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A CHARACTERISATION OF ORGANICALLY MODIFIED POLYMERS

Rodica CHIHAI (PEȚU)*, Claudia Veronica UNGUREANU*, Vasile BRIA, Adrian CÎRCIUMARU

Research and Development Centre for Thermoset Matrix Composites, Cross-Border Faculty, Dunarea de Jos University of Galati (Romania)

*Corresponding author's e-mail: claudia.ungureanu@ugal.ro; rodica.petu@ugal.ro

Abstract

Epoxy resins have many attractive properties, such as solvent and chemical resistance, low shrinkage, ease of cure and processing, good adhesive strength, excellent electrical and mechanical properties and ease of modification to optimize their features. These epoxy resins have been widely used as adhesives, surface coatings, aerospace composite matrix, laminates, membranes, pottings, encapsulants for semiconductors and insulating material for electronic devices. However, these systems do have some environmental problems. One problem of epoxy resins is that all the curing agents are still environmentally unfriendly and toxic before the cure. Therefore, the development of environmentally friendly epoxy systems has a great importance for designing the green and biocompatible materials used in many applications. For this study, two protein substances, gelatine and wheat gluten, were used to change the basic properties of three types of epoxy resin. Protein polymers are natural macromolecules derived from plants and animals, which make them an easily obtainable and renewable resource. The main purpose of this study was to determine the modifications of epoxy resins basic properties induced by organic modification agents. To highlight the effect of these proteins in an epoxy matrix, the mechanical tests, such as three-point bending and tensile were performed.

Keywords: organic polymers, proteins, gelatine, wheat gluten, mechanical properties

1 Introduction

Polymeric materials are of particular importance in everyday life. They can be of biological or synthetic origin and they are used in all industries, including textiles, automobiles, household goods, and medical devices. Composite materials are materials consisting of at least two components, the matrix representing the epoxy resin and the immersed phase, in this case the powder with organic components (gelatine and wheat gluten) [1-3]. Epoxy resin is a very versatile material because epoxy groups have a high reactivity to many functional groups, such as carboxyl, amino and hydroxyl groups [4]. Gelatine is a natural polymer obtained either by partial acid or alkaline hydrolysis or by thermal or enzymatic degradation of structural animal collagen protein [5-7]. Gelatine has a similar composition to that of collagen. Some changes in composition are due to its manufacturing process. The formation of collagen from gelatine takes place with the variation in the composition of many amino acids [8].

Hence, wheat gluten contains two main fractions: gliadins and glutenins. The gliadin fraction has a molecular weight of 30 – 60 kDa, can be dissolved in aqueous alcohol and the glutenin fraction has a molecular weight up to several million Da and is not soluble in alcohol [9-11]. The advantages of these composite materials are the high chemical resistance, good strength characteristics, low weight, low friction coefficient, and high wear resistance [12].

There is a multitude of mechanical tests [13-15], and because the requirements to be transposed are diverse, they can be performed in the static or dynamic conditions, at ambient temperature, as well as at high or low temperatures, in air or in corrosive environments. The behaviour of the composite material to the mechanical stresses produced by external forces depends on certain specific properties of it [16]. Most tests involve the application of test tubes until the material yields and the strength limit is reached. The way in which the material yields as well as the appearance of the rupture section are determined by mechanical tests, consisting of the stress of material in suitable conditions to highlight its properties. The purpose of these mechanical tests is to obtain qualitative data on the behaviour of the material under appropriate stress conditions, called mechanical characteristics, which use quantitative parameters to express mechanical properties. An important indicator of the type of mechanical behaviour of a material is its characteristic curve - the graph resulting from the value of the applied stress and that of the deformation of the specimen - which is drawn during some of the mechanical tests.

The main purpose of this study was to analyse the modifications of epoxy resins basic properties induced by organic modification agents. To highlight the effect of these proteins in an epoxy matrix, mechanical tests such as three-point bending and tensile were performed.

