Enhancement of mechanical properties and interfacial adhesion by chemical modification of natural fibre-reinforced polypropylene composites

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INTRODUCTION
The use of natural fibre as reinforcements in thermoplastic polypropylene composites offers an environmentally friendly alternative to glass-fibre-reinforced plastics in some technical applications. The use of natural fibres has many advantages: high strength, low density, and biodegradable (De Bruyne, 2004 and Van de Velde et al., 2001). However, some disadvantages such as variable quality, poor interfacial resistance and incompatibility with hydrophobic polymer matrix limit their potential use in industrial application (Nembashi et al., 2003). The incompatibility is due to the hydrophobicity of natural fibre, which is composed of cellulose that contains strongly polarized hydroxyl groups (Baley, 2002).

The mechanical behaviour of the composite depends to a great extent on the interfacial adhesion between the reinforcing fibre and the polymer matrix (Cantero et al., 2003). To improve this interfacial interaction, many chemical treatments can be used. The most popular is the maleic anhydride polypropylene copolymer (MAPP) (Mishra et al., 2000; Gouthier et al., 1998 and Arbelaz et al., 2003).

All chemically-modified composites revealed an improvement in tensile and flexural modulus in comparison to the unmodified composite. The impact strength of all the chemically-modified composites showed a decrease in comparison to the unmodified composite as shown in Figure 3. The composite modified with 2,4-pentadienoic acid showed the highest impact strength (53.4 kJ/m²), which is comparable to that obtained in glass-reinforced composites (54 kJ/m²) (Jang & Lee, 2000).

The authors would like to thank L Boguslavsky for processing the nonwovens.

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REFERENCES

Table 1: Mechanical data for flax-reinforced polypropylene composites, where the polypropylene was treated with different chemicals

<table>
<thead>
<tr>
<th>Modification</th>
<th>Tensile strength (MPa)</th>
<th>Tensile modulus (GPa)</th>
<th>Flexural strength (MPa)</th>
<th>Flexural modulus (GPa)</th>
<th>Impact strength (kJ/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>56.9 (±4.5)</td>
<td>2.8 (±0.4)</td>
<td>51.7 (±3.3)</td>
<td>2.3 (±0.3)</td>
<td>55.8 (±6.4)</td>
</tr>
<tr>
<td>Acrylic acid 1%</td>
<td>56.9 (±4.5)</td>
<td>2.8 (±0.4)</td>
<td>51.7 (±3.3)</td>
<td>2.3 (±0.3)</td>
<td>55.8 (±6.4)</td>
</tr>
<tr>
<td>2,4-pentadienoic acid 2%</td>
<td>70.4 (±3.8)</td>
<td>6.5 (±0.2)</td>
<td>70.43 (±6.8)</td>
<td>4.67 (±0.1)</td>
<td>16.1 (±2.2)</td>
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The proposed chemical interaction between the fibre, coupling agent and polypropylene is shown in Scheme 2.

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Figure 1: Schematic representation of the reaction, where maleic anhydride is used as a coupling agent between polypropylene and cellulosic fibre

EXPERIMENTAL
Polypropylene sheets are grafted by either acrylic acid, 4-pentanoic acid, 2,4-pentadienoic acid or 2-methyl-4-pentenoic acid. Composites are processed by compression moulding using a film stacking method of layers of polypropylene sheets and flax nonwovens.

RESULTS AND DISCUSSION
Grafting of acrylic acid onto polypropylene is initiated by peroxide radicals. The proposed mechanism for the acrylic acid grafting onto polypropylene and binding to the cellulose is shown in Scheme 3.

Verification of the grafting of acrylic acid onto the polypropylene comes from infra-red spectra shown as Figure 2.

The data for the mechanical properties are given in Table 1 and Figure 3. A maximum modulus is achieved at a 2% treatment.

The tensile modulus of the as-received fibre composite was very low (1.4 and 1.0 GPa) compared to hemp-reinforced composites that gave excellent tensile and flexural modulus (5.4 and 4.7 GPa). The tensile and flexural modulus of the as-received fibre composite was very low (1.4 and 1.0 GPa) compared to hemp-reinforced composites that gave excellent tensile and flexural modulus (5.4 and 4.7 GPa). The tensile and flexural modulus of the as-received fibre composite was very low (1.4 and 1.0 GPa) compared to hemp-reinforced composites that gave excellent tensile and flexural modulus (5.4 and 4.7 GPa).

The hemp fibre composite showed the highest tensile and flexural strength (71 MPa and 71 MPa) while sisal fibre composite showed the lowest (31 MPa and 31 MPa). The composite made from hemp, kenaf and sisal all displayed low impact strength (71 MPa and 71 MPa) while sisal fibre composite showed the lowest (31 MPa and 31 MPa).

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