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Characterization of thermal and acoustic insulation of chicken feather reinforced composites

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Abstract

This work evaluates the application potential of chicken feather fibres in the reinforcement of polymeric materials, particularly thermosetting ones as epoxy resins. Due to the morphology of this type of protein fibres, which is characterized by being hollow, its study and application has particular interest as components being able to contribute for the thermal insulation, once air is well known as a bad heat conductor. Composite materials were produced using compression moulding process, and subsequently thermal and acoustic insulation tests were performed to evaluate the influence of chicken feather fibres as potential reinforcements for thermal and acoustic insulation composites applications. The experimental results show that the chicken feather fibres present high potential to be applied as reinforcement in composite materials. It was verified that the thermal resistance of composite materials is favourably dependent on the chicken feather fibres mass fraction, being registered a value of 0.175 m^2 K W^{-1} when an 80:20 ratio (chicken feather fibre and epoxy resin, respectively) was used. Moreover, comparing with coir fibres reinforcing polypropylene, it was verified a better performance, once this composite material just revealed a thermal resistance around 0.114 m^2 K W^{-1}.

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Keywords: Surface treatments; Flax fibre; Composites; Mechanical properties.

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1. Introduction

Chicken feathers are typically considered as residues of the poultry industry. This industry generates billions of kilograms of this waste per year, which are usually burnt and incinerated, without any use or recycling process. However, this waste disposal method led to the generation of greenhouse gases, which are hazardous to the environment [1]. Due to current concerns about the earth sustainability, several studies have been conducted on the use of recyclable and environmentally friendly materials. In this perspective, the fibres extracted from the chicken feathers have also been the subject of some research studies. Among these studies, it was concluded that morphological structure of chicken feather fibres has potential to be used as reinforcement of composite materials, mainly in textile applications related to thermal control. As main characteristics, these fibres present low density, high compressive [2] and tensile strengths [3], and Young's modulus of about 4.7 GPa.

Actually, composite and non-woven materials are the main applications of recycled or reused chicken feather fibres [4]. However, due the fact of the chicken fibres are not classified as high performance materials, their target applications have been registered as thermal and acoustic insulation [3].

In this paper, which explains the morphology of the chicken feather fibre and its combination with an epoxy resin, it was intended to study its influence on the thermal and acoustic insulation properties of composite materials. The fibre morphology was studied by optical and electronic microscopy, and the composite materials were produced using compression moulding process. Afterwards, chicken feather fibers reinforced composite plates were characterized by thermal and insulation characterization tests.

Nomenclature

SEM	scanning electron microscope
Au	gold
Pd	palladium
DSC	differential scanning calorimetry
PP	polypropylene

2. Experimental

2.1. Materials

Chicken feather fibres were extracted from chicken feathers supplied by Dudico, Cialine Group, Brazil. The animals were slaughtered after 42 days of life, and their feathers present can be grouped in 3 types, according to the length, namely: short, medium and long. The extracted fibres used in this research work present an average length of 2.6 cm.

Epoxy resin supplied by Sika, reference SR GreenPoxy 56, with up to 56% of its molecular structure coming from plant origin, was used to impregnate the chicken feather fibres. This percentage is a function of the carbon origin contained in the epoxy molecule. This resin is out coming from the latest innovations in bio-based chemistry. SR GreenPoxy 56 has a density of 1.198 g cm^{-3} and a viscosity of 800 mPa s at 25°C.

2.2. Morphological and thermal study of chicken feather fibres

Morphological characteristics of the chicken feather fibres were obtained by optical and electronic microscopic analysis. Optical microscopy was performed with an optical microscope Olympus BH2, coupled to a JVC TK1280E chamber and an image capture software. The chicken feather fibres were observed using a 40×65 magnification. Electronic microscopy was performed on ultra-high resolution scanning electron microscope (SEM), Nova NanoSEM 200 model. The chicken feather fibres samples were covered with 80:20 wt % Au-Pd (gold-palladium) film and the images were obtained with an acceleration voltage of 15 kV.

Thermal characteristics of chicken feather fibres were obtained by differential scanning calorimetry (DSC), in order to analyze their behavior with thermal variation. This test was performed in a Perkin-Elmer equipment, DSC-4 model, with a heat rate (φ) of 10°C min^{-1}, between 40 and 280°C.

2.3. Composite Materials Production

After the morphological and thermal study of chicken feather fibres, the reinforcement potential of chicken feather fibres in a thermosetting polymer, an epoxy resin, at different volume fractions was studied as described in Table 1. The composite materials were produced by compression moulding process, using appropriate mould, with 25×25 cm dimensions, showed in Fig. 1. Epoxy resin and chicken feather fibres were mixed to obtain an homogeneous mixture with the fibers fully impregnated. The composite materials were developed at 120°C, using 2 ton pressure for 6 minutes. After this heating step, the samples were cooled at room temperature until complete curing of the resin.

