Particle Board from Leaf Fibre Residues of Sugarbeet

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The making of particle boards from sugarbeet leaf fibre residue left after protein extraction using different binder systems, viz. urea-formaldehyde (UF) resin, phenol-formaldehyde (PF) resin and in situ condensation of urea and formaldehyde without applying any resin is described. Laboratory studies of the physico-mechanical properties of the prepared particle boards show that these are comparable to those of other particle boards made from similar lignocellulosic materials. The properties of the investigated boards conform to the BIS specifications for medium density general purpose particle boards which could be used for panelling, ceiling, partitioning, etc. in interior decoration.

Introduction

Sugarbeet (Beta vulgaris L.) is an important source of sugar, contributing nearly 40% to the world sugar production. The plant is conventionally grown as a summer crop in temperate regions but it is cultivated as winter crop also in subtropical regions. The plant is a good source of succulent fodder during the hot months of summer when other green fodders are scarce. The roots of the plants are used for industrial production of alcohol, pectin, etc. while the leaves are a supplementary source of protein in human nutrition². Sugarbeet leaves have been used as a source material for leaf protein extraction¹. During bulk extraction of protein from sugarbeet leaves, huge amount of lignocellulosic fibrous residue (~ 80%) is obtained as a waste by-product which creates disposal problems, causing environmental pollution. Commercial utilization of this lignocellulosic biomass by conversion to useful products will make leaf protein extraction from sugarbeet leaves more profitable and will benefit the rural population economically. It is well established that lignocellulosic biomass of different agrowastes can be profitably utilized, replacing wood for making pulp, paper, particle board, etc.

The particle boards are a good substitute for plywood and can be used in the furniture industry as well as in the construction of houses where they are used in flooring, partitioning, ceiling, and also on the outer walls with suitable coatings. Wood chips obtained from forest thinning and timber mill wastes are commonly used for the production of particle boards. The world production of particle board is estimated to increase @ 7.05% annually¹ to meet the growing demand. In India, the demand for particle board is on the rise with growth in population and increased activity in the construction sector as plywood has become scarce and costly due to large scale deforestation in the country. Owing to declining forest potential, alternative raw materials like lignocellulosic agrowastes are increasingly used substituting wood for the production of particle board. The present paper deals with the preparation of particle board and evaluation of its physico-mechanical properties using leaf-fibre residue which is obtained in bulk quantities after the protein extraction from sugarbeet leaves.

Materials and Methods

Fresh green leaves of sugarbeet plant (Beta vulgaris L.) were collected from the field of Gupta Niwas, Indian Statistical Institute, Calcutta. The leaf protein was extracted from the green leaves by International Biological Programme (IBP) pulper and press³ when a large quantity of fibrous residue was obtained as the by-product. The leaf fibre residue was dried in air and powdered in a disintegrator to 60-80 mesh. The fibrous residue was

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defattted with alcohol-benzene mixture (1:2, v/v) in a Soxhlet apparatus after refluxing for 6 hours. The major chemical constituents like α-cellulose, hemicellulose and lignin of the leaf fibre residue were estimated by TAPPI standard methods⁷ using defatted samples. Ash content was estimated by heating one gram raw sample in a muffle furnace for 4 hours at 550 °C. Modified acid detergent fibre⁸ (ADF) and neutral detergent fibre⁹ (NDF) were also estimated from the defatted samples by standard methods.

Preparation of Particle Board

The weighed quantity of powdered fibrous residue was sprayed with the required amount of resin. Particle boards of dimension 16 cm x 16 cm x 1.3 cm were prepared from the resin impregnated material on an electrically heated hydraulic press (PEECO hydraulic press, capacity 30 tonnes) at 140°C under a pressure of 40 kg/cm² for 20 min. Different types of particle boards were prepared using three different binders, viz. (i) urea-formaldehyde (UF) resin (solid content 60%), (ii) phenol-formaldehyde (PF) resin (solid content 50%), and (iii) in situ condensation of urea and formaldehyde in 3:1.6 ratio (wt/wt) without applying any resin. Both UF and PF resins were supplied by Hindusthan Adhesives, Calcutta.

Testing of Particle Board

The specimen boards were cut to specified size, as per the Indian Standard specifications¹⁰. The test specimens were conditioned by exposing to the atmosphere for at least 48 h immediately before testing. The boards were tested for physical properties like moisture content, density, water absorption (%) after 2 hours and 24 hours soaking in water. The swelling value (thickness swelling) and mechanical properties like impact strength and tensile strength were calculated according to BIS specifications¹¹. The tensile strength, perpendicular to the surface of board, was measured by UTS (Universal Instron Strength Testing) machine while an Impact strength machine (Avery, India) was used to measure the impact strength of the prepared particle boards.