2 Materials and methods

For the formation of polymeric composite materials, several steps are followed. First of all, we determined the matrix and the immersed phase. The matrix is epoxy resin (type C, type E and type HT), and the immersed phase is an organic compound (wheat gluten and gelatine). For this study, we obtained the modified composite materials formed with three types of epoxy resin (Epoxy Resin C as type C, Epiphen RE4020-DE4020 as type E, and Epoxy Resin HT as type HT), which were modified in proportion of 1%, 2%, 3% weight ratios with both gelatine powder and wheat gluten, in equal amounts. For each type of resin we used the appropriate type of hardener: Härter C, Epoxy HARDENER DE4020 and HARDENER HT. The mixture was stirred with a magnetic stirrer for 24 hours at 60ºC and a mixing speed of 500 rpm. Then, the homogeneous composites were poured into polypropylene tubes. They were left for 24 hours in natural homogenization conditions, after that they were extracted and prepared for further testing. Specimen size used for bending tests was 110 mm and 150 mm for tensile tests. Five tests were performed for the unmodified materials and for those modified with organic agents. The determination of the mechanical bending and tensile properties of protein-modified composite materials was experimentally performed on the INSTRON 8030 mechanical test machine.

3 Results and discussion

In order to determine the three-point bending behaviour of unmodified and modified polymeric materials, five tests were performed on cylindrical specimens, and the obtained results are shown by the following graphs (Figures 1-3).

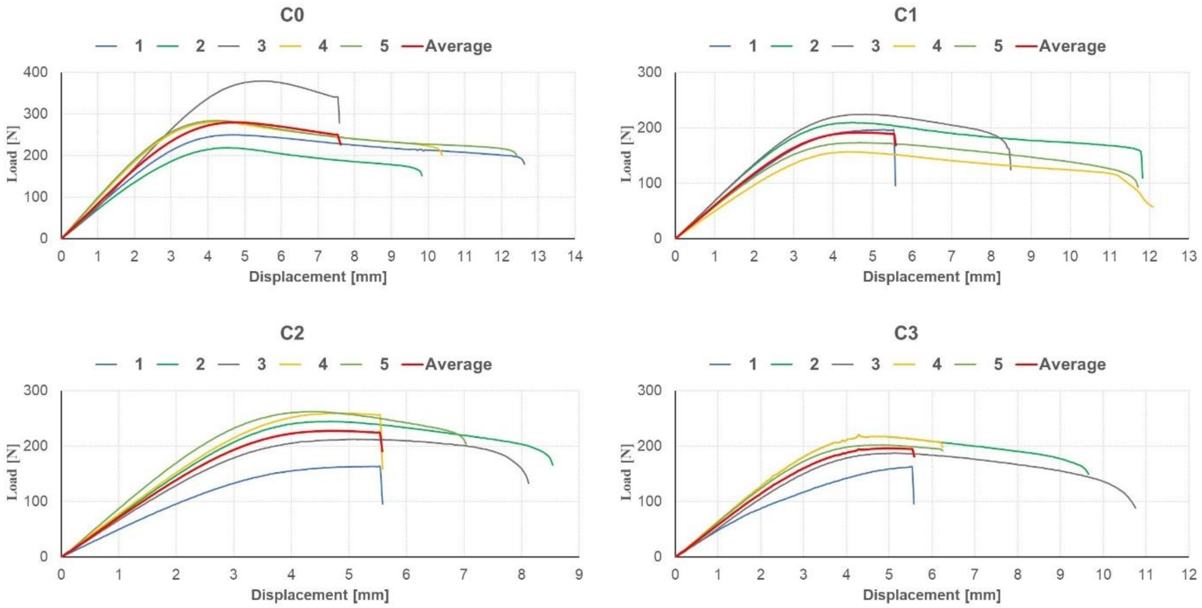


Figure 1. Bending behaviour of type C materials (C0 – reference; C1, C2, C3 – 1%, 2%, respectively 3% of proteins mixture added to the C epoxy resin).

