Biopolymer Applications Journal *Samia BENMESLI et al.* Vol 3. N°2, 2024, pp. 01-04
e-ISSN : 2800-1729

Development and characterization of a new composite material based on polyvinyl chloride and common reed flour

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Received: 13 June, 2024; Revised: 25 June, 2024; Accepted: 20 July, 2024

Abstract

The objective of this work is to develop and characterize a composite material with a polyvinyl chloride matrix and filler of plant origin, common reed flour. The filler is obtained by grinding and sieving. The composites were prepared on a two-roll mixer. Filler contents of up to 30% by weight were added in order to study the effect of this plant powder on the mechanical properties in tensile, water absorption and morphology. The results obtained from the characterizations carried out show that the PVC matrix becomes more rigid but not resistant due to the absence of adhesion between the PVC and the plant filler. PVC which contains plant powder absorbs more water than pure PVC. The dispersion of the filler within the matrix is influenced by the difference in nature between the two phases of the composites.

Keywords: *Biocomposite, plant filler, polymer matrix, PVC, common reed.*

I. Introduction

Polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyvinylchloride (PVC) are thermoplastic materials that have good thermal, mechanical and lightness properties. They are widely used in several applications, particularly in the agricultural, biomedical and food processing/packaging industries.

The waste of these plastic materials has become a big problem for nature and for living beings. Bags and packaging products made of plastics cause a source of environmental pollution due to their stability and its resistance to degradation which can last for years under severe climatic and natural conditions. However, the disposal of solid waste, especially non-biodegradable synthetic polymers, poses serious environmental problems, caused by the emergence of a large number of plastic industries around the world [1].

Various approaches have been undertaken for post-consumer recycling of plastic waste considering the economic and environmental challenge [2,3], but the deterioration of mechanical and physical properties due to peroxidation [4] have limited to a large extent the recycling process

In recent times, the awareness of populations and authorities regarding these environmental problems has strongly encouraged the development of a new concept called "eco" or "organic" which consists of developing materials from resources renewable (from biomass) with the aim of preserving the environment and better managing natural resources. Thus new materials called ecomaterials, biocomposites or eco-designed have emerged [5].

It is with this in mind that the use of renewable resources in plastic materials is becoming more and more common these days, and markets are increasingly geared towards a demand for more environmentally friendly products. To develop and improve them, research is carried out in numerous laboratories internationally. These materials, called eco-materials, bio-composites, wood-polymer composite materials, etc. have taken on importance in various developed and developing societies. The technical advantages of using lignocelulosic materials such as esparto, sisal, cotton, etc. in polymeric materials offers several technical-economic advantages: low cost, low density, high toughness, mechanical strength properties, increased energy recovery and biodegradability [6]. In Algeria several natural fibers are found in abundance. Their harvests and industrialization are a considerable source of income for entire populations. One of the local plant fibers in our region is the common reed. This fiber is interesting from an economic point of view, because of its abundance and availability. Common reed (Phragmites australis (Cav.) Trin. ex Steud.) is growing in several regions of the Netherlands, mostly in nature conservation areas, which are managed by Natuurmonumenten [7]

PVC is commonly used in plastics, pipes, electric wires, window profiles, siding due to its acceptable mechanical properties, fire, moisture & fungus resistant and long lifetime PVC produced from cracking of petroleum or natural gas have a randomly distributed Mw and some degree of viscosity. Additives with PVC can control its physical, thermal, mechanical properties and also improve processability, weathering resistance, colour, cost performance and electrical properties [8].

The general objective of this work is to highlight this plant in the development of a composite material based on PVC and the flour of the latter, then characterize it by physical properties: water absorption, mechanical tensile test and morphological test (optical microscopy).

II. Material and methods

PVC type 3000H is obtained from the calendering company "CALPLAST" in Sétif, Algeria

The added plasticizer is dioctylphthalate (DOP). The industrial grade thermal stabilizer used is a mixture of epoxidized soybean oil (HSE 100S) and NEW STAB 26, and stearic acid as a lubricant. The vegetable filler used is common reed flour (CRF). Common reed flour obtained after sieving having an average particle diameter equal to 180µm.

II.1. Preparation of composites

Films of polyvinyl chloride/common reed flour (PVC/CRF) composites with a thickness of 0.5 mm were prepared using an OFFICINA MECCANICA E FONDERIA RODOLFO COMERIO brand two-roll mixer. The temperature is maintained at 160°C for a mixing time of 15 minutes.

The proportions of the PVC/CRF mixtures used respectively are: 100/0, 90/10, 80/20, 70/30.

II.2. Caracterization

The composite materials prepared were characterized by several techniques, such as the study of tensile properties, the measurement of the water absorption rate, the analysis of the morphology by the optical microscope.

The samples intended for mechanical characterization (tensile test) were cut from the sheets obtained from the two-cylinder mixer, these specimens are tested according to the ASTM D638-72 standard on a Zwick/Roell brand machine with an elongation speed equal to 25mm/min.

