Unlocking the Potential of Local Indian Biobased Materials for Circular Cricket Gear

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October 2026

This research study has been funded by the University for the Creative Arts (UCA) UKRI Impact Accelerator Account (IAA)

Table of Contents

1. Introduction 3
2. Background 3
3. Scope for the Study on Potential Local Indian Biobased Materials for Circular Cricket Gear 4
3.1 Sugarcane Bagasse 6
3.2 Rice Straw 6
3.3 Wheat Straw 7
3.4 Maize Stover and Husks 7
3.5 Cotton Stalk Residues 7
4. Mycelium-Based Bio-Foam Prototype Development 8
5. Conclusion 10
References 11

1. Introduction

This report forms part of the Decathlon Collaboration: Circular Cricket Gear from Concept to Production Project [DC_Cricket], led by The Centre for Sustainable Design ® (CfSD) at the University for the Creative Arts (UCA) in collaboration with Decathlon Cricket (India). The project was funded by the UCA's UKRI IAA grant and ran from August 2025 to July 2026 and forms part of the overall research on sustainability in cricket, through its Platform for Accelerating Sustainability in Cricket (PASIC) led by CfSD in association with Department of Architecture, University of Cambridge.

The [DC_Cricket] project is a collaborative research and development initiative that aims to explore the design and development of circular cricket gear for the Indian market. The project responds to the growing need to reduce the environmental impacts associated with sporting goods by integrating circular economy principles into the design, manufacturing, use, and end-of-life management of cricket equipment.

The primary focus of the project is the development of circular cricket batting gloves and pads that meet performance, quality, and manufacturing requirements while reducing reliance on virgin fossil fuel-based materials and improving product circularity. Through a value-chain approach involving stakeholders across design, manufacturing, material supply, retail, and end-user communities, the project seeks to generate new knowledge on the practical implementation of circular design strategies within the cricket equipment sector.

The specific findings presented in this report relate to potential sustainable material substitution. The report, "Unlocking the Potential of Local Indian Biobased Materials for Circular Cricket Gear, has been guided by the following research question:

Can existing fossil fuel-based components used in cricket batting pads be replaced by locally sourced biobased materials without compromising product performance and functionality?

2. Background

Following a week-long innovation workshop delivered by CfSD with Decathlon Cricket Innovation Team in Bangalore in February 2026, four circular design concepts for next-generation cricket batting pads were developed. Building on the outcomes of this workshop, together with existing research undertaken through (PASIC), this report aims to highlight the feasibility of using locally sourced Indian bio-based materials as alternatives to conventional materials used in cricket pad construction.

The research presented in this report focuses on identifying sustainable material substitutes for the high-density polymeric foam e.g. high-density foam (HDF) currently employed within batting pads. This material was identified as a significant environmental hotspot through the completion of a streamlined Life Cycle Assessment (LCA) conducted by CfSD in 2023.[1] The assessment revealed that the high-density foam contributed disproportionately to the product's overall environmental burden, particularly in relation to human health impacts associated with carcinogenic emissions arising from its manufacture and upstream supply chain processes. As a result, it was decided to complete a study to examine the potential application of bio-based materials derived from locally available Indian agricultural residues and waste streams as substitutes for high-density foam components.

[1] https://cfsd.org.uk/wp-content/uploads/2023/05/Final-Streamlined-LCA_batting-pads.pdf

The selection of candidate materials was informed by the functional requirements of cricket batting pads, with particular emphasis placed on impact energy absorption, mechanical flexibility, formability, moisture resistance, and sweat-repellent characteristics. These performance criteria are essential to ensuring that any proposed bio-based alternative can meet the protective, ergonomic, and durability requirements expected of high-performance sporting equipment while simultaneously reducing environmental impacts.

While technical performance and environmental sustainability represent the primary assessment criteria, the study also considers the potential socio-economic implications of sourcing and valorising agricultural residues and waste streams. Circular economy research increasingly recognises that material substitution strategies can generate unintended social consequences if they alter existing resource flows, disrupt local livelihoods, or contribute to unequal access to and control over valuable secondary resources (Barford & Ahmad, 2021; McCauley, 2025).

Agricultural residues identified as potential feedstocks may already fulfil important functions within local socio-economic systems, including use as animal feed, bioenergy feedstocks, construction materials, and other income-generating resources. Diverting these materials into new industrial applications could therefore create resource competition and disrupt existing value chains. To account for these considerations, the study examines existing uses of candidate feedstocks and identifies materials that are currently underutilised or present a lower risk of displacing established economic activities.

