is obtained which acts as a single polymer, the characteristics of which depend on those of the "parent" polymers.

The authentic mixtures, those that lead to homogeneous materials, are case studies. More often than not, most pairs of polymers are not miscible (we will still talk about mixing) and at the microscopic level, we can distinguish several phases [16]

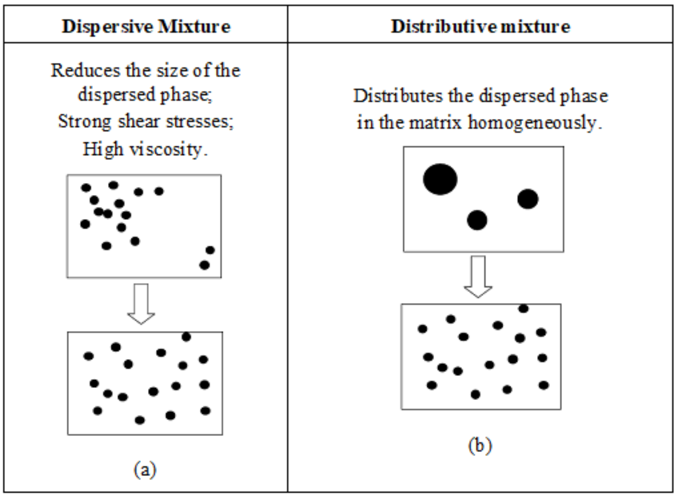


Figure 2 Dispersive and distributive mixtures

In the case of mixtures, in addition to the thermodynamic and chemical aspects, it is very important to consider the mechanical aspects in the use of polymer mixtures.

Regarding the governing principles in the mechanism of mixing two immiscible viscous liquids such as polymers, the dispersive mixture and the distribution mixture are often distinguished, the characteristics of which are specified in the Figure 2.

3.1.3. Profiling process

In general, the mixtures of the charge are often shaped in the molten state in more or less standard machines of the extruder type, the screw profile of which must be carefully chosen so as to "optimize" the dispersion and distribution of a polymer in the other. For both technical and economic reasons, mixing in solution is hardly envisaged in the context of an industrial process (figures 3).

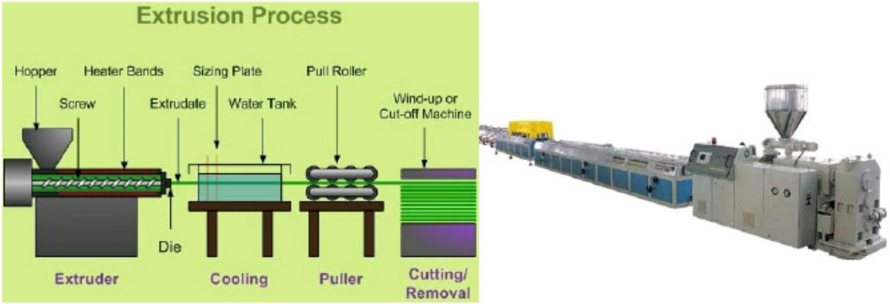


Figure 3 Extrusion Process

This bio-charge addition rate has been confirmed experimentally following several assay attempts tested on different flexible and rigid PVCs [5] and according to Société chimique of France, PVC contains on average 10% additives [17].

In the case of mixtures of immiscible polymers, it will be necessary to disperse and distribute the phases, often in the presence of compatibilizers, which generally requires case-by-case studies.

3.1.4. Punching test specimens

Then, the plate thus formed by the extrusion process, is punched or cut out to give batches of test tubes according to the ISO 527-2, standard 1BA and of form "Haltère" (Table 3).

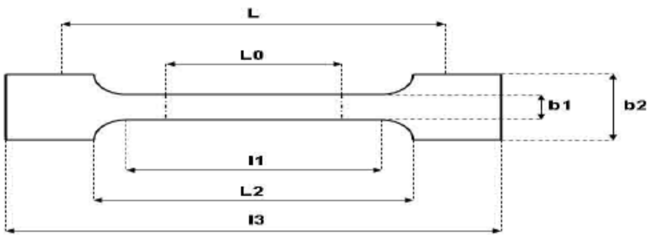
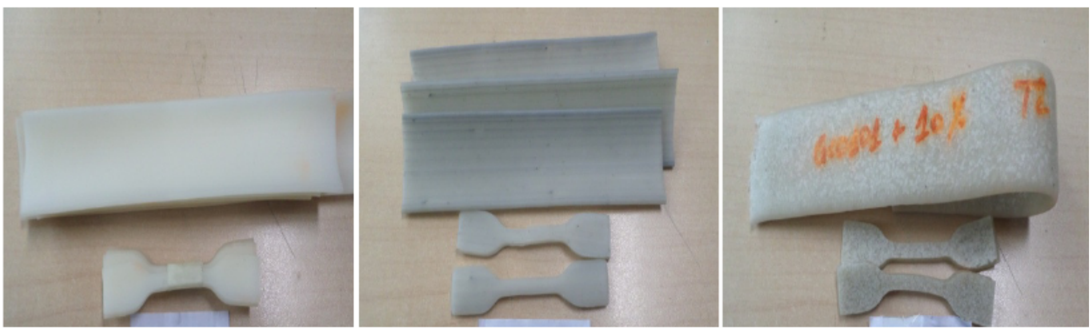


Figure 4 Drawing of specimen of standard traction.