Results and Discussion

The major chemical components of sugarbeet leaf fibre residues (expressed as per cent oven dried weight) was as follows: α-cellulose, 35.64; hemicellulose, 30.64; lignin, 12.50; ash, 13.83; ADF, 40.00; NDF, 47.40. The biomass contained high carbohydrate content, low lignin but high ash content and resembled the tropical hardwood¹². Structurally, it was similar to some lignocellulosic materials like bagasse¹³, jute stick¹⁴, cotton stalk¹⁵, etc., commonly used for particle board production.

The physico-mechanical properties of particle boards prepared from sugarbeet leaf fibre residues by different binder systems are given in the Table. The fibre content of the prepared boards was 38-40%. Boards prepared by in situ condensation of urea and formaldehyde showed inferior physico-mechanical properties in comparison to the boards prepared using UF and PF resins. The water absorption of the boards was high due to the presence of high content of hygroscopic hemicelluloses. The water absorption could be reduced by adding

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Table 1 — Physico-mechanical properties of particle boards prepared from sugarbeet leaf fibre residue with different binder systems

<table>
<thead>
<tr>
<th>Material</th>
<th>Binder</th>
<th>Moisture content (%)</th>
<th>Density (kg/m³)</th>
<th>Water Absorption value (%) After 24 h soaking</th>
<th>Thickness swelling (%)</th>
<th>Impact strength (kgf/cm)</th>
<th>Tensile strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarbeet</td>
<td>UF resin</td>
<td>9.30</td>
<td>612.46</td>
<td>22.67</td>
<td>61.44</td>
<td>3.17</td>
<td>2.5</td>
</tr>
<tr>
<td>Leaf fibre residues</td>
<td>PF resin</td>
<td>12.29</td>
<td>652.68</td>
<td>50.27</td>
<td>60.41</td>
<td>4.03</td>
<td>3.5</td>
</tr>
<tr>
<td>Cotton stalk</td>
<td>UF resin</td>
<td>3.6</td>
<td>570-720</td>
<td>29-72</td>
<td>57-100</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Coconut pith</td>
<td>UF resin</td>
<td>10.2</td>
<td>668.5</td>
<td>5.3</td>
<td>13.6</td>
<td>4.8</td>
<td>—</td>
</tr>
<tr>
<td>Jute stick</td>
<td>UF resin</td>
<td>10</td>
<td>407</td>
<td>39.5</td>
<td>51.7</td>
<td>9.5</td>
<td>1.5-2.9</td>
</tr>
<tr>
<td>IS specifications</td>
<td>—</td>
<td>5-15</td>
<td>500-900</td>
<td>25</td>
<td>50</td>
<td>10</td>
<td>—</td>
</tr>
</tbody>
</table>

Column labels: Material: Sugarbeet, Leaf fibre, Cotton stalk, Coconut pith, Jute stick, IS specifications; Binder: UF resin, PF resin; Moisture content (%); Density (kg/m³); Water Absorption value (%) After 24 h soaking; Thickness swelling (%); Impact strength (kgf/cm); Tensile strength (N/mm²).
certain water repellent coatings or by adding suitable water repellent chemicals in the formulation during the board preparation, depending upon the end use. The lignin content present in the fibre residues gets softened at high temperatures and pressures and acts as a binder in the board formation. A comparison of the performance of particle boards prepared from sugarbeet leaf fibre residues and other lignocellulosic wastes like jute stick\textsuperscript{12,15}, cotton stalk\textsuperscript{14} and coconut pith\textsuperscript{16} with regard to various physico-mechanical properties is shown in the Table 1.

The typical physico-mechanical properties of the particle boards prepared from sugarbeet leaf fibre residues conformed to the BIS specifications\textsuperscript{11} of medium density fibre board for general purpose requirements like paneling, cladding, surfacing and partitioning materials for indoor applications. It is evident that sugarcane leaf fibre residues can be utilized like other lignocellulosic wastes for making particle boards of commercial value. The main advantages of the developed particle board are use of renewable raw material, cheaper than wood, replacement of wood for interior applications, protecting the forest, and an eco-friendly process with indigenous equipments utilizing an agrowaste which otherwise creates disposal problems, causing environmental pollution.

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References