Fig. 1: Moulding compression equipment and mould used

Table 1: Composite materials produced

Sample	Epoxy Resin mass fraction (%)	Chicken feather fibres mass fraction (%)
A1	20	80
A2	30	70
A3	40	60

2.4. Characterization Tests of the Composite Materials

The thermal insulation properties of the obtained composite materials were evaluated using an Alambeta device with circular samples with a radius of 55 mm. This device measures the thermal resistance of these materials to the heat flux, and the properties of thermal conductivity and thermal resistance are obtained.

The acoustic insulation properties were obtained using an acoustic insulation chamber, Fig. *2*, according to ASTM D575-91 and E90 standards, by evaluating the noise reduction in the interior area, emitted by a sound source in the exterior area.

Fig. 2: Acoustic insulation chamber

3. Results and Discussion

3.1. Morphological and thermal study of chicken feather fibres

From the optical microscopy was intended to study the chicken feathers surface and their longitudinal characteristics, as shown in Fig. 3. As referred by Reddy et al. [5], the picture shows the main structural units of the chicken feathers, namely the rachis (1), barbules (2) and barbs (3).

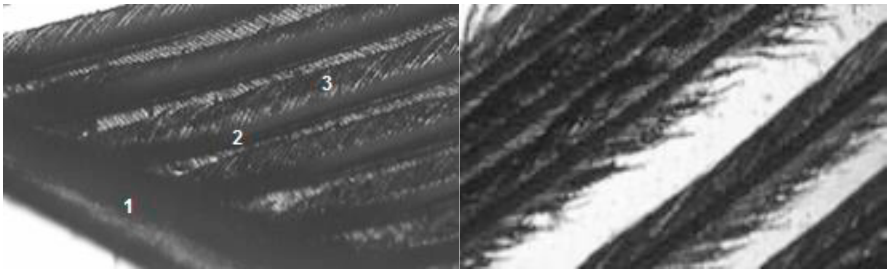

Fig. 3: Optical microscopy of chicken feather fibres

Electronical microscopy was used to analyze traversal section of the chicken feathers and their characteristics. From Fig. 4 it can be observed that the barbs are connected to the barbules. Besides that, it was also showed that the barbs present a heterogeneous distribution of diameters, which may vary between 16.90 and 43.52 µm. Moreover, there are many hollow internal channels with several diameters, between 3.12 µm and 10.26 µm.