Table 3 Values normalized in millimeters of the dimensions of the specimen to be tested.

ISO 527-2	1BA	I3>75	I1=30±0,5	b2=10±0,5
Haltère	b1=5±0,5	h> 2	L0=25±0,5	L2 +2; L2=58±2



a) Basic PVC **(b)** Bio-loaded PVC at 130°C **(c)** Bio-loaded PVC at 145°C

Figure 5 Flat profiles and specimens of bio-load soft PVC at 10%

A tensile tests phase consist of submitting three series of five standard test pieces to extension to test the elasticity of the PVC material dosed at 10% of the bio-load and at successive temperatures 130 ° and 145 °(figures 5 (a); (b) and (c)).The second objective of our attempt is to check the advanced assumptions and to acquire criteria of positive improvement to acquire positive improvement criteria on the mechanical qualities of bio-loaded PVC such as the maximum constraint with the rupture, the relative deformation and the Young modulus of new eco-material [7-18].

3.1.5. Test bench

For the tensile test, a universal tension and compression tester of type LLOYD Instruments LR50K is put in work at a speed crosses 1mm/min, a temperature of test of 23°C and moisture of 50±10%.

Figure 6 LLOYD Instruments LR50K

The test bench is equipped with auto-tightening bit and a cell of force having a capacity of 5kN. Its piloting is made by the software expert Test which at the same time makes it possible to consign the test parameters, gather and treat data (Figure 6).

3.2. Behavioral synthesis of the new material

Mixtures of compatible polymers are rare to find, however, PVC, by the presence of its hydrogen at α, is miscible with a large number of polymers.

The main aims of mixtures of polymers based on PVC are: to facilitate the implementation of the PVC itself, minimizing both its Tg and its viscosity as well to improve its impact resistance since PVC is fragile if it is not reinforced [15].

Tables 4; 5 and 6 result the tensile tests carried out on the soft PVC bio-loaded specimens at 10% and at temperatures 135 ° then 145 ° PVC, the relative curves of which are represented by the figures 7; 8 and 9:

3.2.1. Test results for soft PVC before loading

Table 4 Tensile test results of the soft PVC

Group of test pieces	Stress at break (MPa)	% Elongation at break
1	13,3	310
2	10,8	300
3	11,1	310
4	10,6	325
5	11,3	320
Mediane	11,1	310

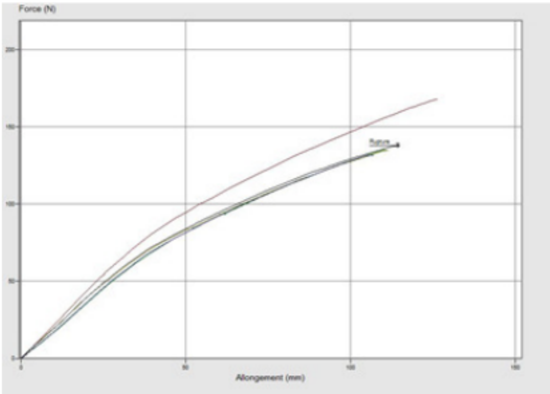


Figure 7 Traction curves of soft PVC

3.2.2. Test results for soft PVC after loading

Table 5 Tensile test results of the bio-loaded soft PVC at 130°

Group of test pieces	Stress at break (MPa)	% Elongation at break
1	10,9	310
2	10,6	300
3	11,8	325
4	10,8	325
5	10,8	325
Mediane	10,8	325

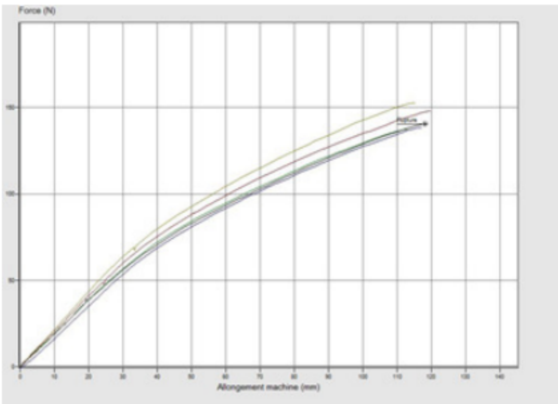


Figure 8 Traction curves of flexible bio-loaded soft PVC at 130°

Table 6 Tensile test results of the bio-loaded soft PVC at 145°

Group of test pieces	Stress at break (MPa)	% Elongation at break
1	6,2	125
2	6,9	150
3	7,1	150
4	8,9	165
5	5,8	150
Mediane	6,9	150

