CHAPTER 5

Mechanical Properties of Multilayer Hildegardia Natural Fabrics/Wheat Protein Isolate green-composites
5.1. INTRODUCTION

In recent years there has been an increasing search for new materials with high performance at affordable costs. With growing environmental awareness, this search has particularly focused on eco-friendly materials, with terms such as “renewable”, “recyclable”, “sustainable” and “triggered biodegradable” becoming buzzwords. This underscores the emergence of a new type of materials - a change from non-renewable but difficult to degrade or non-degradable based to renewable and easily degradable materials (1-5).

The interest in using biodegradable resins receive considerable attention as earth concise materials (eco-materials) and have been recognized as materials with a small environmental load, because biodegradable resins may be resolved in both water and carbon dioxide after perfect biodegradation by the action of microorganisms (6-8). Because almost all of the biodegradable resins have relatively low strength, which is equivalent to the strength of a general-purpose polymer such as polypropylene or polyethylene, it is impossible for biodegradable resins to be used as high strength structural components. In order to improve the properties of biodegradable resins, they are often mixed with bio-fibers. The main advantages of using bio-fibers are renewability, high strength and modulus, low density, non-abrasiveness, ease of separation and biodegradability. So, in the past several years much research has been carried out to develop fully green composites using natural plant based fibers and biodegradable polymers (6-17).
In the present work, it is proposed to develop the completely biodegradable polymer composites with natural polymers like wheat protein isolate (WPI) as matrix and the natural uniaxial oriented fabric Hildegardia as reinforcement. Wheat protein based Hildegardia fabric composites are made for the first time. In the early work we prepared modified wheat protein isolate films using glycerol used as a plasticizer and glutaraldehyde as a crosslinking agent and studied the effect of cross linking agent and plasticizer on the properties of the WPI films.

Among various investigations of composite materials reinforced with natural fibers, only few studies were reported for wheat-based green-composites, reinforced with different natural cellulosic fibers, such as hemp (18), basalt (19), cotton (20), and hydroxyethyl cellulose (21).

Further, fewer reports are available on the use of the uniaxial natural fabric Hildegardia Populifolia as reinforcing material for composites. Hildegardia fabrics were chemically modified by alkali and characterized by density; Fourier transformed infrared spectra (FTIR), Scanning electron microscope (SEM), Thermogravimetric analysis (TGA), and X-ray diffraction (XRD) techniques. Hildegardia fabric reinforced composites were prepared using different polymers and polymer blends as the matrices (22, 23). Recently Hildegardia fabrics have also been used as reinforcement in partially degradable composites with polypropylene and fully biodegradable Poly (propylene carbonate) (24-28).
Populifolia (Roxb). Schott & Endil is a dry deciduous tree species, which belongs to the family of Streculiceae. The natural fabric from this tree is available with the fibers in uniaxial direction. The fibers in it are slightly inter-woven and loosely bound together. The Hildegardia trees are available in large number in Anantapur district of Andhra Pradesh, India.

5.2. MATERIALS

Wheat protein isolate (WPI) powder was obtained from Honeyville Food Products, Salt Lake City, Utah, and USA. WPI was reported by the manufacturer to contain 90% protein, 4% fat (acid hydrolysis) about 5% ash and 1% other minor constituents. Glutaraldehyde solution 25% LR was purchased from S.D fine Chem Limited Mumbai, India. Glycerol about 98% purified and Analytical grade sodium hydroxide (NaOH) were purchased from MERCK Chemicals, Ahmadabad, India. 3-aminopropyltriethoxysilane was used as a coupling agent.

5.3. METHODS

5.3.1. SEPARATION AND MODIFICATION OF REINFORCEMENT

The unidirectional bio-fabric Hildegardia was extracted from the branches of the tree. The fabrics were washed with distilled water and dried in the sun for several days to ensure the removal of the moisture. The average thickness of the fabric is 0.1mm. Some of the fabric samples were treated with 5% aq. NaOH solution for one hour, washed
thoroughly and dried in the oven. Small amounts of the alkali treated and untreated samples were treated with 3-amino propyl triethoxy silane coupling agent diluted to 1% in acetone.