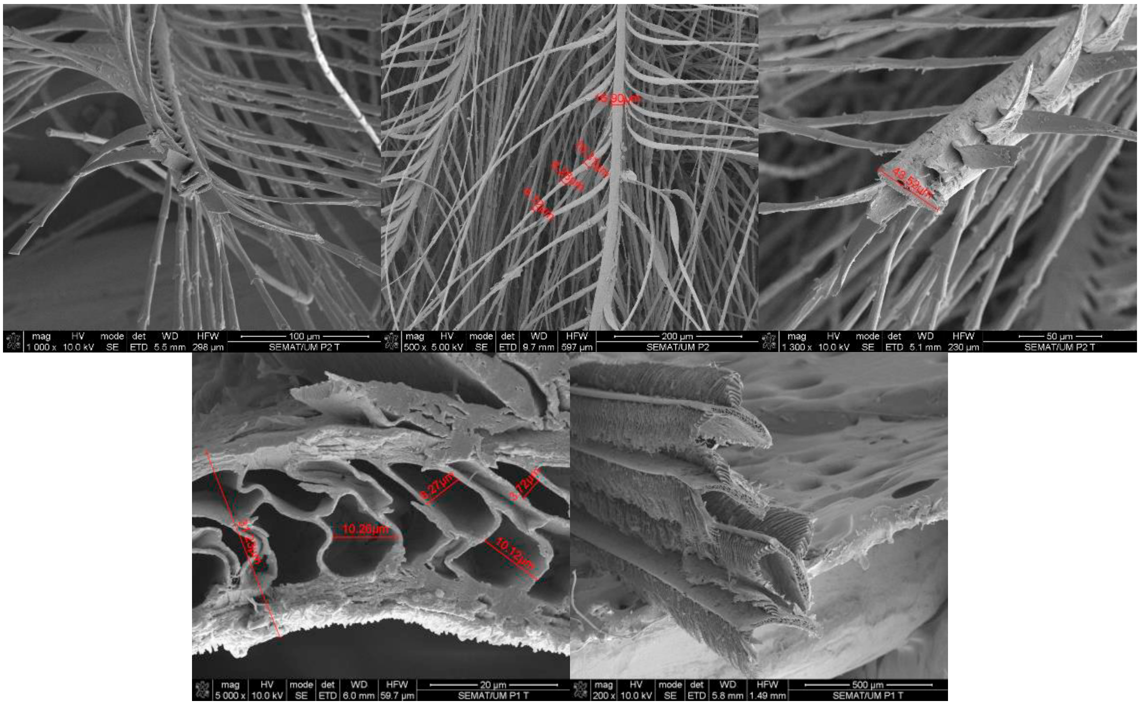

Fig. 4: Electronic microscopy of chicken feather fibres

Through the thermal test by DSC, Fig. 5, it was concluded that the degradation of the chicken feathers fibres begins at 220°C, and at 237°C this material completely degrades. This information is important to ensure that the processing temperatures does not affect the properties of the chicken feather fibres, during the composite materials production.

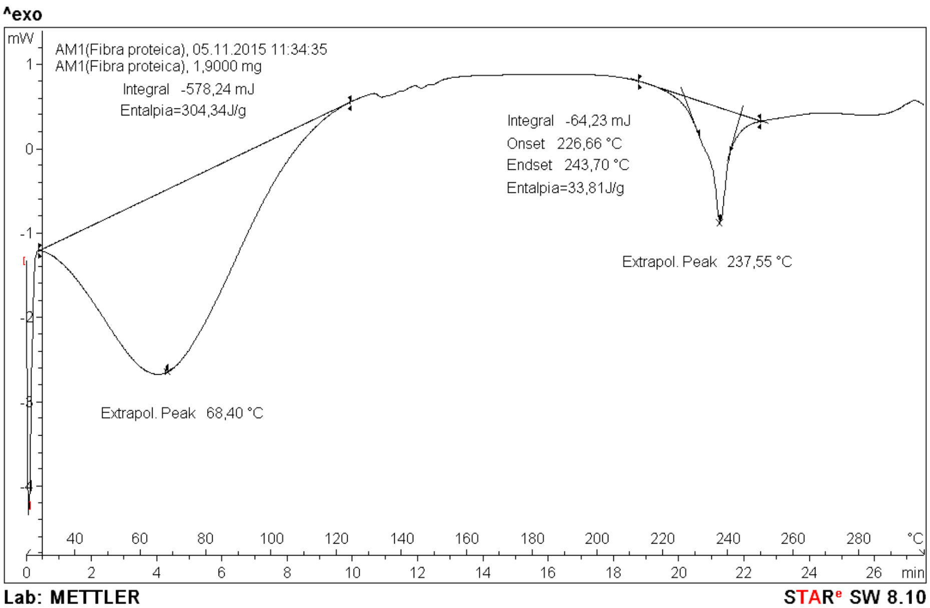

Fig. 5: DSC curve of chicken feather fibres

3.2. Thermal and acoustic performance

The results obtained in the thermal and acoustic tests performed on the composite material samples, Fig. 6, are presented in Table 2. From these results, it can be verified that the thermal resistance increases with the chicken feather fibres mass fraction. It was demonstrated that the thermal resistance increases by 0.128 $m^2\ K\ W^{-1}$ to 0.175 $m^2\ K\ W^{-1}$, for 60:40 and 80:20 ratios. This can be a result of morphological structure of chicken feathers fibres. As referred before, chicken feathers present many hollow internal channels, which strongly contribute for the thermal performance. Then, in theory, the thermal resistance will be greater as the chicken feathers fibres content increase, as showed in Fig. 7.

Fig. 6: Composite materials with chicken fibres reinforcing epoxy resin

Table 2: Results of thermal and acoustic insulation tests of chicken feather fibre reinforced epoxy composites

Sample	Epoxy Resin mass fraction (%)	Chicken feather fibre mass fraction (%)	Thermal Resistance, R ($m^2\ K\ W^{-1}$)	Noise Reduction at 500 Hz (dB)
A1	20	80	0.175 ± 0.004	5.5 ± 0.16
A2	30	70	0.165 ± 0.004	6.8 ± 0.38
A3	40	60	0.128 ± 0.003	6.7 ± 0.42

