Final Report

Opportunities for UK-produced Biomaterials in Circular Cricket Batting Pads

Dr Darshil U. Shah

Centre for Natural Innovation

Department of Architecture

University of Cambridge

July 2024

Funding for the Circular Cricket project was provided by AHRC Design Accelerator Scheme

Table of Contents

1. Introduction

Cricket is the 2nd most popular sport and is gear intensive. Cricket gear, such as batting pads, gloves, and balls, are characterised by wasteful, linear (i.e. non-circular) product lifecycles. The manufacture of cricket gear is predominantly carried out in South Asia, thus increasing the embodied carbon of imported cricket gear. Aside from some stages of cricket bat manufacture (and the harvesting of willow for export), and cricket ball manufacture (mainly leather procurement and treatment, and final polishing and branding), no other cricket gear is manufactured in the UK. Against a background of global climate challenges – and the UK's Net Zero agenda – cricket governing bodies are also turning their attention to sustainability and widening access to the sport, for example, by hiring for sustainability and accessibility posts. The Marylebone Cricket Club (MCC), England and Wales Cricket Board (ECB) and Surrey Country Cricket Club, for example, all have set net-zero targets for 2030 and 2040. In 2023, the ECB published its first *Impact of Cricket* [1] report in which it presented a strategy for 'promoting environmental sustainability'. That the first ever report on the 'Impact of Cricket' was only published in November 2023 is indicative of the delayed and limited response pf the sector to the issues around climate change and sustainability. Recommendations by the ECB include, "*encourage responsible management of resources and to reduce the waste associated with cricket activities"*, and more specifically, "*supporting recreational cricket in its initiatives to reduce waste associated with cricket activities: [such as by] Promoting the re-use of cricket kits; Allowing parents to opt out of receiving kits; Reducing the volume of new plastic bats provided.*" However, the execution of the recommendations from the report are still to be seen, and anecdotal observations suggest that projects are thin on the ground. In fact, the ECB recently had to issue a notice[2] to parents and clubs advising them to stop using (i.e. '*throw away*') plastic balls, batting tees and banners distributed through its popular youth cricket schemes (All Stars and Dynamos) due to the presence of excess phthalate chemicals in these plastic items. Initiatives around cricket kit recycling, such as by Lord's Taverners and Yorkshire County Cricket Club, are making some direct impact, though larger-scale programmes with wider stakeholder engagement, particularly cricket gear manufacturers, is necessary.

Based on the Heritage Crafts list, cricket gear manufacture is either extinct (e.g. for pads, gloves, balls) or endangered (e.g. bats) in the UK.[3] To enable the production of cricket gear in the UK, there is a need to develop and foster skills in relation to design and making of cricket gear in the UK, such as through training, sharing and apprenticeships. If a UK-based production model – that relied on local materials, workers and manufacturers – could be established, this would reduce the environmental impacts associated with cricket gear lifecycles in the UK, and also revitalise heritage crafts and skills in this sector. Reestablishment of such a productive cricket gear sector in the UK that responds to sustainability and net-zero challenges requires a long-term plan and roadmap, collaboration amongst diverse stakeholders, establishment of re-use and repair schemes, up-skilling and training of workers,

[1] ECB, England & Wales Cricket Board. The Impact of Cricket 2023. https://resources.ecb.co.uk/ecb/document/2023/11/27/c9b20f7b-03aa-4e0b-9e6e-ff48c398c86a/ECB-Impact-of-Cricket-Report-2023.pdf

[2] ECB (2024). IMPORTANT NOTICE: All Stars Cricket and Dynamos Cricket equipment. https://www.ecb.co.uk/news/3932259/important-notice--all-stars-cricket-and-dynamos-cricket-equipment

[3] Heritage Crafts Association (2024). https://www.heritagecrafts.org.uk/skills/crafts/

as well as substantial research and development around new concepts of designs, materials, product supply-chains and business models.

Focussing on the UK, this report forms part of a deliverable from the AHRC Design Accelerator (DA) Scheme funded project "Circular Cricket: Prototyping and Socially Engaged Manufacture of Cricket Pads, using Circular Design, Biomaterials, Recycled Materials and Component Reuse". The Circular Cricket project focused on developing circular cricket batting pads in the UK using home-grown/produced biomaterials, and recycled and reused materials/ components, as well as exploring local social enterprise schemes (including training) to make, repair and refurbish cricket pads.

The Centre for Sustainable Design ® (CfSD) at University for the Creative Arts (UCA) and the Centre for Natural Material Innovation (CNMI) at the University of Cambridge have worked together on a number of projects in the recent past on developing concepts for circular cricket gear (e.g. bats, balls, pads, gloves), through materials research, design development and prototyping, as well as stakeholder engagement, including with manufacturers and users. While the priority has been innovation for extending the life of cricket gear products through re-use, refurbishment and repair, exploration of lower environmental impact alternatives of conventional materials used in cricket gear has also been an important research aim. Research as part of The Platform for Acceleration of Sustainability in Cricket (PASIC)[4,5] , the AHRC IAA-funded Vegan Leather Cricket Gear project (VLCG) [6], and the UKRI CE-Hub funded Circular Cricket Gear (CCG) project [7, 8] identified gaps in knowledge and data, and incrementally identified a range of sustainable alternatives that may replace current component materials, based on the function requirements they satisfy in the cricket gear. The Circular Cricket project runs parallel to and extends findings from an AHRC IAA funded Advancements in Circular Cricket Gear (ACCG) project [9].

Cricket batting pads are used as a case-study in the Circular Cricket project. Batting pads represent a multi-component and multi-material cricket gear product. Batting pads typically contain a mix of polyurethane, paperboard, cane, polyester mesh, high-density foam, thermoformed polystyrene, polyester lining, and wadding (made of 50% cotton and 50% polyester). These materials, parts and components are likely to end up in landfill at the end of the product's lifecycle and most are made from non-renewable sources. The total carbon footprint of a pair of batting pads is equivalent to 2.60 CO_2 eq. Kg/functional unit[10] with, for example, 351,000 pairs of pads (552 tonnes) coming to the end of their first use life annually[11]. This is why sustainable alternatives are being investigated in the form of biomaterials that a) are wholly or partially derived from plants, trees, or animals, and b) are grown, processed, and produced locally, as well as c) integrated with new designs that extend the useful life of the cricket gear, and can be recycled at the end of their useful life.