According to Figure 1, the bending behaviour of type C polymeric materials is evaluated. We notice that C2 material has properties very close to that of the reference material (C0), the average bending stress ranged between 200 N and 280 N. In the case of C1 and C3 materials, it is observed homogenous stress values of approximately 200 N (average value).

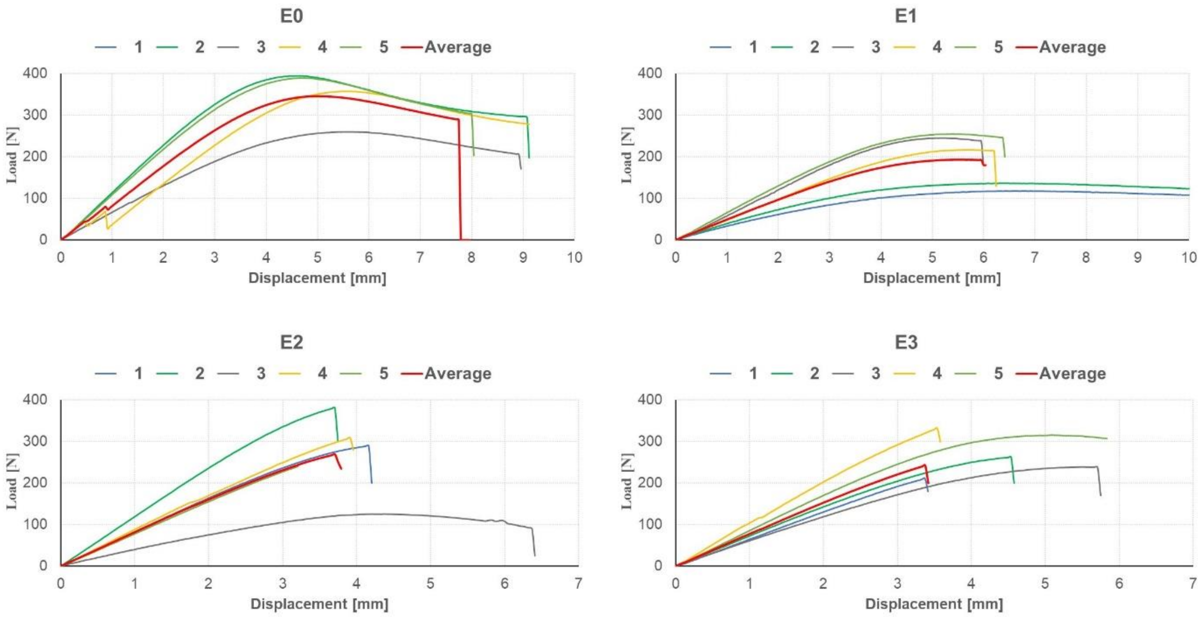


Figure 2. Bending behaviour of type E materials (E0 – reference; E1, E2, E3 – 1%, 2%, respectively 3% of proteins mixture added to the E epoxy resin).

In the case of type E materials, according to the graph from Figure 2, we notice that the 4th specimen (E3) has an atypical behaviour compared to the other tested specimens, which may be influenced by the formation mode. The modified polymeric material with a concentration of 2% showed a bending stress of almost 400 N, as well as E0. As in the case of epoxy resin E, E1 and E2 materials have similar properties.

The behaviour of the modified materials in the case of HT1 and HT2 points out low stress value towards the unmodified resin, but the value of the determined parameters following the three-point bending tests are very similar for HT0, HT1 and HT3.

