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Path towards a sustainable bioeconomy: Conversion of locally available rice straw to nanocellulose

Extract: The Sri Lankan agriculture sector has the potential to support a national bioeconomy. Rice straw is a key by-product generated from paddy cultivation. While it is traditionally treated as a waste matter, straw can be a valuable resource in producing biomass fibers in the green composite production due to properties such as recyclability, biodegradability, renewability, nontoxicity, and high functionality. Comprehensive investigations have been carried out on the chemical, mechanical, and thermal properties of cellulose fibers extracted from locally available straw. The study outcomes can help in determining how this material can be effectively used in various applications.

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Nowadays most of the developing countries are adopting bioeconomy as a path towards achieving their Sustainable Development Goals (SDGs). Contribution of bioeconomy can be measured either in terms of employment opportunities and value addition, or social and environmental aspects. Sustainable use of natural resources and renewable biomass is one of the contributors to a sustainable bioeconomy.

Agriculture sector in Sri Lanka is significant in terms of land resource utilization as well as labor deployment. 21st century is directing economies to go circular as well as embrace a bioeconomic approach. In that context, the paddy production can be viewed in a completely different perspective.

Paddy is cultivated as a wetland crop in almost all parts of the country except at very high altitudes with traditional or technically modified varieties. In addition to health benefits, traditional rice is recommended for those who suffer from non-communicable diseases. Traditional rice varieties also possess robust and unique characteristics which make them resilient to diverse climatic conditions like floods, heavy rains and drought. On the other hand, technically modified rice varieties were developed to get the characteristics lacking in traditional varieties such as high yield, greater resistance to pests and diseases, increased response to fertilizer, and better grain quality etc.

One of the major by-products generated from paddy cultivation and processing is rice straw. It is considered as agricultural waste in the country since it has less commercial value and has not been converted into any valuable by-product. Rice straw is a lignocellulosic biomass composed of both organic and inorganic matter. Cellulose, lignin, hemicellulose, some proteins and vitamins are the organic components while the major inorganic mineral component is silica.

Cellulose is the most abundant natural biopolymer on earth which is gaining the momentum as an ideal replacement for synthetic fibers that are currently in use. It is also a suitable candidate for biomass fibers in the green composite production due to their properties such as recyclability, biodegradability, renewability, nontoxicity, low density, some favorable mechanical properties, and high functionality.

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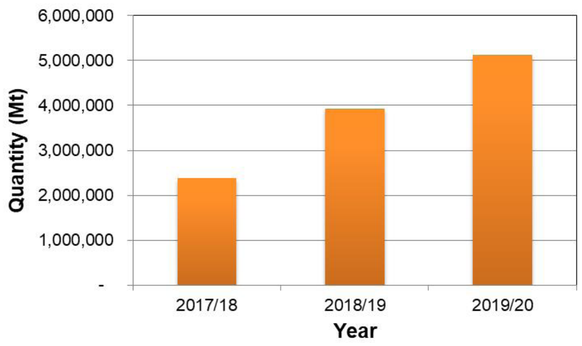

Figure 1: Total paddy production during Yala and Maha seasons in Sri Lanka
(Source: Department of Census and Statistics, Paddy Statistics, 2017/18, 2018/19 and 2019/20)

As a path towards value addition of this commercially under-utilized waste, initially cellulose fibers were successfully extracted from locally available straw of traditional and technically modified rice varieties via a series of chemical treatments. These chemically extracted cellulose fibers were then disintegrated into micro and nano-cellulose using chemical and mechanical processes. Also a comprehensive investigation of structural, morphological and thermal properties of these chemo-mechanically extracted cellulose, micro-cellulose and nanocellulose were carried out.

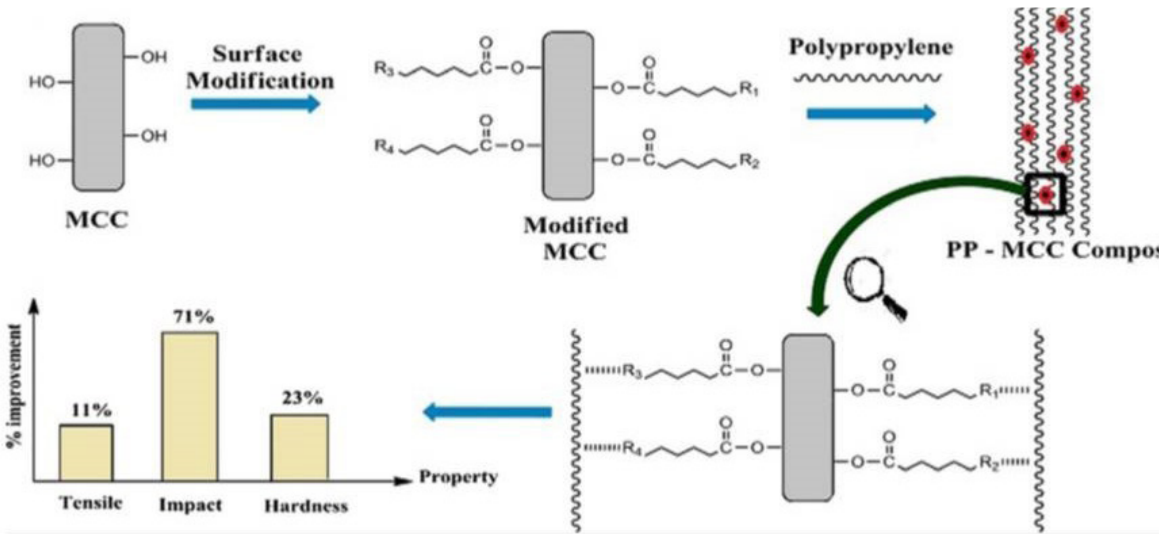

Figure 2: Microcellulose (MCC) surface modification to achieve improved thermo-mechanical properties of a polypropylene composite

Furthermore, a bio-based approach was studied to enhance surface hydrophobicity of microcellulose and thereby improve the compatibility with a hydrophobic polypropylene (PP) matrix. This environmentally friendly green chemistry approach introduces a monomolecular long-chain fatty acid layer on the microcellulose surface, making the surface hydrophobic. The inclusion of surface-modified microcellulose in the PP matrix significantly improved the thermo-mechanical properties and thermal stability of the composite. The improved compatibility between microcellulose and PP also reduces gap and flaw formation at the fiber and matrix interface, lowering the water uptake of the modified microcellulose-PP composites.

Apart from this, these micro and nanocellulose fibers can be utilized as reinforcement for nanocomposites, protective coatings, barrier membranes and filtration systems, scaffolds for tissue engineering, drug delivery systems and antimicrobial films. The findings of these studies will not only add value to the commercially under-utilized waste rice straw and also emphasize sustainable transition to a bioeconomy in the country.

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