3. Scope for the Study on Potential Local Indian Biobased Materials for Circular Cricket Gear

The initial scoping of the study was assisted by the use AI, namely Chat GPT[2] , which was prompted to include a list of agricultural produce in and around a 50km radius of the cricket gear manufacturing hub the Punjab Region of Jalandhar. The evaluation of agricultural residues as potential substitutes for high-density foam (HDF) in cricket batting pads was undertaken using a multi-criteria assessment framework encompassing technical performance, environmental impact, resource availability, and socio-economic considerations. The primary functional requirement is the development of a lightweight, impact-absorbing cellular material capable of replicating the protective performance of HDF.

The following is a list of the top 5 agricultural residues that present an opportunity to produce a bio-foam with ranking focused on the material's technical performance.

Rank	Agricultural residue	Bio-foam potential	Availability near Jalandhar	Main rationale
1	Sugarcane bagasse	Very High	Moderate–High	Strong candidate for bio-based foam development; availability depends on access to regional sugar mills and processing facilities.
2	Rice straw	High	Very High	Abundant residue from paddy cultivation across Punjab; potential for cellulose-based porous materials.
3	Wheat straw	High	Very High	Widely available agricultural residue with potential for lightweight cellulose-based structures.

[2] Disclaimer: the AI assisted findings presented in this report have been validated via further desk research and direct communications with industry experts to the best of the authors' knowledge.

4	Maize stover & husks	Moderate–High	Moderate	Potential for fibre-reinforced foams and composites; availability depends on local maize cultivation.
5	Cotton stalk residues	Moderate	Low–Moderate	Suitable for cellulose extraction and reinforc ement; cotton production is concentrated el sewhere in Punjab.

As mentioned in the introduction, the assessment of the materials identified also recognises existing material, uses, accessibility, and potential impacts on local communities and resource governance as secondary potential impacts alongside technical requirements. While the focus remains on identifying a material that possess the functional properties required for the application of cricket batting pads, the following evaluation of potential competing resource demands and socio-economic impacts has been completed to raise awareness of these considerations.

Agricultural residue	**Existing uses and competing demand**	**Responsible sourcing considerations**	**Potential socio-economic impacts and local livelihoods**	**Circular economy opportunities and risks**
Sugarcane bagasse	Commonly used by sugar mills for energy generation; also used in pulp and other biobased products.	Assess whether surplus bagasse is available without displacing existing energy uses, consider moisture, storage, processing and transport requirements.	Potential to create additional revenue for sugar mills and opportunities for regional processors. Benefits may be concentrated among established industrial operators rather farmers.	Opportunity: valorisation of surplus processing residue. Risk: diverting bagasse from energy production may increase demand for alternative fuels.
Rice straw	Used for animal bedding, fodder in some contexts, soil incorporation, bioenergy and other applications. Significant quantities are also burned in Punjab.	Priorities straw that would otherwise be burned or remain underutilised. Ensure sustainable residue removal rates and consider soil nutrient requirements.	Potential additional income for farmers, collection contractors and local processors. Collection and transport costs may create barriers for smaller farmers.	Opportunity: reduce open field burning and support local circular supply chains. Risk: excessive residue removal may reduce soil organic matter and nutrient cycling.
Wheat straw	Widely used as livestock fodder, particularity dry roughage, as well as bedding and other agricultural applications.	Avoid diverting straw from established fodder markets. Assess competing demand, seasonal process and local livestock requirements.	Potential additional revenue for farmers but increased industrial demand could raise fodder prices and affect livestock dependent households.	Opportunity: Develop higher-value applications for genuinely surplus straw. Risk: competition with essential agricultural uses may undermine social and economic sustainability.
Maize stover & husks	Used for animal fodder, soil cover, composting and occasionally fuel or other fiber applications.	Assess the quantities available after meeting livestock feed and soil management needs. Consider collection logistics and seasonal supply.	Opportunities for farmers, small scale processors and agricultural cooperatives to supply biomass. However, additional collection and processing may increase labour and equipment requirements.	Opportunity: diversification of agricultural residue use. Risk: competing fodder demand and soil impacts if residues are removed excessively.
Cotton stalk residues	Used as fuel, bioma ss feedstock and so metimes for fibrebo ard or other applica tions; some residue s are disposed of or burned.	Consider longer transport distances from cotton growing regions, pesticide residues, processing requirements and existing uses.	Potential new income opport unities for cotton-growing communities and bio mass processors, although be nefits may be less localised ar ound Jalandhar.	Opportunity: productive use of residues with limited higher-value applications. Risk: transport emissions, processing impacts and reduce local sourcing benefits.