---

[4] Charter, M. and Clark, T. (2022), Sustainability, Cricket Gear, Clothing and Apparel: Report on Cricket Gear.
[5] Wetherfield, M., Charter, M., Shah, D., Whitaker, C. (2022) Sustainability, Cricket Gear, Clothing and Apparel: Report on Components, Materials, and Innovation Opportunities.
[6] Taylor, B., and Shah, D. (2023) Leather Alternatives for Cricket Gear.
[7] Taylor, B., and Shah, D. (2023) Application of Vegan Leathers for Cricket Balls and Gloves.
[8] Shah, D., (2023) Materials in cricket balls, gloves and pads and their sustainable alternatives.
[9] Shah, D. (2024) Local sustainable material alternatives for cricket gloves and pads.
[10] Sanchez-Moreno, L., Charter, M., (2023). Streamlined Life Cycle Assessment: Pair of Cricket Batting Pads.
[11] Wetherfield, M., Charter, M., Shah, D., Whitaker, C. (2022) Sustainability, Cricket Gear, Clothing and Apparel: Report on Components, Materials, and Innovation Opportunities.

This report is a deliverable the Circular Cricket project [12] (funded by the AHRC DA Scheme) and aims to address the following question: "What are the opportunities and challenges of developing UK-produced, low carbon, circular cricket batting pads?" The specific objectives of Work Package 2 – on Materials Identification – of the Circular Cricket project include:

- Identifying UK-produced biomaterials that could substitute for non-renewable materials in circular cricket batting pads production
- Build a database/list of UK-produced biomaterials/recycled materials for production of circular cricket batting pads
    - Distinguish, *if possible*, between "fully home-grown/produced" and "imported raw/pre-processed materials"
- Explore avenues for materials production from the agriculture and agro-waste sectors

The report builds on learning from a separate report[9] completed within the 'Advanced Circular Cricket Gear' (ACCG) project and develop further detail from the findings. The database of UK-producers is unique to the Circular Cricket project report. In addition, this report also explores the potential of biomaterials production from agro-waste (distinct from ACCG's consideration of biomaterials from food-waste). The work is based primarily on desk research.

2. Biomaterial and Recycled Material Alternatives and their Producers in the UK

2.1 Who is a 'UK-producer'?

Here, we define a "UK-producer" as a company that is UK-registered (i.e. on Company House) and does more than just act as an agent and/or distribution centre. In other words, a UK-producer of biomaterials will actually produce all or part of the materials, or carry out R&D, or focus on product development from the materials in the UK.

As supply-chains and value-chains are increasingly multi-national and global, it is very difficult to state whether a company produces and processes all ingredients, feedstocks, materials and products in the UK. In fact, often, material flows are not explicitly clear, and sometimes are even confidential or protected as trade secrets. Generally, companies do not share material flow data or the names of their suppliers. In the vast majority of cases, UK companies do import bio-based feedstocks or raw materials or pre-processed materials, or even sub-contract part of the processing elsewhere. This is typically on the basis of economic cost considerations and supply-chain efficiencies, particularly in the biomaterials and materials recycling industries. The processing of biomass – such as producing sawn timber from tree logs (roundwood) – is usually most efficient when processing facilities (e.g. sawmills) are close to where the biomass is harvested from (e.g. forests). This is in part because conversion of roundwood into sawn timber is only 50-70% efficient – around 30-50% is sawdust, chips, and

[12] https://cfsd.org.uk/projects/cc/

bark [13]. By removing this 'waste' (sawdust, chips and bark), pre-processing of logs close to site of harvest substantially reduces the volume of material that needs to be transported, as well as adds value to the product being sold or exported.

In the context of this report, there are two cases where the flow of materials is (currently) clear:

i) Companies that have an explicit focus on social-impact, and visions to exploit global value chains for rural development and poverty alleviation in developing countries (e.g. Ananas Anam, Bananatex).

ii) Companies that are working (or perhaps 'testing' technologies) at small lab-scales or pilot-lines at present (e.g. Biophilica and Arda biomaterials), but this may therefore change with upscaling.

Companies can apply to use a "Made in Britain" logo [14] or "Grown in Britain" certificate [15]. The Made in Britain scheme promotes UK-based manufacturing, enabling buyers and consumers to identify UK-made products. The logo is the official Trademark for UK manufacturing. To be eligible, i) you need to be a UK-based registered business, ii) the products need to be designed, manufactured, produced, or created in Great Britain, iii) 80% of the value chain needs to be within Britain (*not including raw materials*). Made in Britain offers a portal to identify producers that use their logo [16]. For example, only 3 producers of bioplastic products in the UK (of over 35 listed in the database below) produce "some" products that have a Made in Britain logo: Floreon Technology Limited, Solutions 4 Plastics and Bio-bean Ltd. Note that the scheme focusses on "products" (e.g. compostable bin bags, extruded plastic tubes, furniture), rather than on "material" specifically.

While Made in Britain is applicable to all manufactured products (i.e. not 'materials'), the Grown in Britain scheme focusses on forestry products, particular to support the use of UK grown timber. It offers Chain of Custody (CoC) certification and is the sole provenance standard that assures UK grown timber products. No biomaterial companies highlighted in this report have a 'Grown in Britain' certificate; however, there is clearly scope to produce biomaterials from home-grown timber.

Another relevant certification scheme relates not to provenance or chain-of-custody certification, but for those companies that meet high standards of social and environmental performance, transparency, and accountability. This is a certified B Corporation, or B Corp. A number of UK-producers of biomaterials and recycled materials identified in this report are certified B-corps [17], such as Floreon, Kelpi, Bio-Pak, Vegware, Novamont, Smart Plastics Ltd., and Ananas Anam.