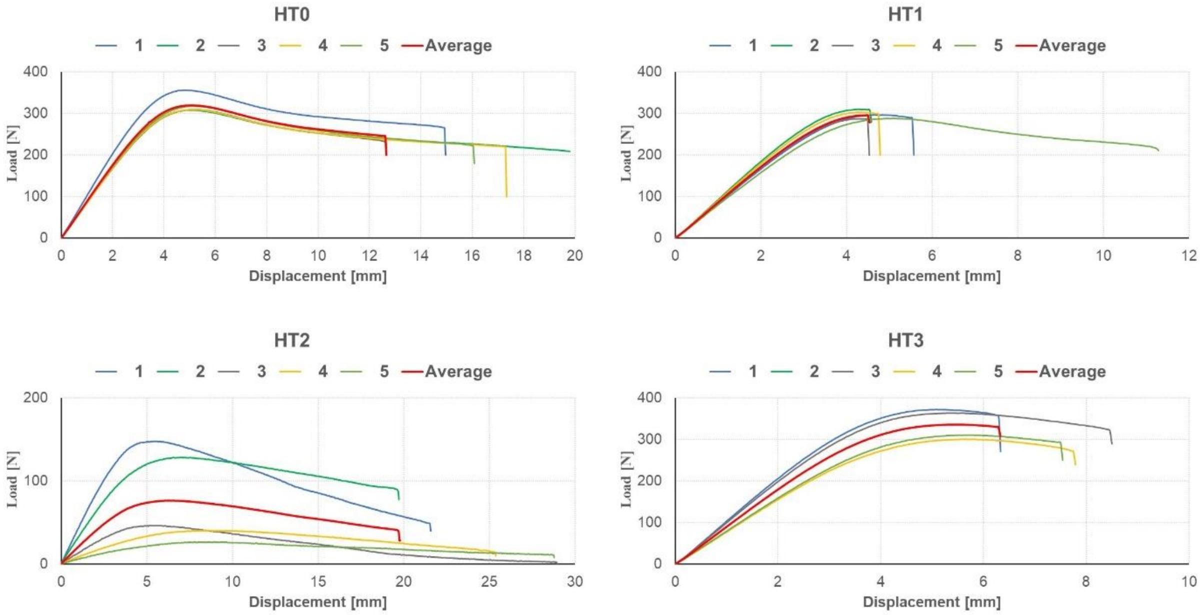
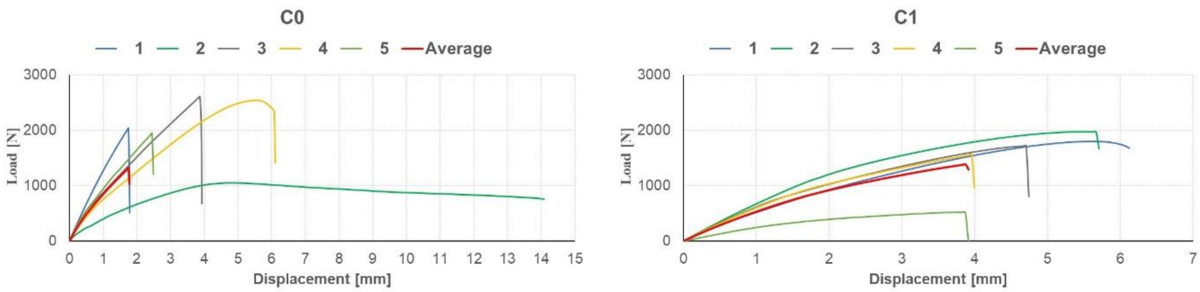


Figure 3. Bending behaviour of type HT materials (HT0 – reference; HT1, HT2, HT3 – 1%, 2%, respectively 3% of proteins mixture added to the HT epoxy resin).

In addition, the materials modifying with organic agents in proportion of 2% have an atypical behaviour (Figure 3). This behaviour can be characterized by the way the mixture is blended and thus the lack of a uniform interface between the modifying agent and the epoxy system during polymerization process. Tensile testing is one of the safest and most widely used methods for determining how a material behaves when it is mechanically stressed.