Given the primary objective of this research to identify the material with the greatest immediate potential to replace conventional high-density foam (HDF), sugarcane bagasse remains the strongest technical

candidate. However, further sourcing analysis is required to establish the availability of surplus material without displacing existing energy generation or industrial applications.

The following section provides a more detailed assessment of the five shortlisted agricultural residues, examining their potential for bio-foam development and suitability as HDF substitutes in both the short and longer term.

3.1 Sugarcane Bagasse

Sugarcane bagasse demonstrates the strongest technical potential for the development of bio-based impact-absorbing materials.[3] Sugarcane bagasse has favourable fibre characteristics and established potential for composite manufacture.[4] It has also been successfully processed into lightweight, porous biofoam structures with measurable compressive properties.[5] Bagasse-fibre composites have demonstrated impact-energy absorption through mechanisms including fibre pull-out and interfacial failure.[6] Together, these findings indicate the potential of bagasse as a feedstock for lightweight, bio-based impact-protection structures.

However, unlike rice straw and maize residues, bagasse is not an underutilised waste stream. Across India, bagasse already supports significant industrial activity, particularly within the sugar sector, where it is widely used for cogeneration of electricity and heat, paper manufacturing, fibreboard production, and bio-based materials. Consequently, large-scale diversion of bagasse towards sporting equipment applications may create competition with established value chains and potentially increase material prices. While these risks are not necessarily prohibitive, they require careful consideration within a circular justice framework, particularly if increased demand leads to the concentration of material ownership or limits access for existing users.

3.2 Rice Straw

From a socio-environmental perspective, rice straw presents a significant opportunity. Large quantities remain underutilised across northern India, and open field burning continues to generate severe environmental and public health impacts.[7] The valorisation of rice straw into bio-based products could therefore contribute to emissions reduction while creating additional income streams for agricultural communities.

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[3] Zheng Y, Liao J, Fang Y, Gui R, Hou Y, Zhang M, Dong Y, Zheng Q, Luan P, Chen X. Innovative fabrication of eco-friendly bio-based foam from sugarcane bagasse and sodium alginate with enhanced properties and sustainable applications for plastic replacement. Int J Biol Macromol. 2024 Dec;282(Pt 6):137464. doi: 10.1016/j.ijbiomac.2024.137464. Epub 2024 Nov 9. PMID: 39528172.

[4] Y.R. Loh, D. Sujan, M.E. Rahman, C.A. Das, Sugarcane bagasse—The future composite material: A literature review, *Resources, Conservation and Recycling, Volume* 75, 2013, Pages 14-22, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2013.03.002.

[5] Indarti, E., Muliani, S. and Yunita, D. (2023) 'Characteristics of Biofoam Cups Made from Sugarcane Bagasse with *Rhizopus oligosporus* as Binding Agent', *Advances in Polymer Technology*, 2023, Article 8257317. https://doi.org/10.1155/2023/8257317.

[6] Sérgio Luiz Moni Ribeiro Filho, Pablo Resende Oliveira, Tulio Hallak Panzera, Fabrizio Scarpa, Impact of hybrid composites based on rubber tyres particles and sugarcane bagasse fibres, Composites Part B: Engineering, Volume 159, 2019, Pages 157-164, ISSN 1359-8368, https://doi.org/10.1016/j.compositesb.2018.09.054.

[7] Prasad, R., & Shivay, Y. S. (2018). *Management options to alleviate the menace of rice (Oryza sativa) straw burning—An overview*. *Indian Journal of Agricultural Sciences*, 88 (11). DOI: 10.56093/ijas. v88i11.84879.

However, despite these environmental benefits, rice straw presents limitations for applications requiring high and consistent mechanical performance. Rice straw is characterised by a relatively high silica content compared with other cereal straws, and this inorganic fraction can influence the processing and performance of rice-straw-based materials. Studies of rice-straw composites and boards have shown that silica content affects bonding and material properties, with *deashing*[8] treatments being investigated to improve composite performance (Van Soest, 2006; Kurokochi & Sato, 2015; Basta et al., 2014). Significant material engineering would be required to achieve performance levels comparable to conventional foam. Furthermore, increasing commercial demand for rice straw may affect emerging markets that already utilise the material for bioenergy, animal bedding, paper production, and soil management applications.