5.3.2. PREPARATION OF GREEN COMPOSITES

Unidirectional fabric-reinforced green-composites were fabricated from wheat protein isolate (WPI) biopolymer solution containing 20% glutaraldehyde and 10% glycerin reinforced with 2.5, 5, 7.5, 10, and 12.5 wt% of natural fabric Hildegardia Populifolia. The wet fabrics were aligned layer by layer on a Teflon® coated glass plate to make a 150 mm × 150 mm sheet and dried for 48 hours at room temperature. For measurement of properties in the longitudinal direction, 10 mm wide specimens of these ‘pre-cures’ sheets were prepared. The dried sheet was then placed between two 150 × 150 mm stainless steel plates and hot pressed (cured) on a hydraulic hot press (Model PF-M15, Techno search Instruments, Kolbad, Maharashtra, India) at 120 °C and 2 MPa measurement of properties in the longitudinal direction, 10 mm wide specimens of these ‘pre-cured’ sheets were prepared. The dried sheet was then placed between two 150 mm pressure for 20 min. The plates with cured composites were removed from the press and allowed to cool down.

5.3.3. MECHANICAL PROPERTIES OF GREEN-COMPOSITES

➢ TENSILE PROPERTIES

The tensile properties of Hildegardia /WPI unidirectional composites were studied using INSTRON 3369 Universal Testing Machine according to ASTMD 3039 procedure using approximately 1mm thick and 20mm wide specimens. A gauge length of 50mm was
maintained for all samples. The tensile parameters – maximum stress, modulus and %
elongation at break were determined at a crosshead speed of 5mm/min. In each case, five
samples were tested and the average values reported.

➢ FLEXURAL PROPERTIES

Flexural properties of *Hildegardia* /WPI unidirectional composites were
characterized accordance to ASTMD 790-99 procedure. Five thickness measurements were
made along the length of each specimen and the average value was used for calculating the
flexural parameters. The flexural tests were carried out at crosshead speed of 2mm/min and
a span length of 25mm. In each case, five samples were tested and the average value
reported.

5.4. RESULTS AND DISCUSSION

➢ TENSILE PROPERTIES

The tensile strength, Young's modulus, the % elongation at break of the
composites under study are presented in Table 5.1. Tests were conducted to understand the
effect of the fibre loading and coupling agent on the mechanical properties of Hildegardia-
MWPI green composites. The tensile strength, Young’s modulus and % of elongation at
break of the green composites were measured at 22 °C and 50% relative humidity. The
importance of the treatment with coupling agent can be assessed by comparing the results of
the untreated and treated fabric composites. Fig 5.1 illustrates the graphical representata of
tensile strength of Hildegardia fabric filled composites containing the untreated and treated
Table 5.1

The Tensile Properties of the matrix and the composites in different weight (%) of natural fabric Hildegardia reinforced in MWPI in the presence of 10% glycerol

<table>
<thead>
<tr>
<th>Fabric Loading</th>
<th>Stress at maximum (Mpa)</th>
<th>Tensile Modulus (Mpa)</th>
<th>%elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UWOCA</td>
<td>UWCA</td>
<td>TWOCA</td>
</tr>
<tr>
<td>2.5</td>
<td>23.1</td>
<td>37.3</td>
<td>40.2</td>
</tr>
<tr>
<td>5</td>
<td>36.1</td>
<td>70.6</td>
<td>87.5</td>
</tr>
<tr>
<td>7.5</td>
<td>65.5</td>
<td>86.0</td>
<td>92.5</td>
</tr>
<tr>
<td>10</td>
<td>103.2</td>
<td>105.9</td>
<td>116.7</td>
</tr>
<tr>
<td>12.5</td>
<td>41.7</td>
<td>44.1</td>
<td>80.2</td>
</tr>
<tr>
<td>Matrix</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WOCA** - without coupling agent, **WCA** - with coupling agent.
Fig: 5.1 (a) Tensile strength of the matrix and Wheat Protein Isolate composites reinforced with

- **UNTWOCA**: Untreated fabric without coupling agent
- **UNTWCA**: Untreated fabric without coupling agent
- **TWOCA**: Alkali treated fabric with coupling agent
- **TWCA**: Alkali treated fabric with coupling agent
Fig. 5.1 (b) Tensile modulus of the matrix and Wheat Protein Isolate composites reinforced with