[13] Rummer, B. (2019) https://www.highlandwoodworking.com/woodworking-projects/waste-in-woodworking.html

[14] Made in Britain. https://www.madeinbritain.co/Apply-Now#:~:text=In%20order%20to%20apply%20to,Britain%20(not%20including%20raw%20materials)

[15] Grown in Britain. https://www.growninbritain.org/

[16] Made in Britain portal. https://www.madeinbritain.org/products/search?cat=&q=bioplastic

[17] https://www.bcorporation.net/en-us/find-a-b-corp/?refinement%5Bcountries%5D%5B0%5D=United%20Kingdom

2.2 Identifying biomaterials and recycled materials producers

For cricket batting pads, the following component/material groups were identified based on the functions they fulfil in a batting pad:

- Rigid, impact-resistant, lightweight (Moulded plastics, composites)
- Cushioning, impact-resistant, lightweight (foams, fibre fill and wadding)
- Breathable linings and skins (fibres, textiles and leathers)
- Coatings and Adhesives

A synthesised list of alternative lower impact materials produced in the UK and grouped under generic categories was also developed, in the ACCG project:

- Bio-based polymers and plastics (e.g. PLA/PHA, seed-oil derived plastics, starch-based plastics)
- Bio-based composites (e.g. flax reinforced PLA)
- Fibres and textiles: plant-based; animal-based (e.g. wool); insect-based (e.g. silk); semi-synthetic (e.g. viscose)
- Wood and wood pulp based materials
- Leathers and alternative leathers
- Micro-organism based (e.g. algal materials; mycelium/fungal materials)

The above pre-defined groups and categories have been used in the ACCG project to identify UK-based producers of alternative lower environmental impact materials.

In the following sub-sections 2.2.1-2.2.5, for each component group identified above, currently used materials are listed first alongside where they might be used in a batting pad, followed by a list of alternative bio-based/biosynthetic or recycled materials and their UK-producers.

As introduced in the ACCG project, while 'biomaterials' or 'bio-based materials' are wholly or partly derived from biomass (e.g. wood and biocomposites, cotton and plant fibres), 'biosynthetic materials', a subset of biomaterials, involve bio(chemical) processes using biotechnology and/or biofabrication carried out by living cells and/or microorganisms (e.g. protein, bacterial, microbial, enzymatically driven processes, and PLA/PHA, mycelium, algal materials).

By recycled materials, we include both open-loop and closed-loop recycling in the definition. Closed-loop recycling refers to recycling a product into the same (or an almost identical) product – such as from beverage packaging to beverage packaging. Open-loop recycling refers to recycling a product into a new product – such as from a beverage bottle to clothing textile, or a water transport pipe. Recovery – which includes energy recovery through incineration – is not included in our definition of recycling. Around 40% of plastic packaging waste generated in the UK is recycled [18,19], however only around half of it is recycled in the UK itself, with the

[18] British Plastics Federation. (2024) Recycling Roadmap. https://www.bpf.co.uk/roadmap.aspx
[19] Smith, L. (2024). House of Commons Library. Research Briefing: Plastic waste. https://commonslibrary.parliament.uk/research-briefings/cbp-8515/

other half being exported for recycling (primarily to Turkey, Netherlands, Germany, and Poland). Notably, ca 40% of plastic waste generated in UK is burnt for energy recovery, and ca 20% is landfilled. The plastic recycling sector in the UK has strengthened in the past decade with more recycling being carried out in the UK. In most cases closed-loop recycling is not possible in the UK, which presents a limitation, however conversion of packaging waste into textiles is possible. Note that recycling is only really possible with thermoplastic materials (e.g. polyester) – thermosets, such as polyurethanes (e.g. used in the foams for cricket batting pads), cannot be readily recycled. However, there are new technologies that are exploring re-conversion of polyurethanes as polyol feedstocks for new polyurethanes. In addition, due to the low volumes of production of bioplastics (such as PLA, PHA) in the UK, they are not currently recycled at scale. The vast majority are turned into compost (as they are biodegradable), incinerated for energy recovery or landfilled. There is infrastructure in some countries, such as Netherlands and Germany, to recycle these bioplastics. However, even in these countries, anecdotal evidence indicates that recycling of bioplastics can be cost-prohibitive due to the low volumes of these bioplastics in waste circulation currently.

2.2.1 Rigid, impact resistant, lightweight components

Current materials

The list of materials below are integrated into cricket batting pads to provide high-impact resistance as well as toughness and strength. They are lightweight materials and are used as they can be moulded into precise contoured and anatomical forms and shapes to provide a wrap-around and snug fit. These materials are covered (e.g. by fabric) in the product and are not 'visible', hence their aesthetic properties are not important.

- Polystyrene (kneecaps in pads for knee protection)
- Polypropylene (kneecaps in pads for knee protection)
- Cane (reinforcement in pads for shin protection)
- Paperboard or cardboard (for above-knee (below-thigh) protection in pads)

Bio-based or recycled material alternatives to the above-listed materials are available in the UK. For polystyrene and polypropylene (and similar plastics) used for rigid, protective components in cricket batting pads (such as kneecaps), a range of alternatives in the form of bioplastic/biopolymers, recycled plastic materials, or short-fibre composites and their sustainable reinforcements are available. For cane and paperboard, substitutes in the form of waste/short timbers and recycled cardboards (e.g. from packaging waste) are available in the UK. These are listed in more detail below, alongside their UK-producers.