3.3 Wheat Straw

Wheat straw occupies a similar position to rice straw, although with improved processability due to lower silica content. Wheat straw is already utilised across a range of agricultural and industrial applications, including livestock feed and bedding, soil incorporation, bioenergy production, and the manufacture of fibreboard (Tufail et al., 2021; Halvarsson et al., 2010). While technically capable of contributing to bio-based composite systems, wheat straw demonstrates limited evidence of suitability for high-performance impact attenuation.

From a socio-economic perspective, wheat straw's established role within rural agricultural systems suggests a greater likelihood of resource competition. As a result, although technically viable, wheat straw presents moderate risks in relation to competing uses and livelihood impacts.

3.4 Maize Stover and Husks

Maize residues present favourable material characteristics, including relatively low density, good fibre flexibility, and moderate compressibility. These properties indicate potential for incorporation into lightweight cellular composites capable of energy absorption. In addition, maize husks are an underutilised lignocellulosic residue with potential for cellulose extraction and incorporation into biopolymer composite systems.[9]

From a circular economy perspective, maize residues may therefore represent an opportunity due to their combination of technical properties and relatively low levels of existing commercial utilisation. The principal challenge relates to the dispersed nature of maize production, which may increase collection and logistics costs while creating difficulties in establishing stable supply chains.

3.5 Cotton Stalk Residues

Cotton stalk residues demonstrate moderate potential for bio-based impact-absorbing materials due to their lignocellulosic composition and suitability for cellulose extraction and fibre reinforcement.[10]

[8] Deashing refers to the removal or reduction of inorganic mineral constituents, including silica, from biomass through mechanical, chemical or biological pre-treatment processes. In rice straw, these treatments may improve fibre bonding and composite performance.

[9] Motshabi N, Lenetha GG, Malimabe MA, Gumede TP. Cellulose Nanofibril-Based Biodegradable Polymers from Maize Husk: A Review of Extraction, Properties, and Applications. Polymers (Basel). 2025 Jul 16;17(14):1947. doi: 10.3390/polym17141947. PMID: 40732826; PMCID: PMC12301024.

[10]Reddy, N. and Yang, Y. (2009). 'Properties and potential applications of natural cellulose fibers from the bark of c otton stalks'. Bioresource Technology, 100(14), pp. 3563–3569. https://doi.org/10.1016/j.biortech.2009.02.047

Research has also demonstrated their conversion into bio-based polyols for polyurethane foam production, with measurable compressive properties.[11] However, evidence of their suitability for repeated impact-energy absorption remains limited. Further investigation is therefore required to establish their performance in protective applications, particularly regarding energy absorption and recovery under repeated loading.

From a circular economy perspective, cotton stalks offer opportunities for agricultural residue valorisation and additional income for farming communities.[12] However, cotton cultivation in Punjab, is concentrated in the south-western districts, limiting residue availability near Jalandhar. Existing uses, including fuel and biomass applications, alongside potential pesticide residues, collection requirements and transport distances, may affect their viability. Their suitability for local circular manufacturing would therefore depend on reliable sourcing, environmental performance and avoiding adverse impacts on existing users and livelihoods.

4. Mycelium-Based Bio-Foam Prototype Development

Developing and producing material samples at a Technology Readiness Level (TRL) of at least 4 was not feasible within the remaining timeframe of the project that ran from August 2025 to July 2026. This finding highlights the gap between identifying a technically promising feedstock and demonstrating a material that is sufficiently developed and validated for application within a high-performance sporting product.

To maintain momentum towards material substitution as a circular design strategy, and to enable CfSD to continue its product innovation activities within the cricket gear sector, the next stage of development was to investigate a material that could be produced and tested as batting pad inserts within the time frame of the DC 1.0 project. As such, the bio-foam development shifted toward a mycelium-based bio-foam despite not forming part of the original scope of the desk-based research on the potential for a bio-foam made from agricultural waste within a 50km radius of Jalandhar. The change to explore prototype development of mycelium-based bio-foam rather than the identified agricultural waste materials identified in the earlier sections of the report is due existing research, expertise and material resource availability at The Department of Architecture, University of Cambridge. Furthermore, a mycelium-based bio foam was explored as it has the potential to be cultivated in moulds in Jalandhar (Punjab) and other places in India

The proposed 4–6-week scoping study examined the feasibility of forming mycelium-based composites (MBC) into the thin, elongated insert geometries required for protective sports equipment. The prototypes used a commercially prepared, pre-inoculated Ganoderma lucidum substrate supplied by GROWN.bio, mainly comprising corn stover and hemp pith. Fungal growth binds the agricultural particles into a composite. The detailed formulation is given in the companion report. In doing so, it investigated methods to convert the commercially supplied agricultural residue. In doing so, it investigated methods to convert the commercially supplied agricultural residue substrates into pad-dimensioned inserts through fungal growth, reusable tooling, assisted demoulding, and staged cultivation.

