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Physical and mechanical behavior of poly(vinyl chloride) reinforced by corn flour

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Abstract

In this work it was investigated the incorporation of corn flour (CF) as filler with different content in poly(vinyl cloride) (PVC) in the aim to decrease the plastics wastes in the environment. The corn flour were mixed to the PVC using the technique of calendaring and hot compression. The characterization of those compounds was done using phisyco-mechanical analysis. The results indicated that the increase of the corn flour content in the matrix was responsible for the reduction of the elongation and stress of the resulting composites and increased the stiffness, the hardness and water adsorption if compared with pure PVC.

Keywords: *Polyvinyl chloride, corn flou, composite materials, physico-mechanical properties*

I. Introduction

In recent years, the use of composite materials has seen considerable development in different areas; aeronautics, automobiles, packaging, construction, etc.

A considerable part of these innovative materials is intended for the packaging sector, in order to replace plastic materials which are used over a very short period of time and which quickly generate a significant volume of waste.

Recent advances in composite science and the development of natural reinforcements offer significant opportunities to develop new materials from renewable resources [1, 2].

Among the plastic materials most used for the preparation of organic composites is polyvinyl chloride (PVC). The latter is one of the most produced plastic materials. Its global production is 35 million tonnes per year. It is a thermoplastic polymer widely used in various sectors, it is ranked third in terms of tonnage after polyethylene (PE) and polypropylene (PP) [3]. In this context, we have chosen to reinforce this thermoplastic polymer (PVC) with corn flour, which is a vegetable filler.

The choice of using this filler was based on the fact that it naturel reinforcement and it has low cost compared to corn starch. So, the corn flour can be valorized by introducing them into a thermoplastic matrix such as PVC. The resulting materials can be used in a several domains, such as packaging.

However, further studies on the reinforcement of PVC with other filler such as ligno-cellolic fibers are being carried out by several researchers [4-5].

The aim of the present study is to study the phisyco-mechanical properties of polyvinyl chloride (PVC) matrix composites reinforced with corn flour (CF), using a variety of analytical techniques such as: tensile test, hardness test, density test and water absorption measurement.

II. Material and methods

II.1 Materials

The different PVC/corn flour formulations developed for this study were based on PVC from type SE-120 supplied by the company CABEL "Cableworks electric" from Algiers, Algeria. This polymer has the properties physical values: K-Wert, from 70.2 to 72.0; a density of 0.52. Additives have been added for the preparation of the different formulations and which are the phthalate of dioctyl (DOP) as a plasticizer, a thermal stabilizer based on Ca/Zn and stearic acid as lubricant. Corn flour with a particle size ≤ 100 µm and a relative humidity of 7% was provided by the company AGRO CEREAL/Moulin Royal Akbou, Algeria. PVC type SE-1200 was used as a matrix for the production of composites.

II.2 Methods

Determination of dry matter and moisture content of corn flour

A mass of CF is weighed (P_0) into a ceramic mass crucible (P_1). It is placed in an oven at 105°C. After 24 hours, the crucible is removed from the oven and weighed (P_2). The dry matter content is given by the following formula:

$$\% \text{ DM} = \frac{P_2 - P_1}{P_0} * 100 \quad (1)$$

The moisture content (Mc) is determined by the following expression:

$$\% \text{ Mc} = 100 - \% \text{ DM} \quad (2)$$

The density of corn flour (d_{CF}) is determined by pycnometer method using the relation (3):

$$d_{éch} = \frac{W_2}{W_1 + W_2 - W_3} d_{water} \quad (3)$$

With :
w_1 : the mass of the pycnometer full of liquid (water) (gr).
w_2 : mass of CF (gr).
w_3: mass of pycnometer full of liquid with CF immersed (gr).
d_{water}: density of the liquid used (water).

Samples preparation

The different formulations presented in Table 1 were prepared by two transformation processes, namely: calendaring and compression molding. The PVC and its additives were introduced into a T6HK8 type turbo-mixer for 15 min. The resulting mixture is introduced into a two-roll mixer at a temperature of 140°C. Then, the filler (PCF) is added to obtain the mixture for each formulation.

The prepared mixture is introduced into the plates of the TONJINE brand table press at a temperature of 170° C under a pressure force of 300 kN for 5 min. Plates of 250×250×2 mm^3 are obtained and cooled to room temperature, which will be used for cutting samples in the form of dumbbells.

