Final Report

Vegan Leather Cricket Gear Project

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Disclaimer

This open access research has been conducted by the authors to raise awareness of the potential use of alternative leathers in the design and development of cricket gear. It should not be used for any other purpose.

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1. Summary

Cricket is one of the most gear-intensive sports and increasing global participation presents a growing challenge for materials sustainability. An extensively used material in cricket products is animal hide leather, a critical element of cricket balls, and an important component of gloves, boots, and shoes. However, the use of leather is often associated with the release of hazardous chemicals (e.g. chromium) as part of leather's tanning process, as well as negative impact on worker's health.

The Centre for Sustainable Design® (CfSD) at the University for the Creative Arts (UCA) initiated the Vegan Leather Cricket gear (VLCG) project to consider opportunities for the use of more sustainable alternatives to animal hide leather in cricket gear. The project ran from September 2022 to July 2023. The aims of the VLCG project were to analyse vegan leathers[1] and evaluate the feasibility of the use of vegan leathers in the production of cricket gear. It is pertinent to highlight that the term "vegan leather" is controversial and banned in some countries e.g., Portugal[2] and that as the project progressed, market research focused more specifically on plant based vegan leathers [PBVL][3] as these met wider sustainability considerations. However, the prototype that was developed within the project used a non-plant based vegan leather due to pragmatic reasons, including time constraints and challenges associated with procuring samples of PBVLs. Therefore, throughout this report, while reference is made to PBVLs, the initial project outline aimed to explore vegan leathers more broadly. This study was conducted in collaboration with the Centre for Natural Material Innovation at the University of Cambridge (UoC) with the assistance of Gunn & Moore (GM) and Ananas Anam, and in consultation with the British Standards Institute (BSI), the British Association for Sustainability in Sport (BASIS) and Joe Cooke, an ex-professional cricketer. The VLCG project is part of longer-term investigation by CfSD into the sustainability of cricket equipment, apparel, and clothing.

This VLCG study focused on balls and gloves (batter and wicket-keeper). Pads (batter and wicket-keeper) were excluded as research indicated that leather was no longer being used in production and boots were excluded due to time and budget constraints.

The study included:

- Collation of data on markets for cricket balls and gloves
- Collation of data on markets for PBVL
- A review of cricket gear manufacturers and suppliers
- A player survey of attitudes to PBVL.
- Research into the performance characteristics of PBVLs compared to conventional leathers used in cricket gear.
- Production of a database of PBVLs that are commercially available and those in R&D.

[1] Vegan leather refers to a material made from plant-based or sustainable sources that is considered an eco-friendly replacement for animal leather.

[2] https://www.huffingtonpost.co.uk/entry/portugal-bans-vegan-leather-should-we_uk_62175648e4b0ef74d72b4afb

[3] The acronym PBVL is used throughout this report for consistency and refers to leathers classed as PBVL or other alternatives to bovine leather, recognising that use of the term 'vegan leather' is controversial and banned in some countries.

- Testing various samples of PBVLs for performance against standards and specifications.
- Evaluation of standards for cricket balls and gloves.
- Disassembly and refurbishment of a right-handed batting glove using a vegan leather[4]
- Development of a prototype wicket-keeping glove using a vegan leather[5]
- A qualitative sustainability assessment of a pair of cricket batting gloves using a PBVL piloting the Product Sustainability Framework

The focus was on England and Wales while considering the global context.

The findings and conclusions for each of the study tasks is summarised here. Details are provided in individual project reports.[6]

Market and leather consumption for balls and gloves

Little data is readily available on production and consumption of cricket gear in England and Wales (E&W) and globally. Nevertheless, market estimates have been made based on assumptions of use by cricket players. For the stated assumptions on use (see footnotes)[7] the annual quantity of leather consumed for balls and gloves in E&W is estimated to be 100 tonnes[8]. Of this, around 86% is for balls. This is based on the following estimation of annual numbers of items sold: 1.8 million balls, 0.5 million pairs of batting gloves and 50,000 wicket-keeping gloves.

A review of cricket gear suppliers and manufacturers

A review of cricket gear suppliers and manufacturers was undertaken between August 2022 and March 2023 to identify e-commerce platforms, suppliers, and distributors of cricket gear in the UK market. Previous research indicated that the UK has approximately 200 cricket gear suppliers; however recent expert discussions have indicated that the number might be closer to 250. However, there is no specific industry association representing the sector in E&W and a significant proportion of cricket gear appears to be produced in India and Pakistan. Findings from the review are the following:

- Specific details of 83 cricket gear suppliers in the UK were identified.
- From the 83 suppliers identified, 70% had a physical address and 30% operated solely online.

[4] A vegan leather was used rather a PBVL for producing a prototype. This was mainly due to pragmatic reasons-specifically, those related to time constraints and the challenges associated with procuring relevant PBVL samples. Further details are outlined in the section related to the production of the gloves prototype of this report.

[5] The rationale for using a vegan leather rather than a PBVL for producing a prototype was mainly due to pragmatic reasons-specifically, those related to the challenges associated with procuring relevant PBVL samples. Further details are outlined in the section related to the production of the gloves prototype of this report.

[6] Access to the individual reports can be found at https://cfsd.org.uk/projects/vlcg/research/

[7] Quantities of balls have been estimated from numbers of matches and balls per match at various levels of play; quantities of gloves and other PPE have been estimated from participation, ownership and average life at various levels of play.