Observation of the morphology is carried out on an Optika HC 4*0.1160/0.17 optical microscope.

The water absorption test is carried out as follows:

the samples were dried in an oven at 60°C for 4 hours, then cooled in a desiccator and weighed immediately (m_0).

The samples were then immersed in distilled water at 25°C. Periodic samples every 24 hours were taken, the water on the surface of the sample was absorbed with absorbent paper and the samples were weighed again (m_1). The water absorption rate in (%) was calculated by the following formula:

$$\mathbf{TH} = (\mathbf{m_1} - \mathbf{m_0}) / \mathbf{m_0} * \mathbf{100} \quad \text{.........(1)}$$

m_0: the mass of the sample before immersion

m_1: the mass of the sample after immersion

III. Results and discussion

III.1. water absorption rate

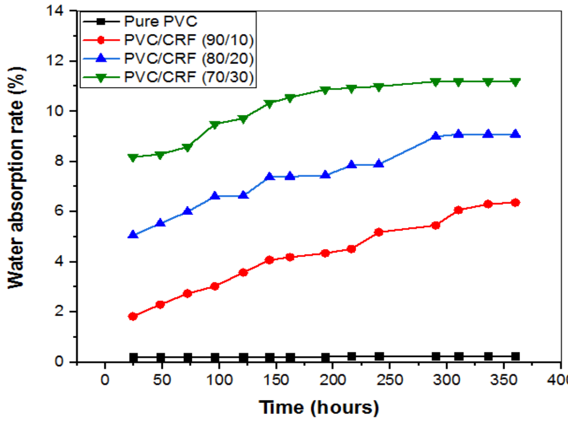

Figure 1: The evolution of the water adsorption rate of PVC/CRF composites as a function of immersion time at different loading rates

Figure 1 represents the variation in the water adsorption rate of PVC/CRF composites as a function of the immersion time in water and the concentration of the filler.

From the figure we can clearly see an increase in the water absorption rate with immersion time and the rate of common reed flour, which is entirely expected, due to the fact that reed flour common is highly rich in hydroxyl groups, the latter form hydrogen bonds with water molecules, so the higher the flour content, the greater the OH concentration and consequently the absorption rate becomes greater. In the case of pure PVC, water absorption is almost zero, this is due to the nature of the polymer which is hydrophobic. The results found in this test are similar to those found in other works [9]

III.2.morphological characterization

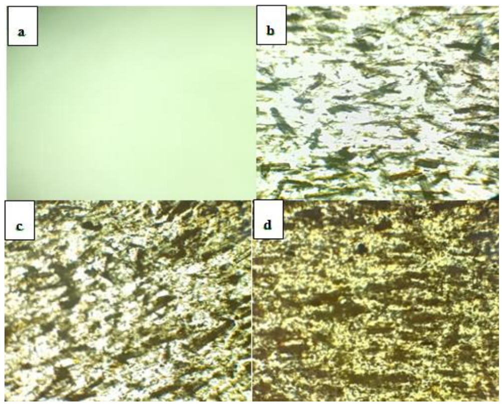

Figure 2 : Photos representing the morphologies of the materials: (a): pure PVC, (b) PVC/CRF (90/10), (c): PVC/CRF (80/20), (d): PVC/CRF (70/30)

Figure 2 represents the morphologies of the PVC/CRF composites as a function of the loading rate. The micrograph of pure PVC (a) presents a single phase, on the other hand those of PVC reinforced by the filler (b, c and d) show the appearance of a second phase corresponding to the particles of the filler dispersed in the matrix. A phenomenon of agglomeration of common reed flour is observed in the images of the formulations containing the filler. This phenomenon was explained by the poor dispersion of the hydrophilic charge in the hydrophobic matrix. Micrographs of the filler-reinforced composites show more agglomerate formation with increasing filler rate.

III.3. Tensile test

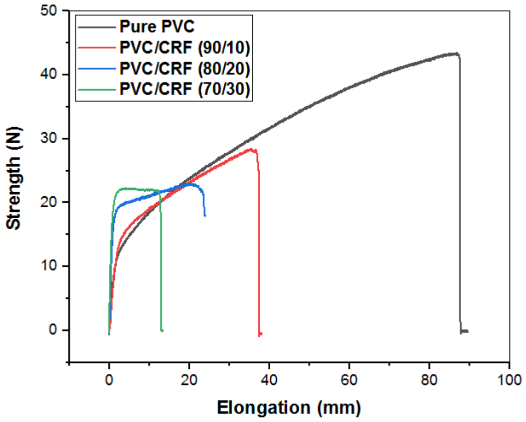

Figure 3 : Curves of variation of strength of PVC/CRF composites as a function of elongation

Figure 3 represents the tensile curves: variation of strength as a function of elongation of PVC/CRF composites at different load rates. From these curves, we calculated parameters such as the modulus of elasticity, the stress at break and the strain at break and we studied the effect of the load rate on these parameters.