Example alternative materials to explore

- Bioplastics and Biopolymers
    - Polylactic Acid (PLA), Polyhydroxyalkanoates (PHA), Polyvinyl alcohol (PVA), Sugar-based and starch based thermoplastics, Seed-oil based plastics (Cashew-nut, soybean oil etc), Furfuryl alcohol (sugarcane waste-derived) resins; algal-based
        - UK producers: Floreon; Biome Bioplastics; BASF; Cambridge Biopolymers; CamBond; Cornware; Rebio Technologies; Duo UK; Emnandi Bioplastics; Innovia; Innovolo (New Product Development &

Design); Parkside; Solutions4Plastic; Xampla; Aquapak; BioPak; Biotec/BioPlast; BioBag Ltd; Central Plains Group; Eco-craft; Ensus (CropEnergies Group); Erthos Inc; Futamura; Leadergrain; Novamont; Total Corbion; Vegware; Aqualyte Ltd; Chip[s] Board Ltd; James Hutton Ltd; Cellucomp Ltd.; Pulpex Ltd; CuanTec Ltd; Cambridge Smart Plastics Ltd.
        - Many companies are currently focussing on packaging
    - Short-fibre biocomposites
        - UK producers: Composites Evolution; Ecocomposites; Margent Farm;
        - Natural fibre reinforcements (e.g. flax, jute, hemp, wool fibres and reinforcements (including waste fibres e.g. denim cotton, carpet wool))
            - UK producers (plant fibres): Margent Farm; Technical Fibres; Offset Warehouse; Hemptex, Natural Fibre Company; Flaxland, Ananas Anam
            - UK producers (wool): HDwool; Woolcool; Doppelhaus; Wool: ReCrafted
            - UK producers (silk): Stephen Walters and Son Ltd (and other similar silk mills)
        - Semi-synthetic fibre reinforcements (e.g. manmade cellulose, protein-based)
            - UK producers (cellulosic): HeiQ, Elissa Brunato
            - UK producers (silk-like): Spintex
- Waste/Short timbers
    - UK Producers: BCL Timber Products Ltd, Birchwood Forestry, Capricorn Eco Timber, Buckland Timber Ltd, BSW Timber Ltd, Coppice Creations, East Brothers, English Woodlands Timber, Ercol, Forest to Home, Hamsphire Chestnut, JM Bower Timber Product Limited, SMR Agrifor Ltd - Cultra Wood, Shelmore Timber, Tyler Hardwoods, UK Hardwood,, Sylva Foundation, The Crown Estate Scotland, The Duchy of Lancaster, Valley Forestry,Vastern,W L West and Sons Ltd
- Recycled cardboards
    - Recycling centres
- Recycled plastic materials (e.g. Polyethylene terephtalate (PET)/ high-density polyethylene HDPE/ polyethylene (PE)/ polypropylene (PP) packaging, polyvinyl chloride (PVC) piping)
    - UK producers [20]: Agri.Cycle, Alpha Polymers Ltd, Arrow Recycling Ltd, Berry Circular Polymers, Biffa plc, Bright Green Plastics Ltd, CHP Polymers Ltd, Clean Tech UK Ltd, Duclo Recycling, Eurocell Recycle, Global Plastic Ltd, Impact Recycling, JP Recycling Ltd, KS Plastics Ltd, MBA Polymers UK Ltd, Monoworld Recycling Ltd, Pro Environmental Services Ltd, Roydon Ltd, Vanden Recycling Ltd, RECOUP, Pulse Plastics Ltd, Recycled Plastics UK Ltd, Rubber & Plastic Collection Services Ltd

[20] https://www.enfplastic.com/directory/plant/United-Kingdom

2.2.2 Cushioning Foams and Filling

Current materials
The list of materials below are integrated into cricket batting pads to absorb impact energy by deforming but being durable and having shape retention properties (e.g. due to repeated impacts). These materials play an important role in giving the external 'shape' to the product by 'filling out' the encasing material, without adding substantial weight. Their lightweight properties are also therefore important.

- High-density Polyurethane (PU) Foam (reinforcement in pads for shin protection)
- Wadding (cotton/polyester blends) (reinforcement in pads for shin and above-knee protection)

Bio-based or recycled material alternatives to the above-listed materials are available in the UK. For high-density polyurethane foams, a range of alternatives in the form of bio-polyurethanes, and biosynthetic materials (mycelium- and algal-based materials) are currently available. For wadding, substitutes in the form of natural fibres and waste fibres are possible. These are listed in more detail below, alongside their UK-producers.

Example alternative materials to explore
- Non-isocyanate PUs – no current producers in the UK
- Bio-PUs – huge number of players for applications ranging in buildings/construction, automotives, sports, furniture/bedding.
    - Natural oils or natural carbohydrate feedstocks.
    - Ranging from soybean oil-based, sugar-based, cashew nut seed oil based, rapeseed oil based, castor oil-based etc.
    - UK producers: AIGreen and Biocleave UK; BASF; Covestro UK
- PLA-based foams – no current producers in UK
- Mycelium-based materials
    - UK producers: Biohm
- Algal/sea-weed based materials
    - UK producers: FlexSea Ltd; Kelpi; Notpla Ltd
- Natural fibre reinforcement for wadding – listed in Section 2.2.1
- Waste fibres from agriculture or fruit harvest – no current supply-chain in UK as such

2.2.3 Breathable Linings and Skins

Current materials
The list of materials below are integrated into cricket batting pads to internally line and cover the side of the pad that is in direct contact with the batters leg. Consequently, breathability and moisture performance are critical, to provide comfort during extended periods and offering sweat-management. The internal lining also needs to offer grip (i.e. should not slip when the batter is running or moving). Such materials may also be used in straps and for fitting.

- Breathable polyester meshes (on the internal lining in contact with the batter's leg, or for straps and fittings)
- Flax, cotton, wool, nylon threads (as stitching threads)

Bio-based or recycled material alternatives to the above-listed materials are available in the UK. For polyester meshes and flax, cotton, wool or nylon stitching threads, a few potential alternatives in the form of recycled polyesters and natural, recycled, semi-synthetic or blended fibres are possible. These are listed in more detail below, alongside their UK-producers.

Example alternative materials to explore

- Recycled polyesters (Bottle to Fabrics)
    - UK producers: IVL, Repreve Ltd., Vescom, Project Re:claim
- Fibres: Semi-synthetic (e.g. Viscose), Natural fibres, Recycled fibres, Blending of fibres
    - *Various listed in Section 2.2.1*

2.2.4 Leather skins and covers

Current materials

The list of materials below are integrated into cricket batting pads as exterior skins or covers, for the side of the pad that will be directly impacted by the ball. Consequently, moisture performance and good wear and abrasion performance is critical – for example if a batter dives to the ground during running. Aesthetic properties are also important, as this face is visible and may be adorned by branding.