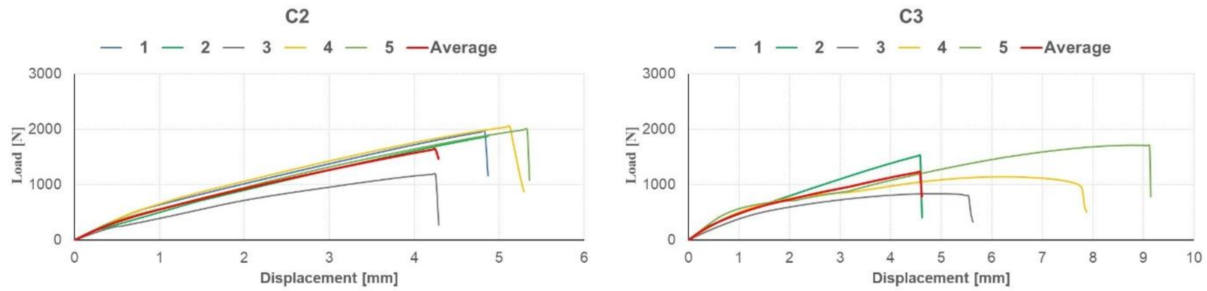


Figure 4. Tensile behaviour of type C materials (C0 – reference; C1, C2, C3 – 1%, 2%, respectively 3% of proteins mixture added to the C epoxy resin).

Figure 4 shows the mechanical tensile behaviour of the unmodified and modified type C materials. A similar tensile response was observed for C1, C2, respectively C3 materials, when the force value was lower than 2000 N and an average displacement was 6 mm.

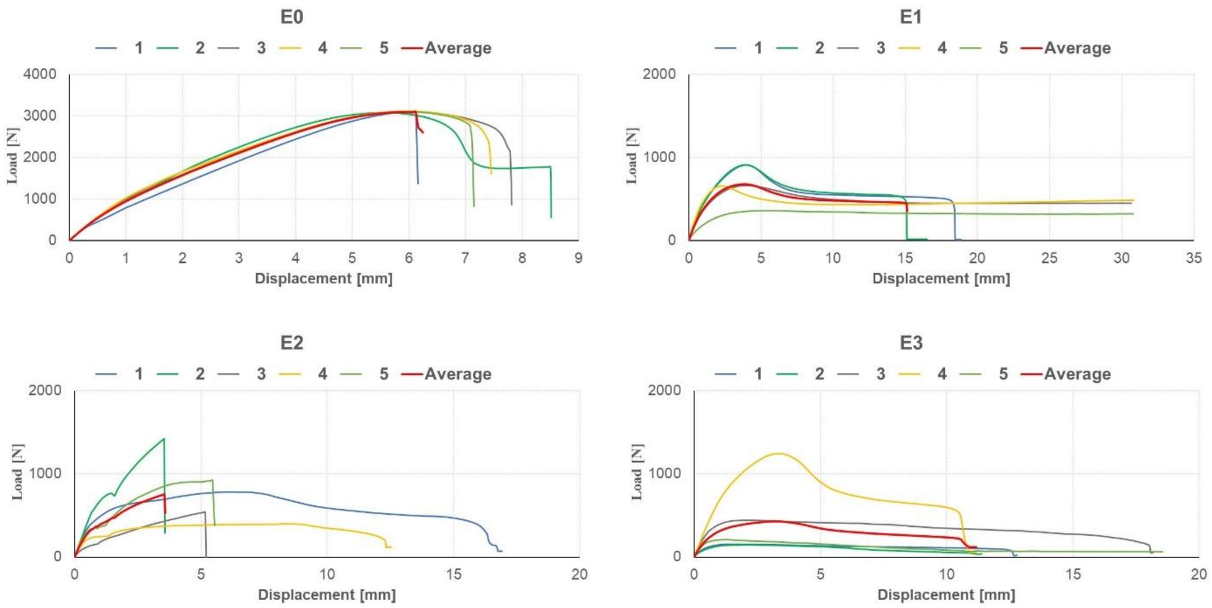


Figure 5. Tensile behaviour of type E materials (E0 – reference; E1, E2, E3 – 1%, 2%, respectively 3% of proteins mixture added to the E epoxy resin).