[11] Wang, Q. and Tuohedi, N. (2020). 'Polyurethane Foams and Bio-Polyols from Liquefied Cotton Stalk Agricultural Waste'. Sustainability, 12(10), 4214. https://doi.org/10.3390/su12104214.

[12] Reddy, N. and Yang, Y. (2009). 'Properties and potential applications of natural cellulose fibers from the bark of cotton stalks'. Bioresource Technology, 100(14), pp. 3563–3569. https://doi.org/10.1016/j.biortech.2009.02.047

Reusable moulds were 3D-printed in polylactic acid (PLA) to produce 28 inserts for two pairs of batting pads (four individual pads): 16 long inserts (420 × 30 × 15 mm) and 12 short inserts (300 × 30 × 15 mm) The development of the mycelium inserts addressed the production of these component shapes and their physical characteristics following cultivation and drying.

Apparent dry density ranged from 125 to 239 kg/m³, with means of 156 kg/m³ for long inserts and 194 kg/m³ for short inserts. Most specimens had densities below 200 kg/m³, the lower end of the reference HDF density range of 200–250 kg/m³.

Fabrication observations included fragility of wet inserts during demoulding, bending or damage in some specimens, and uneven mycelial surface growth. Visible contamination was also recorded on some specimens. These observations identify supported demoulding, clean handling and consistent growth as priorities for future trials.

The fabrication process, dimensional changes, surface quality and mass are presented in detail in the companion report, *Development of Mycelium Based Inserts for Cricket Batting Pads*, by Darshil U. Shah and Chuheng Tan (2026), to be published alongside this report on the PASIC website.

Lastly, further research is required to evaluate the mechanical flexibility, durability and impact energy absorption characteristics of the proposed bio-based foam to determine their suitability as alternatives to conventional high-density foam (HDF). Additionally, future investigations could explore their potential application in cricket batting gloves, where the smaller, more compact protective components may be better suited to the material properties and current fabrication capabilities than the larger inserts required for batting pads.

5. Conclusion

This study explored the potential of locally sourced Indian agricultural residues as bio-based alternatives to conventional high-density foam (HDF) used in cricket batting pads, with the broader objective of reducing reliance on fossil fuel-based materials and advancing circular design principles within the cricket gear manufacturing sector.

The assessment identified five agricultural residues with varying levels of technical potential, local availability and socio-economy implications. Sugarcane bagasse emerged as the strongest technical candidate for bio-foam development due to its favorable fibre characteristics and demonstrated potential for producing lightweight, porous structures with compressive properties. However, the established industrial uses present potential challenges relating to resource competition and responsible sourcing.

Rice straw offered the greatest socio-environmental opportunity, particularly given its abundance in Punjab and the potential to reduce agricultural residue burning while generating additional income for local farming communities. Nevertheless, further material development would be necessary to achieve the mechanical proper ties required for protective sporting applications.

The findings highlight the importance of considering material performance alongside environmental and socio-economic factors when developing circular material alternatives. Local availability alone does not guarantee sustainability, particularly where agricultural residues already support established industries, agricultural practices and rural livelihoods. Responsible sourcing, resource competition and potential impacts on existing value chains must therefore form part of future material selection and development processes.

Although developing a bio-based material to Technology Readiness Level (TLR) 4 was not feasible within the project's time frame, the subsequent research into mycelium-based bio-foam demonstrated the practical feasibility of producing pad-sized inserts using reusable moulds and an established fungal cultivation process. The production of 28 prototype inserts provided preliminary insights into material density, dimensional stability and fabrication challenges.

Further research is required to assess and improve the mechanical flexibility, durability, impact energy abortion, moisture resistance and structural consistency of bio-based alternatives, alongside appropriate safety and environmental testing. Future investigations could also explore their application in cricket batting gloves, where smaller and more compact protective components may offer a more suitable initial application for materials with current fabrication and performance limitations.

Overall, the study demonstrates the potential for agricultural residue derived materials to contribute to the development of more circular cricket gear while highlighting the technical, environmental and socio-economic challenges that must be addressed before commercial application. The research established a foundation for further material innovation, prototype development and performance validation, supporting longer-term ambition of integrating locally sourced bio-based materials into cricket equipment manufacturing in India.

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