Table 1. Mass composition of the different formulations.

Formulations / Products	F0	F10	F20	F30
PVC compound	100	90	80	70
CF	0	10	20	30

Water absorption test

The water absorption test is carried out according to ASTM D7031-04. The samples immersed in distilled water at room temperature with stirring. The samples are weighed every 24 hours until their mass is stabilized. The variation of mass is given by the following formula :

$$WA(\%) = \frac{w - w_0}{w_0} \times 100 \quad (4)$$

where :
WA : the water absorption (%),
W : the final mass of the sample
W_0 : the initial weight of the sample

Density test

Sample density was determined using a DSM density Meter.

Tensile testing

The mechanical behavior of the composites produced was determined using an MTS Criterion tensile testing machine, in accordance with NFC 32-200.

For each formulation five specimens were tested. As a result, Young's modulus, strain and stress were determined.

Shore D hardness test

Shore D hardness is measured by applying a force the pointed steel needle of a shore D durometer, on plates of shore D durometer, on 5x5 cm^2 plates of a different thickness.

III. Results and discussion

Physical properties of corn flour

The results recorded (Table 2) show that the density of CF is 1.58. This result is similar to the density values given by Benjamin et al. [6], which is 1.62.

Dry matter content and moisture content are 88.37% and 11.63% respectively. These results corroborate previous research [6, 7].

Table 2. Physicochemical characteristics of corn flour.

Caracteristics	CF
Density	1,58
Mc (%)	11,63
DM (%)	88,37

Water absorption test

The evolution of the water absorption of PVC and PVC/CF composites as a function of filler ratio and immersion time in distilled water is illustrated in figure 2. The results show that the water absorption of virgin PVC is negligible, due to the hydrophobic nature of this polymer, whereas the addition of filler to the PVC matrix increases water absorption with increasing filler ratio and immersion time in distilled water. This can be explained by the presence of hydroxyl groups in starch (a major constituent of corn flour). These groups form hydrogen bonds with water molecules, giving starch-based materials their hydrophilic character. The higher the loading rate, the higher the OH concentration in the composites, and the greater the rate of water absorption. The water absorption rate after 34 days' immersion is 0.27% for virgin PVC and 2.19, 4.8 and 10.7% for F10, F20 and F30 formulations respectively. Similar results have been recorded by several authors who have introduced plant fillers into different hydrophobic matrices [8, 9].

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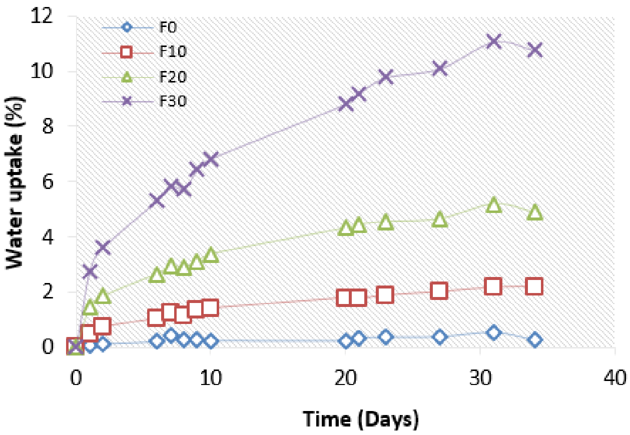

Figure 1. Evolution of the water uptake of PVC and PVC/CF composites.

Density test

The results of the density test on PVC/FM composites as a function of filler ratio are shown in Fig. 4. It is clear that the addition of corn flour to the PVC matrix results in a slight increase in density, which is not significant. It increases from 1.23 for PVC compound to 1.25, 1.25 and 1.27 for filler contents of 10, 20 and 30% respectively. This is explained by the fact that CF has a low density (Table 2). This result is in agreement with the results recorded by Kormin et al. [8] who introduced different types of starch as filler in LDPE.