- Polyurethane (PU) leathers (artificial leathers) (as covers for batting pads)
    - Historically, batting pad covers were made from animal hide (typically bovine) leathers, however polyurethane-based leathers have replaced these entirely, in principal due to better durability and lighter-weight [21].

A range of bio-based or recycled material alternatives to PU leathers are available, in the form of alternative leathers from plant, fish, mycelium, and waste sources, as well as synthetic and recycled leathers. It is important to note that 'leather' is a protected term. A material that does not meet the definition stated in BS EN 15987:2022 cannot be sold as 'leather', as this definition is used as a guide in applying consumer protection legislation (such as the Sale of Goods Act and the Trade Descriptions Act). This has implications on the use of terms such as 'recycled' or 'reconstituted' leathers, as well as 'leather alternatives' [22]. Nevertheless, 'alternative' or 'plastic-free' leathers are being explored as substitutes to PU-based leathers as a longer-term movement in the right direction, similar to the historic transition from bovine

[21] Many batting gloves do continue to use lambskin (Pittard's) leather for the palms. Notably, Pittard's is a UK-producer, though the company entered administration in 2023

[22] The definitions of leather and its implications on the use of alternative leathers has been discussed in detail in the Vegan Leather Cricket Gear project report: Taylor, B., and Shah, D. (2023) Leather Alternatives for Cricket Gear.

leather to PU-based leather. Examples of available leather alternatives alongside their UK-producers are listed below.

Example alternative biomaterials to explore

- Alternative leathers - >10 firms in UK, all are start-ups with small-scale or pilot production lines.
    - Fish-based: Hide Biotech, The Fish Leather Company
    - Fungi-based: Amadou Leather, Mykkö, Really Clever
    - Bacterial cellulose: Modern Synthesis
    - Plant-fibre based: Ananas Anam / Pintatex
    - Collagen-based: 3D Bio-Tissues
    - Waste-based: Biophilica (leaf litter); Thamon (leaf litter); Arda Biomaterials (beer waste)
  - Many have a sizeable non-renewable content, or have coatings for better durability
  - Currently targeting non-performance sectors
- Synthetic chamois leathers (3M, Halfords) – based on PVA or viscose
- Recycled leathers – Recyc Leather TM; Generation Phoenix (formerly ELeather)

2.2.5 Coatings and Adhesives

Current materials

The list of materials below are integrated into cricket batting pads as coatings of the exterior skins and covers. They protect the skins and covers from wear and moisture-related damage (e.g. by being water repellent), provide a glossy, durable and cleanable surface that can be adorned with branding.

- Polyurethane (PU) coatings
- Polyvinyl alcohol (PVA), epoxies

Bio-based alternatives to the above-listed materials are available in the UK. For PU-coatings and adhesives, bio-polyurethane coatings, nitrocellulose lacquers, and beeswax are available. These are listed in more detail below, alongside their UK-producers.

Example alternative biomaterials to explore

- Bio-polyurethane (BPU) coatings.
  - The majority of emerging alternative biomaterials and leathers, including Pinatex® and Bananatex use PU or polytetrafluoroethylene (PTFE) coatings for durability and moisture performance, and BPUs may be a drop-in alternative.
  - Production of BPUs is at industrial scale (several 100s of tonnes [23]), but small: BPUs account for ca 0.001% of the PU market.
  - UK based producers include:
    - Covestro UK (with British Coatings Federation)

[23] https://www.grandviewresearch.com/industry-analysis/bio-based-polyurethane-industry

        - Feedstocks are i) waste vegetables or those not for human consumption, or ii) waste or residual oils and fats, or iii) raw sugar from corn, straw or wood for industrial sugar to produce aniline using microorganisms as catalysts
    - Biocleave UK (from corn/cellulosic feedstocks for leathers and polyols)
    - AIGreen

- Nitrocellulose lacquer – mostly plant (cotton or wood) derived substance mixed with acids.
    - UK producers: TTC Ltd, Hagedorn NC. Medium to large scale production.
- Beeswax – also suitable for leathers.
    - UK producers: various including Poth Hille. Relatively large-scale production.
- Biophilica Adhesive – synthesised using leaf litter waste and is plastic-free, and suitable for leathers.
    - UK producer: Biophilica. Start-up and very small-scale production at present.

3. Biomaterials and Bio-synthetic materials from agricultural waste

Feedstocks are raw, unprocessed materials that are required to produce intermediate materials for finished products, such as cricket batting pads. In the vast majority of cases, feedstocks for cricket batting pads are virgin, synthetic materials (rather than recycled or bio-based materials). Not only is there no current cricket gear (i.e. batting pads) production in the UK, even if local UK-based manufacturing of batting pads was to be considered, a large proportion of the feedstock for cricket gear materials would need to be imported to the UK. That is, the UK does not have sufficient production of raw materials or feedstocks for completely local cricket gear manufacture. Bio-based materials are interesting from sustainability perspective for circular cricket gear, however even feedstocks of bio-based materials would have to be imported to the UK, due to lack of local production. The imported nature of the virgin bio-based feedstock, their relatively higher costs (in comparison to non-bio-based feedstocks for example), and the relatively lower volumes that are readily available (due to various competing uses) are a barrier to rapid commercial production and uptake of biomaterials – for circket gear production, and generally for many other products – in the UK. Hence, locally sourced bio-based feedstocks from agricultural waste might be an interesting avenue to explore for the production of materials for cricket gear, including batting pads.

Agricultural waste is defined as waste from all agricultural operations, particularly 'on the field' or during farming. Agricultural waste is typically categorised into non-natural waste and nature waste [24, 25]. Around 0.5Mtonnes of agricultural waste annually is non-natural waste, e.g. including 135Ktonnes of plastic waste per annum (which includes 33Ktonnes of packaging waste, 104Ktonnes of non-packaging waste, such as batteries). Currently, these wastes are managed by on-farm burning, burial and stockpiling, and inclusion in the household waste collection.