UNTWOCA : Untreated fabric without coupling agent
UNTWCA : Untreated fabric without coupling agent
TWOCA : Alkali treated fabric with coupling agent
TWCA : Alkali treated fabric with coupling agent
fabrics with amino-based coupling agent as a function of fiber loading from 2.5 to 12.5% W/W. The matrix properties are also presented in the same table for comparison. From the Table 5.1 and Fig. 5.1(a) and (b), it clearly evident that the tensile strength and Young's modulus were increased for fabric loading of 2.5% to 10% (w/w) and beyond this decreased. This behavior can be explained on the basis that at higher fabric loading the fabric-fabric contacts overshadow the resin matrix-fabric contact hence there was decrement in tensile strength beyond 12.5%. The tensile properties of MWPI- composites prepared using alkali treated fabric in the presence of amino-based coupling agent were higher compared to the matrix and composites with untreated fabrics. The increase in the tensile strength when the fabrics were treated with amino-based coupling agent can be explained by the better adhesion between the fabrics and the matrix. Better adhesion improves stress transfer through fabrics; therefore increase in tensile strength of the green composites.

All green composites showed a increase in Young's modulus as fabric loading increased up to 10% (W/W) and beyond this decreased. The increase in Young's modulus due to the amino treatment can be attributed to the better adhesion between the fabric and the matrix by chemical deformation. Better adhesion yield to more restriction to deformation capacity of the matrix in the elastic zone increasing Young's modulus.

> FLEXURAL PROPERTIES

The flexural strength and modulus of WPI/Hildegardia composites are presented in Table 5.2 and graphically represented in Fig 5.2(a) and Fig 5.2(b) respectively. For
Table 5.2

The Flexural Properties of the matrix and the composites in different weight (%) of natural fabric Hildegardia reinforced in MWPI in the presence of 10% glycerol

<table>
<thead>
<tr>
<th>Fabric Loading</th>
<th>Flexural Strength at maximum (Mpa)</th>
<th>Tensile Modulus (Mpa)</th>
<th>%elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WOCA</td>
<td>UWCA</td>
<td>TWOCA</td>
</tr>
<tr>
<td>2.5</td>
<td>20.1</td>
<td>28.6</td>
<td>34.5</td>
</tr>
<tr>
<td>5</td>
<td>32.3</td>
<td>48.5</td>
<td>49.9</td>
</tr>
<tr>
<td>7.5</td>
<td>49.8</td>
<td>51.4</td>
<td>56.8</td>
</tr>
<tr>
<td>10</td>
<td>62.0</td>
<td>79.6</td>
<td>81.5</td>
</tr>
<tr>
<td>12.5</td>
<td>58.3</td>
<td>72.5</td>
<td>620.</td>
</tr>
<tr>
<td>Matrix</td>
<td>8.81</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WOCA- without coupling agent, WCA- with coupling agent.
Fig. 5.2 (a) Flexural strength of the matrix and Wheat Protein Isolate composites reinforced with

- **UNTWOCA**: Untreated fabric without coupling agent
- **UNTWCA**: Untreated fabric without coupling agent
- **TWOCA**: Alkali treated fabric with coupling agent
- **TWCA**: Alkali treated fabric with coupling agent
Fig. 5.2 (b) Flexural Modulus of the matrix and Wheat Protein Isolate composites reinforced with

UNTWOCA : Untreated fabric without coupling agent
UNTWCA : Untreated fabric without coupling agent
TWOCA : Alkali treated fabric with coupling agent
TWCA : Alkali treated fabric with coupling agent
comparison, the values for the matrix are also presented in the same table. From the Table 5.2 and Fig; 5.2(a) and (b), the flexural properties of all composites reinforced with alkali treated fabrics in the presence of amino-based coupling agent of the composites were found to be higher which can be attributed to the modification in the molecular level of the fabrics due to chemical bonding between fabric and the amino groups. Such linkage might have led to better interfacial bandage, better adhesion, and effective stress transfer. Both flexural strength and modulus were found to increase with fabric content from 2.5 to 10 % (w/w) and beyond this decreased, because higher fabric loading does not exhibit a higher retention in strength properties after exposure. The values are also higher when the fabric was treated with an alkali and a coupling agent.
REFERENCES