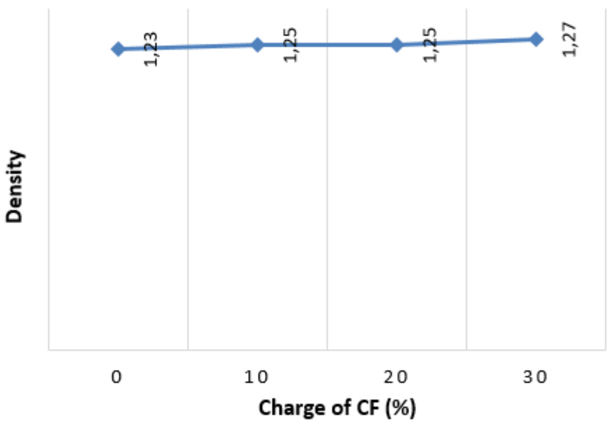

Figure 2. Density of PVC and composites PVC/CF with 10, 20 and 30% of the charge.

Tensile testing

The comparison in tensile properties of pure PVC and PVC reinforced with CF for different formulations is illustrated in figure 3.

For tensile strength (Figure 3-a), a decrease in this property is recorded with the introduction of CF into the PVC matrix. A decrease of 36.38%, 48% and 67.48% is recorded for F10, F20 and F30 formulations respectively, compared with unfilled PVC. These results are in agreement with those obtained by other researchers who have worked on LDPE/corn starch composites [7]. They explained this result by the tendency of corn flour particles to group together, forming agglomerates that induce heterogeneities and non-uniform stress transfer within the matrix, resulting in material embrittlement.

Figure 3-b shows the Young's modulus of PVC/CF composites as a function of filler ratio. These results indicate that the introduction of filler into the matrix increases the stiffness of the materials in formulations F10 and F20, which translates into an increase in Young's modulus, but a decrease is recorded in formulation F30. This can be explained by the rigid nature of CF compared with soft PVC. Above 20% plant filler, there is poor dispersion of this filler in the polymer matrix. At high filler contents, the material becomes rough and the surface cracks [10].

For elongation at break, it can be seen that this parameter tends to decrease significantly with the introduction and increase of filler content into the matrix. The elongation at break drops from 118.75% for PVC to 75.99%, 61.99% and 33% for composites filled with 10, 20 and 30% CF respectively. Similar results were observed for LDPE/starch [7] and PVC/wood pulp composites [11].

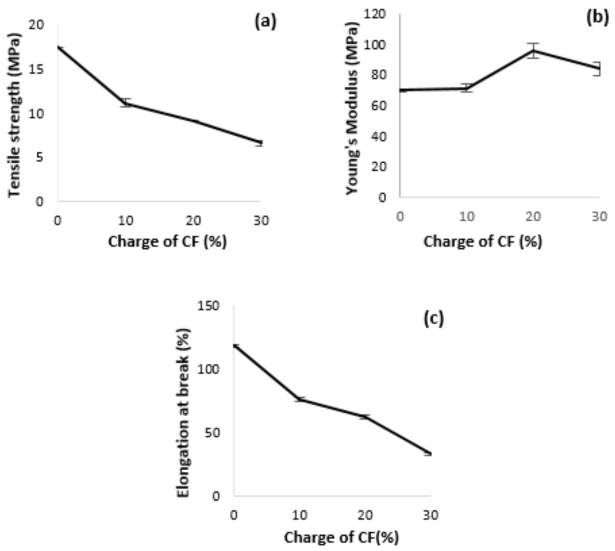

Figure 3. Tensile properties of PVC and PVC/CF composites: (a) tensile strength (b) Young's modulus and (c) elongation at break.

Shore D hardness test

Figure 4 shows that the hardness of PVC/CF composites increases as the filler content in the PVC increases. This behavior can be explained by the fact that corn flour is stiffer than soft PVC, consequently, the material gains more resistance to penetration, so the hardness will be higher. This observation is in perfect agreement with others studies [3, 12, 13] which reported similar results.

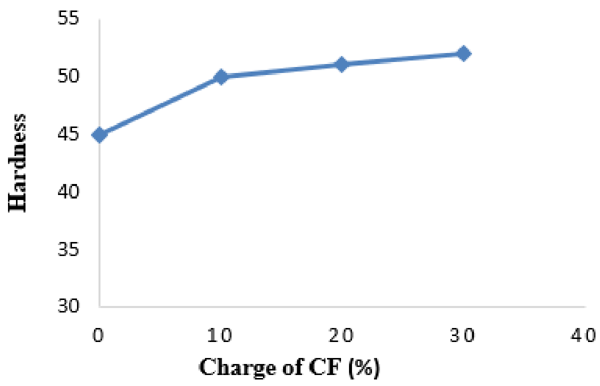

Figure 4. Hardness of PVC and composites PVC/CF with 10, 20 and 30% of the charge.