[24] Waste Managed (2024). Agricultural Waste Guide 2024. https://www.wastemanaged.co.uk/our-news/agriculture/agricultural-waste-guide/

[25] Environment Agency (2001). Towards sustainable agricultural waste management. https://assets.publishing.service.gov.uk/media/5a74be3aed915d502d6caa08/geho0003bieo-e-e.pdf

In natural waste, manure and slurries account for 43Mtonnes per annum. These are typically managed on farm (e.g. for soil fertilisers, compost or burning). Crop residues from the growing and harvesting stages accounts for around 10Mtonnes per annum. Crop residues are typically managed on the farm, and may be returned to the soil for decomposition, or used as animal bedding or feed, or increasingly converted to biofuel (e.g. bioethanols). Notably, 25% of food wasted in UK is at the farming stage [26]. The ACCG project focussed on food-waste in the post-farming (production and end-user) stages. Typically, food waste is converted into animal feed, biofuels, compost, land-spreading (for ecological/agricultural benefit) and energy recovery [27].

Here, the focus on agricultural waste is on crop residues and at-the-farm food waste. Such crop and food waste are rich in a range of material building blocks (e.g. sugar, starch, protein, fibre, oils), such as in bioplastics and biomaterials. However, converting these agricultural waste resources into suitable and consistent feedstock and then into functional materials does require overcoming a number of challenges:

- Supply-chain and logistics
    - Quantity – viable volumes, collection points, transportation.
    - Quality – treatments, impurities, refining, quality control to ensure consistency
- Technological progress is needed to enable up-scaling, utilisation of biowaste, higher yield and quality biosynthesis and advanced processing technologies
- Perception and market penetration – generating confidence amongst consumers (including businesses and end-users) on the quality, particularly durability and requisite functional performance, of food waste-derived products, and leveraging mechanisms to drive behaviour change in consumption patterns (i.e. moving away from current materials to waste-derived materials).
- Entrepreneurial and legal – creating an environment to support businesses (including start-ups and ventures) to explore these at various scales. Many biosynthetic materials producers in the UK are start-ups. There might have to be legal or policy levers to support wider use of waste-derived materials (e.g. no VAT on such materials).

A number of UK companies are exploring agro-waste as a feedstock or resource for the production of biomaterials. To name a few:

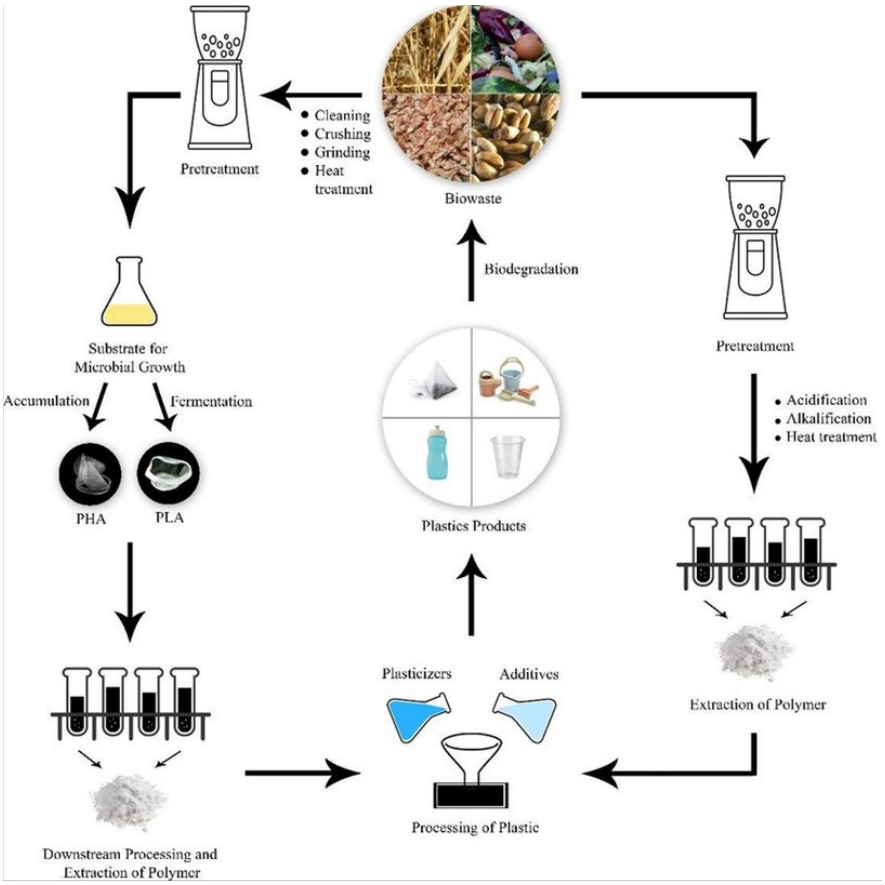
- *Pulpex Ltd., Cellucomp Ltd., Nova Biochem Ltd.,: Bioplastics* from fibrous non-food agricultural waste
- *Covestro UK, Biocleave UK, AIGreen: Bio-PUs* from corn/cellulosic waste feedstocks (e.g. residual oils, fats)
- *Biophilica, Thamon: leaf-litter waste* for textiles and leathers
- *Amadou Leather, Mykkö, Really Clever, Biome*: *mycelium materials* using agro-waste as substrates

[26] WWF. Hidden Waste: The scale and impact of food waste in UK primary production. https://www.wwf.org.uk/our-reports/hidden-waste

[27] Department for Environment Food & Rural Affairs (2024). Statutory guidance Food and drink waste hierarchy: deal with surplus and waste. 1 Jan 2024. https://www.gov.uk/government/publications/food-and-drink-waste-hierarchy-deal-with-surplus-and-waste/food-and-drink-waste-hierarchy-deal-with-surplus-and-waste

3.1 What do the process flowcharts of agro-waste materials look like?

The process flow-charts of such materials are complex, requiring large-volume production for economic feasibility, and various steps for purification and quality control. Below is a schematic from George et al (2021) of the various stages necessary to convert agro-waste into bioplastics, with some steps including pre-treatment and purification, fermentation and microbial growth, extraction of polymer and processing of plastic and thereafter product manufacture. Bioplastics from agro-waste could be an important lower-environmental impact alternative to a number of convention cricket batting pad component materials, as highlighted in Section 2.2, including high-density PU foam, polyester wadding and meshing. At present, other competing uses (e.g. for biofuel or animal bedding or feed), lower-quality than virgin resources, relatively high-cost, and low yields are big challenges. This may impede adoption for cricket gear, such as batting pads. Indeed, more technological progress is also needed, including in up-scaling, utilisation of biowaste, biosynthesis and processing technologies.