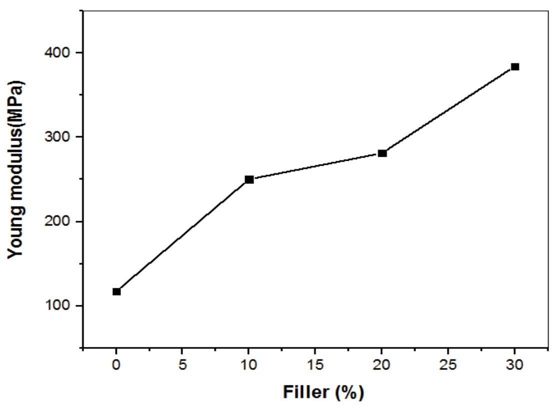

Figure 4 : Variation of the Young modulus of PVC/CRF composites as a function of the loading rate

Figure 4 shows the variation in the Young modulus of PVC/CRF composites as a function of the loading rate. It is observed that the modulus of elasticity increases with the increase in loading rate, this is due to the increase in the rigidity of the matrix: polyvinyl chloride by the addition of rigid plant particles. Common reed flour contains biopolymers which have high crystallinity and therefore rigid behavior. The increase in the rigidity of PVC is also observed in the case of the introduction of wood flour into the PVC [10].

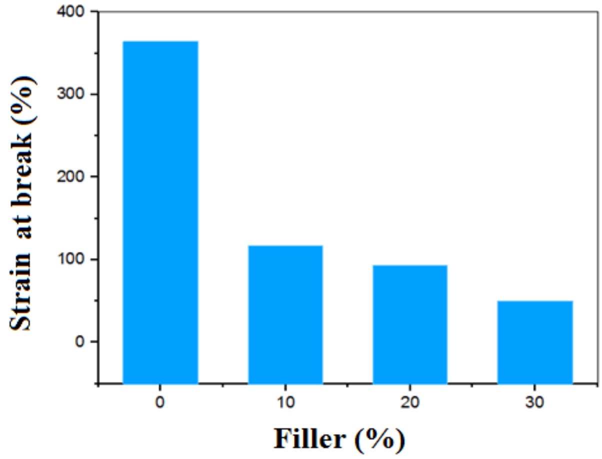

Figure 5 : Variation of the strain at break of PVC/CRF composites as a function of the load rate.

Figure 5 shows the variation in the strain at break of PVC/CRF composites as a function of the load rate. From the figure we observe that the breaking strain of PVC decreases as a function of load rate. This reduction can be explained by the change in the mechanical behavior of the PVC matrix from a flexible behavior to a rigid behavior which resists deformation (less deformation). This is always due to the presence of a rigid plant powder within the matrix and this is confirmed by the values of the modulus of elasticity. The tensile results are similar to those found in a study of composites based on polyvinyl chloride reinforced with palm fibers [11].

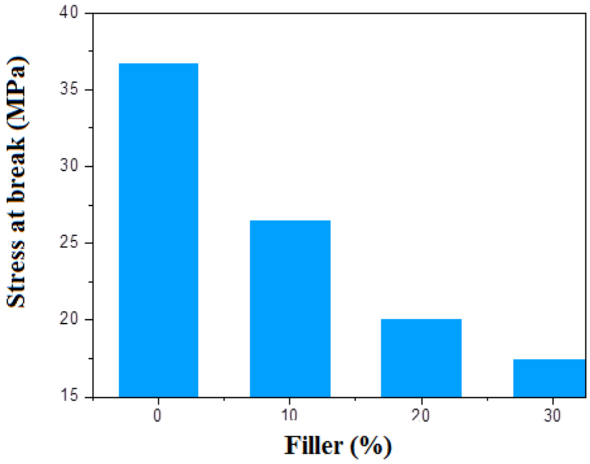

Figure 6 : Variation of the breaking stress of PVC/FRC composites as a function of load rate

Figure 6 shows the variation in the breaking stress of PVC/CRF composites as a function of the loading rate. From the histograms we notice that the results obtained show that this mechanical property tends to decrease depending on the flour content compared to pure PVC.

This reduction is due to the fact that the particles have a hydrophilic character and the PVC is hydrophobic, which leads to water absorption and to the incompatibility that exists between the matrix and the plant filler.

IV. Conclusions

The various tests and analyzes carried out on the prepared materials showed that:

The water absorption rate of the composites increases depending on the charge rate in the PVC matrix, this confirms that the common reed is a hydrophilic plant

The study of the mechanical properties of the composites produced shows that:

The addition of common reed flour changed the mechanical behavior of the plasticized PVC from a flexible material to a rigid material which tends to become fragile with the increase in the loading rate. This result is confirmed by the reduction in deformation.

Examining the morphology of the different composites allowed us to conclude that:

The dispersion of common reed flour in the PVC matrix is affected by the presence of humidity between the particles of the filler (formation of agglomerates) as well as the absence of interfacial adhesion between the two phases, This is confirmed by the reduction in the breaking stress of the composites.

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