In Figure 5, regarding the type E organic polymer materials tested for traction, the modifying agents did not improve their properties. Materials E1, E2 and E3 represent lower force values than material E0. The force for the reference material is over 3000 N, but that of the modified ones is maximum 1500 N.

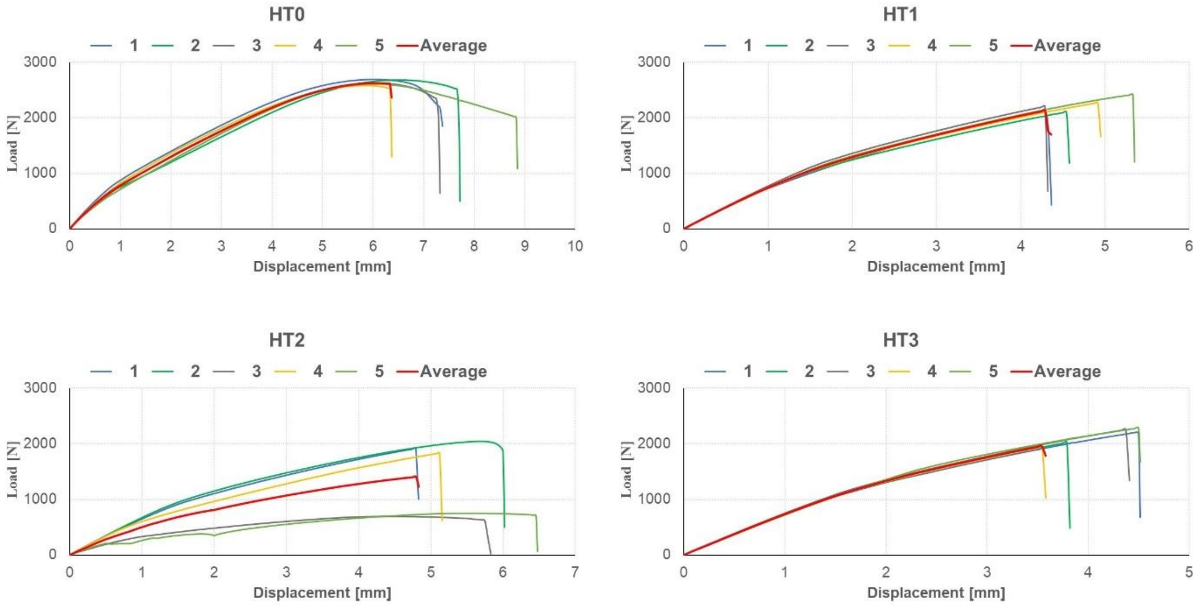


Figure 6. Tensile behaviour of type HT materials (HT0 – reference; HT1, HT2, HT3 – 1%, 2%, respectively 3% of proteins mixture added to the HT epoxy resin).

Also, the type HT materials modified with organic agents (wheat gluten and gelatine) showed a decrease of force value compared to that of the unmodified epoxy system, from 2800 to 800 N (Figure 6).

4 Conclusions

For this study, protein substances (wheat gluten and gelatine) were used to obtain composite materials with special structural and mechanical properties. Regardless the amount of the modifying agent as well as the dispersion mode in the volume of the polymer, the composite material additivated with organic agents modified the properties of the epoxy resins.

Regarding the type of epoxy resin used as a control sample, it can be concluded that the materials formed with type C and E epoxy resin modified with organic agents had good responses to the three-point bending test behaving almost identically to the reference sample.

Based on the performed tests, it was observed that the modifying agents (wheat gluten and gelatine) did not significantly change the properties of the formed material, the composite material modified with proteins had a bending behaviour very similar to the unmodified epoxy system.

However, according to the tensile tests, the modifiers added in the epoxy resin E did not improve their properties. This phenomenon can be influenced by several factors, such as hardening the mixture, the preparation time and how to pour them. Further studies are necessary to validate the preliminary conclusions of the current study.

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