George et al. 2021

Figure 1. Process flowcharts for bioplastic production (PLA and PHA) based on agro-waste.

Aside from conversion of the agro-waste into polymers and bioplastics, a number of recent innovations are in biosynthetic materials. In these cases, biomaterials have emerged from bacterial, algal and mycelium microorganisms, that are grown on agro-waste substrates or feedstock. The resulting biosynthetic materials can be processed into textiles, films, foams, leathers or sheets – all these forms of components exist in cricket gear, particularly batting

pads, as discussed in Section 2.2. The processing steps of these biosynthetic materials are distinct but share some general similarities (Figure 2). In both cases, agro-waste feedstocks can be used as functional substrates or catalysts for biochemical and biotechnological processes. However, a major challenge is around inoculation (introduction or mixing with agro-waste substrate) and incubation (growth) of micro-organisms, such as bacteria, mycelium, or algae on the agro-waste substrate (Figure 2) to ensure high yields and consistent quality of the resulting biosynthetic material. Moulds are used to shape the material or create textures; this processing step could fit well with some shaped batting pad components such as kneecaps, and foam cushioning. Often, the processes need to be carried out in very sterile environments to enable unhindered growth (incubation) of the mycelium or algae. As we rely on the growing of micro-organisms, the processes are relatively slow. Many processes are based on growing or film casting, though faster extrusion-based processes may also be possible. Typically, water is released or used as a solvent in the processes, and a drying step is one of the penultimate steps prior to finishing the biosynthetic material. Biosynthetic materials are relatively new, and most manufacturers are in early R&D phases with lab-scale or pilot production lines in the UK and abroad. Importantly, for high-performance applications, such as cricket gear/batting pads, tests specific to batting pad use would also need to be carried out to demonstrate impact toughness, durability and adequate moisture behaviour amongst other requirements.

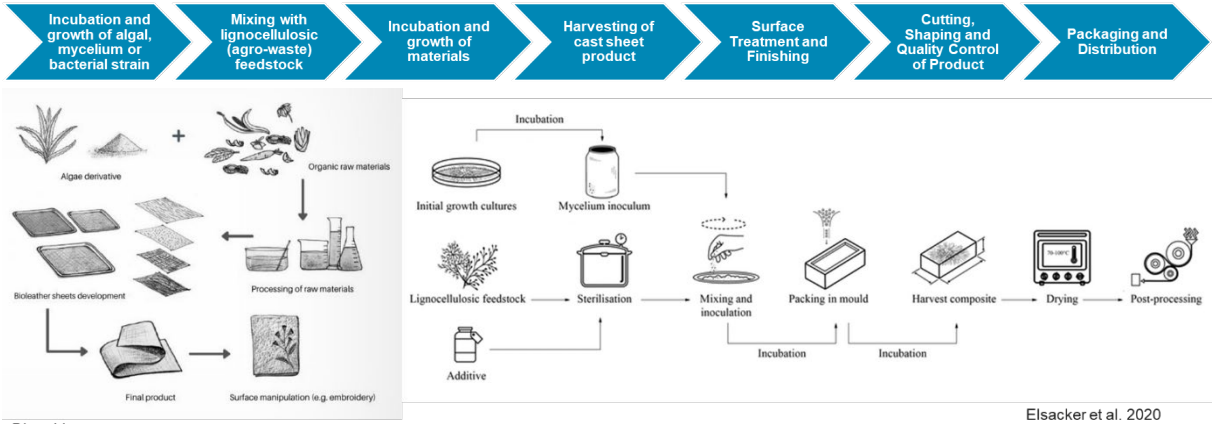


Figure 2. Process flowcharts for biosynthetic materials – such as those based on mycelium and algae growing on agro-waste.

4. Conclusions

There is growing interest in the area of biomaterials and biosynthetic materials in the UK, and there are opportunities to explore their uses as replacements for materials in cricket batting pads. At present, none – as per the author's knowledge – have been designed or tested for sporting gear, let alone cricket gear.

The number of UK producers and scale of production of biomaterials has stagnated since 2017. However, there have been a large number of start-ups around biosynthetic materials in the past 5-10 years (in the UK and abroad) with innovations in biotechnology and bioengineering. Nevertheless, the scales of production are very small, and none are targeting the performance or sports sectors. Scale and scalability are a big challenge, as are supply-

chain challenges due to the disparate/discrete sourcing nature of waste and bioresources, and ensuring quality feedstock and final product. For example, biomass is produced by a large number of farmers (as opposed to a single entity), and similarly waste is produced by a large number of consumers and producers. The aggregation of sufficient volumes of feedstock (biomass or waste) requires coordination with many entities and dealing with diversity of qualities.

Previous research estimates that around 350,000 pairs of batting pads (ca 550 tonnes) come to the end of their useful first life every year in the UK [28], but none are actually produced in the UK. Indeed, cricket gear 'softs' (e.g. pads, gloves) are imported, primarily from the Indian subcontinent. There is also a substantial lack of skills, let alone a supply-chain, for cricket gear manufacture in the UK. However, as part of a longer-term vision to explore strategies for local, sustainable, and circular cricket gear manufacture in the UK, thought-experiments through 'what-if' scenarios are a good start for road-mapping. For example, 'what would the size of biomaterials production need to be for cricket gear to be manufactured in the UK'? Assuming that the same (or slightly higher) number of pads needed to be produced as replacements annually (350,000 pairs), this would require around 500 tonnes of biomaterials. This is a fairly small volume of material. However, there are already other, sometimes more voluminous or economically lucrative, market opportunities for these biomaterials in the UK, such as in packaging or luxury consumer products. To extend (or divert) their uses to cricket gear, such as batting pads, what may be needed is to develop a critical mass of production of cricket gear with biomaterials to move the industry faster in this direction. To unlock this, cricket gear manufacturers have an opportunity to collaborate with gear manufacturers from other sports (e.g. baseball, football and so on), and jointly undertake research and development for the adoption of new low-carbon materials in the sports sector.