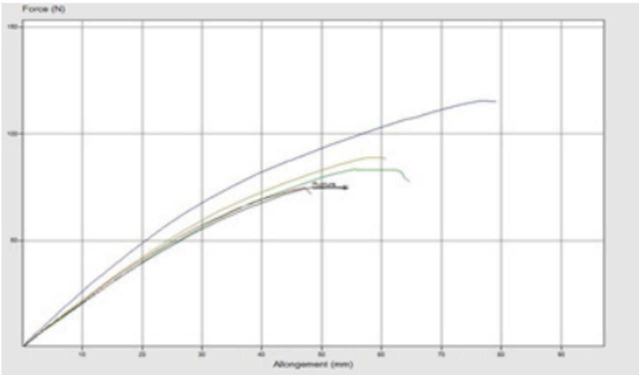


Figure 9 Traction curves of flexible bio-loaded soft PVC at 145°

4. BEHAVIORAL SYNTHESIS OF THE STUDIED MATERIALS

Compatible polymer blends are rare to find, however, PVC, by the presence of its hydrogen, is miscible with several polymers and can incorporate many fillers, which are mainly minerals such as natural or precipitated calcium carbonate, talc, kaolin, or metals intended to improve its mechanical properties, its surface condition and also to reduce the cost price thereof [19].

Figures 5b and 5c, visualizing the soft PVC aspects at 10% alloy and heated to two different temperatures (130°C and 145°C), show a relative biocompatibility and an approved miscibility of the alliance at these two temperatures. Nevertheless, the compactness of PVC at 130°C is better than in PVC at 145°C because the macromolecular structure of PVC is amorphous: the molecules are in disorder and move further away under the effect of heat. Hence, it is necessary to Hence, it is necessary to integrate a compatibilizing agent for improvement of adhesion and biocompatibility of the two phases (specific interactions ...) [20-21].

A new structure manifested by a variation of density in the amorphous phase: more compact at 130°C by a distribution of particles in the volume (Distributive Mixture) (figures 2b and 5b) and at 145°Cit is spread by subdivision of particles in the volume (Dispersive Mixture): (figures 2a and 5c).

In terms of elastic behavior, we can see from the results recorded on the graphs (figures 7, 8 and 9) that the different tensile curves have a plastic behavior without specific threshold. This conventional "CES" threshold can be well defined at the intersection of the line parallel to the tangent at the origin of the curves of a specified slope (0. 1 to 1%) according to the standards. We also note:

at 130°C, a clear softening appears: slightly improved ductility(Figures 8) and at 145°C, a clear drop in the breaking strength accompanied by a decrease in the displacement level and an increase in the Young's modulus: loss of ductility, gain in toughness and hardness(Figures 9).

On the same 10% biofiller grade, the hardening effect is all the more significant when the initial hardness level is low and the effect on the fragility characteristics is all the greater when the difference between the initial and final hardness is high (Figure 9).

Consequently, this new eco-composite may be fragile, tenacious or ductile and its bio-strengthening may contribute to the improvement of these mechanical characteristics through action on the transformation temperature.

5. CONCLUSION

Currently, research on the development of more environmentally friendly materials as a priority, biodegradable materials and recycled materials.

In this perspective, we have highlighted the naturally observed mechanical qualities of an organic material. Its tensile strength test has shown that its elastic behavior is considered favorable to the innovation of certain polymer materials.

At the end of this experimental study of the effect of temperature on the biocompatibility and mechanical behavior of biofilled flexible PVC, the action on the temperature values of the mixture will be able to orient the mechanical qualities of the eco-composite obtained: the hypotheses put forward are verified and an industrial development of biofilled polymers is to be considered for a better recycling of renewable resources.

In terms of sustainable development, two main axes will be developed in this research field: the development of recycling of animal organs at the end of their life thanks to the identification of performance and the development of materials bio-filled with renewable resources from animal biomass.

SCIENTIFIC OBSTACLES

The development of materials organic-sources and organic degradable requires the development of specific tests of evaluation of the biological breakdown of formulated materials. The end-of-life by composting must be maintained whatever the physical properties of materials and the surface treatments carried out. The development of materials from resources first and secondary requires obtaining increasingly important purity in order to aim at applications to strong added values.

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