Conclusions

The results obtained in this study showed that:

- CF has a low density, very rich in dry matter with a low moisture content.
- The introduction of CF as a filler in PVC had no effect on the density of the composites elaborated.
- Water absorption increases with increasing filler content in PVC and immersion time in water.
- A study of the tensile properties of PVC/CF composites showed a decrease in tensile strength and in elongation at break with increasing filler ratio in the PVC matrix. On the other hand, an increase in stiffness was recorded.
- The hardness of composites elaborated increased with increasing CF filler ratio in the PVC.

Although the properties of some blends are acceptable for certain applications, further improvements will be needed, mainly by optimizing the characteristics of the charge-matrix interface.

Conflict of interest

The authors declare that they have no conflict forfinancial interests or personal relationships that howcan influence the work reported in this paper.

References:

[1] L. J. Zhang, Li. P. Peng, F. Bian. Microwave-assisted solvent-free acetylation of cellulose with acetic anhydride in the presence of iodine as a catalyst. Molecules 14, 3551-3566, 2009

[2] S. Thomas, S.A. Paul, L.A. Pothan, B. Deepa, Cellulose Fibers: Bio- and NanoPolymer Composites, Green Chemistry and Technology 3-42, 2011

[3] S. Sahi, H. Djidjelli, S. Touazi, Amar Boukerrou. Valorisation des déchets ligno-cellulosiques pour la préparation d'un nouveau matériau composite PVC/farine des noyaux de dattes. Matériaux et techniques 109, 102, 1-10, 2021

[4] B.L. Shah, L.M. Matuana, P.A. Heiden, Novel coupling agents for PVC/wood-flour composites, Journal of Vinyl and Additive Technology 11, 160-165, 2005

[5] Y.T. Zheng, D.R. Cao, D.S. Wang, Study in the interface modification of bagasse fibre and the mechanical properties of composite with PVC, Composites: Part A 38, 20-25, 2007

[6] B. L. Johnson, M. R. Holland, J.G. Miller, J. I. Katz. Ultrasonic Attenuation and Speed of Sound of Cornstarch Suspensions. The Journal of the Acoustical Society of America 133, 1399-1403, 2013

[7] S. Sahi, H. Djidjelli, A. Boukerrou. Biodegradation study of bio-corn flour filled low density polyethylene composites assessed by natural soil. Journal of Polymer Engineering 36, 245-252, 2015

[8] S. Kormin, F. Kormin, M. D. H. Beg, B. M. P. Mohd. Physical and mechanical properties of LDPE incorporated with different starch sources. Materials Science and Engineering 226, 012157, 2017

[9] Sahi, S. Djidjelli, H. Utilisation de l'amidon comme charge biodégradable dans les matériaux composites polyéthylene basse densite/amidon. Annale de Chimie et Science des Matériaux 38, 189-202, 2013

[10] H. Djidjelli, A. Boukerrou, A. Rabouhi, R. Founas, M. Kaci, O. Zefouni, N. Djillali, L. Belmouhoub. Effect of olive residue benzylation on the thermal and mechanical properties of poly (vinyl chloride)/olive residue composites. Journal of Applied Polymer Science 7, 1459-1455, 2008

[11] N. Sombatsompop, K. Chaochanchaikul, C. Phromchirasuk, S. Thongsang. Effect of wood sawdust content on rheological and structural changes, and thermo-mechanical properties of PVC/sawdust composites. Polymer International 52, 1847-1855, 2003

[12] S. Nedjema, H. Djidjelli, A. Boukerrou, N. Chibani, Effet du désencrage et d'un traitement de surface sur les propriétés mécaniques des composites PVC/fibre de papier journal, Annale de Chimie et Sciences des Matériaux 37, 201-214, 2012

[13] M. Khali, Z. Boussena, L. Boutekrabt, Effet de l'incorporation des noyaux de dattes sur les caractéristiques technologiques et fonctionnelles de la farine de blé tendre, Nature et Technologie 12, 15–25, 2015