It is evident that supply-chains and value-chains are increasingly multi-national and global. In the vast majority of cases, companies do import feedstocks or raw materials or pre-processed materials, or even sub-contract some processing elsewhere (usually based on cost considerations and supply-chain efficiencies). There are some certification schemes (such as Made in Britain, Grown in Britain) that help identify a very small number of close to fully-made-in-UK products, but no certification scheme exists for materials as such. In fact, often, material flows are not explicitly clear, and sometimes even confidential or protected as trade secrets. Companies also do not share material flow data or the names of their suppliers.

Agricultural waste in the form of crop residues and farming-related food waste could be an important resource for new biomaterials. A number of UK-based companies are exploring these for a range of biomaterials, including bioplastics, bio-PUs, textiles and leathers, and even bacterial, mycelium and algal materials that can be grown on agro-waste substrates. Innovate UK's SusBioMM CR&D funding programme is supporting many of these innovations. However, major challenges are related to economic feasibility, supply-chain challenges, and cost and quality. In addition, agro-waste already has some competing uses, and LCAs may clarify the impacts of siphoning agro-waste from animal feed/bedding or biofuels to say bioplastic production.

[28] Charter, M. and Clark, T. (2022), Sustainability, Cricket Gear, Clothing and Apparel: Report on Cricket Gear.

Cricket is the 2nd largest global sport and attracts over 200 million recreational players in the England and Wales. Cricket gear manufacture is either extinct (e.g. for pads, gloves, balls) or endangered (e.g. bats) in the UK, with items primarily manufactured in India and Pakistan. At present, there is a notable lack of skills to support the rejuvenation of gear making at present in the UK. The use of locally grown/produced or locally-recycled lower-environmental impact materials in cricket gear may kick-start a step-change in the supply-chain dynamics and reduce reliance on importing cricket gear materials and finished products. In addition to exploring material alternatives, more direct, higher-impact routes and lower-hanging fruits are related to redesign, re-use, refurbishment, and repair of cricket gear for circularity. These are less straddled by the multiple hindrances around technological and economic barriers that biomaterial innovation faces in the UK.

5. Annex: Database list of Biomaterial and Recycled Material Producers in the UK

Bioplastics producers

Floreon
Biome Bioplastics
BASF
Cambridge Biopolymers
CamBond
Cornware
Rebio Technologies
Duo UK
Emnandi Bioplastics
Innovia
Innovolo
Parkside
Solutions4Plastic
Xampla
Aquapak
BioPak
Biotec/BioPlast
BioBag Ltd
Central Plains Group
Eco-craft
Ensus (CropEnergies Group)
Erthos Inc
Futamura
Leadergrain
Novamont
Total Corbion
Vegware
Aqualyte Ltd
Chip[s] Board Ltd
James Hutton Ltd
Cellucomp Ltd.
Pulpex Ltd
CuanTec Ltd
Cambridge Smart Plastics Ltd.

Recycled plastic producers

Agri.Cycle
Alpha Polymers Ltd
Arrow Recycling Ltd
Berry Circular Polymers
Biffa plc
Bright Green Plastics Ltd
CHP Polymers Ltd
Clean Tech UK Ltd
Duclo Recycling
Eurocell Recycle
Global Plastic Ltd
Impact Recycling
JP Recycling Ltd
KS Plastics Ltd
MBA Polymers UK Ltd
Monoworld Recycling Ltd
Pro Environmental Services Ltd
Roydon Ltd
Vanden Recycling Ltd
RECOUP
Pulse Plastics Ltd
Recycled Plastics UK Ltd
Rubber & Plastic Collection Services Ltd

Biocomposite Producers

Composites Evolution Ltd
Ecocomposites Ltd
Margent Farm
Cambond Ltd
Cellexcel Ltd

Bio-PUs

AIGreen
Biocleave UK
BASF
Covestro UK

Plant fibre producers/recyclers

Margent Farm
Technical Fibres
Offset Warehouse
Hemptex
Natural Fibre Company
Flaxland
Ananas Anam

Wool producers

HDwool
Woolcool
Doppelhaus
Wool: ReCrafted

Silk producers

Stephen Walters and Sons Ltd
Whitchurch Silk Mill
The Gainsborough Silk Weaving Company
Beckford Silk

Semi-synthetic fibres

HeiQ
Elissa Brunato
Spintex

Wood material suppliers

BCL Timber Products Ltd
Birchwood Forestry
Capricorn Eco Timber
Buckland Timber Ltd
BSW Timber Ltd
Coppice Creations
East Brothers
English Woodlands Timber
Ercol
Forest to Home
Hamsphire Chestnut
JM Bower Timber Product Limited
SMR Agrifor Ltd - Cultra Wood
Shelmore Timber
Tyler Hardwoods
UK Hardwood
Sylva Foundation
The Crown Estate Scotland
The Duchy of Lancaster
Valley Forestry
Vastern
W L West and Sons Ltd

Recycled synthetic fibres

IVL Ltd
Repreve Ltd.,
Vescom
Project Re:claim

Mycelium-based materials

Biohm

Algal/sea-weed based materials

FlexSea Ltd
Kelpi
Notpla Ltd

Alternative Leathers

Hide Biotech
The Fish Leather Company
Amadou Leather
Mykkö
Really Cleve
Modern Synthesis
Ananas Anam
3D Bio-Tissues
Biophilica
Thamon
Arda Biomaterials

Synthetic Chamois Leather

3M

Recycled Leathers

Recyc Leather TM
Generation Phoenix (formerly ELeather)

Nitrocellulose lacquer

TTC Ltd
Hagedorn NC

Beeswax

Pothe Hill