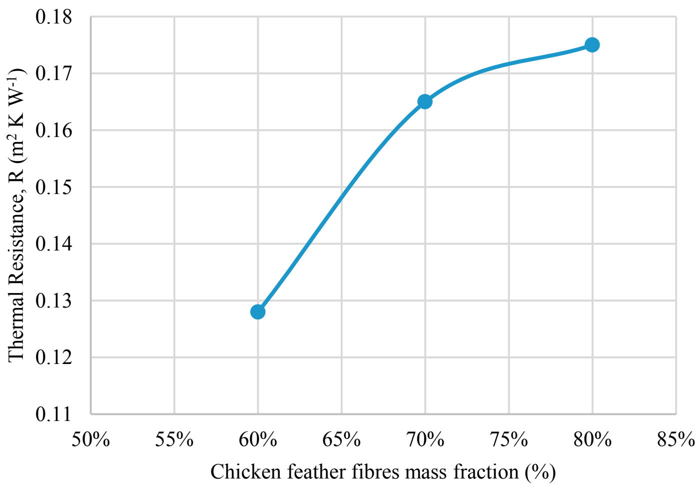

Fig. 7: Effect of chicken feather fibre mass fraction on thermal resistance of composite materials

The obtained results can be compared with other studies previously performed. For instance, PP/natural fiber composites have already been developed and characterized [6]. Natural fiber reinforced composite materials, with 60:40 ratios (natural fibre and polypropylene, respectively) showed thermal resistances of 0.131 m^2 K W^{-1} and 0.115 m^2 K W^{-1} for sisal and coir fibres, respectively [6]. Despite the matrix material was not the same used in this study, it can be concluded that these composite materials can be competitive, mainly if the lower density of chicken feather fibres is considered.

In terms of noise reduction, values of 5,5 and 6.7 dB at 500 Hz were obtained for composite materials with 80:20 and 60:40 ratios, as also showed in the noise reduction curves, Fig. 8. In this context, it can be observed an apparent trend for the decrease of this parameter with the increase of chicken feather mass fraction. Although these are not very high values, these composite materials can be thought as a complementary element for sound insulation to those already existing. This capacity for acoustic insulation can be explained by the morphological structure of the chicken feathers, namely its porosity and the presence of hollow internal channels, which contributes to the absorption of sound waves.

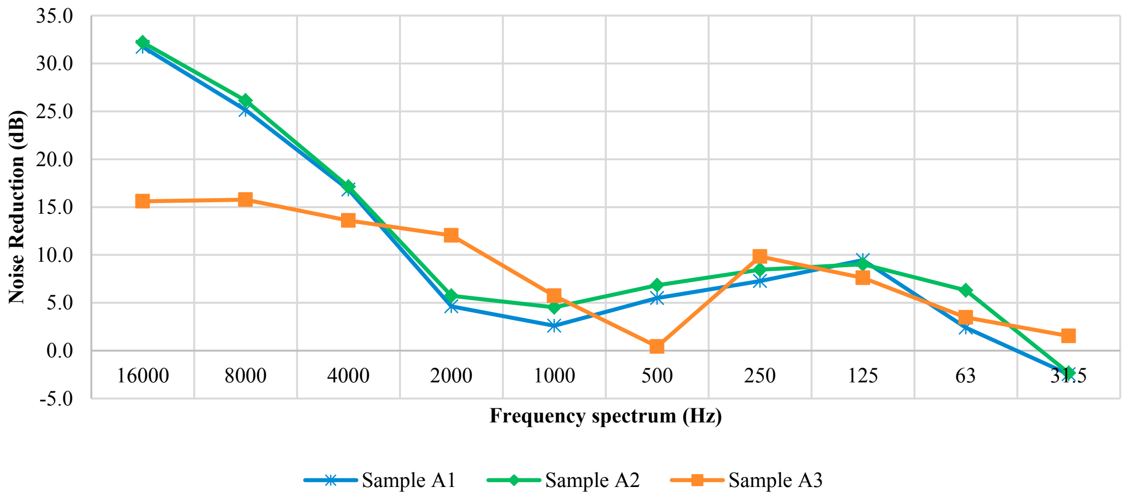

Fig. 8: Noise reduction curves of several samples produced

4. Conclusions

This study shows that the use of natural materials, such as chicken feather fibres, in the reinforcement of polymeric matrices, may lead to interesting properties of thermal and acoustic insulation. Thermal tests showed an increase of approximately 37% on thermal resistance, between samples with 60:40 and 80:20 ratios of chicken feather fibres and epoxy resin, respectively.

The obtained results are competitive, comparing to other developments already carried out with similar materials, such as natural fibres. These results can be justified by the morphological characteristics of chicken feather, which presents hollow structure that favourably contributes to these properties. Moreover, since the density of the chicken feather fibres is lower than these natural materials, their use becomes even more interesting in the development of lighter composite materials.

Thus, from this study, it was verified that this material can be used as reinforcement of composite materials, for several sectors, such as automotive and buildings applications, giving interesting properties in terms of thermal and acoustic insulation.

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