[8] Detailed numbers and assumptions are stated in the final report Sustainability, Cricket Gear, Clothing and Apparel. Available at: https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023-1.pdf

- 90% of these companies are based in the E&W , while 10% are located abroad.
- From the 83 companies, 67 were categorised as e-commerce platforms, suppliers, or distributors, while 16 were manufacturers who also distribute cricket gear.
- Sustainability considerations are not a priority for most cricket gear suppliers, although it was identified that some companies have started to address sustainability concerns and have dedicated sustainability sections on their websites.
- These primarily relate to the implementation of circular economy initiatives[9], sustainable production, and packaging initiatives.[10]

Player survey

An online survey of players was conducted in April 2023 on attitudes towards vegan leathers. The survey was conducted as part of the Circular Cricket Gear project funded by UKRI CE-Hub Flexible Fund.[11] However, questions related specifically to vegan leather were extracted for the VLCG project and details were included in a specific report.[12] The survey was circulated to a list of 114 players at various levels and 42 responses were received. Below are conclusions from the research which should treated as indicative rather than definitive due to the sample size:

- The players did not consider the use of bovine leather to be a high contributor to the negative environmental impact associated with the production of cricket gear.
- There appeared to be high market interest amongst the players for cricket gear incorporating vegan leathers; in addition, interest was expressed in repair services for cricket gloves and other cricket gear.
- The main reasons to use PBVL in cricket gear primarily related to improved product sustainability and alignment with specific lifestyles such as veganism.
- However, the survey also highlighted that player confidence in the quality, durability, and technical performance of PBVL's is low.
- If the players are to adopt cricket gear produced from PBVL, industry must address player confidence in the material. This requires further research into player awareness and understanding, and a wider demonstration of technical and functional properties of these materials for relevant cricket gear.
- The development of PBVL for cricket gear should also address some of the perceived failures of leather. For example, issues related to leather cracking or sweat and odour considerations, which in turn, results in loss of grip of the bat with batting gloves.

It is important to highlight that the findings from the survey are based on an older demographic of cricket players (over 55), and responses were primarily from a male perspective. As such, further research focusing on a younger demographic and from a female perspective would be interesting to gain a better understanding of the requirements for the development of cricket gear incorporating PBVL alternatives.

[9] See for example: https://bradburycricket.com/sustainability/
[10] See for example: https://millichampandhall.co.uk/pages/our-green-policy
[11] CCG project details available at: https://cfsd.org.uk/projects/ccg/
[12] Full report available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final_Players_Vegan_Cricket_Gear-27-04-23.pdf

PBVL market

There is similarly a lack of publicly available information on the market for PBVL or other bovine leather alternatives. There are also few scientific articles covering the material properties of these materials.

- The market research[13] revealed a significant and rapidly growing market. 87 companies were identified producing 123 different materials described variously as sustainable leather, alternative leather, vegan, bio-based, or biomaterial.[14]
- Where possible, the following information was noted for each material: natural and plastic components, manufacturing process, properties, and characteristics. Company information was also noted, including location and sustainability commitments.
- A simple classification system was derived to categorise the various materials based on eight key biological components of the leather alternative material: fungus-based; leaf-based; fruit/vegetable/flower-based; other plant-based; fish scales/shells-based; cell cultured; and other/varying composition.
- Within each category, four sub-categories were identified: waste-based, grown, harvested, and unknown.
- The majority of companies surveyed had missing data. Since most of the companies' materials are either in research and development stages or are being produced on a small scale, many of the firms were unwilling to share details about the material composition or the manufacturing process for intellectual property (IP) reasons.
- In addition, as many of the companies are in phases of securing investment funding, they are wary of supplying samples for testing, as publication of any findings that are negative - however exploratory and preliminary - may have a negative bearing on their venture or brand.
- Furthermore, the majority of the vegan leathers identified target the fashion industry rather than, for example, sports gear e.g. cricket and so are not intended for performance under conditions such as impact and wear. This limited the scope of testing.

Standards review

Standards for cricket balls and gloves were reviewed in order to identify performance requirements and other characteristics which would need to be emulated by leather alternatives.

The study identified the following material properties as being particularly important for cricket balls and gloves:

- For cricket balls: thickness, density, 'mass per unit area', strength and elongation in tension, abrasion behaviour, water absorption, dimensional stability, UV-stability,

[13] Taylor B and Shah DU. February 2023. Leather Alternatives for Cricket Gear. Centre for Natural Innovation, Department of Architecture, University of Cambridge. https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

[14] Taylor B and Shah DU. February 2023. Leather Alternatives for Cricket Gear. Centre for Natural Innovation, Department of Architecture, University of Cambridge https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

machinability (including flexibility, cutability, tear strength, ability to stitch), as well as compatibility with lacquers and compatibility with the core material.

- For cricket gloves: weight (mass per unit area), water repellence, softness of leather over time, comfortable grip, tensile strength and elongation, colour fastness, pH, innocuousness and machinability (cutability, ability to stitch) are identified as important properties. Aside from material-scale testing, product-scale testing is critical.

The current combination of standards and norms currently restricts alternative leathers from being used for cricket balls, but it appears that they could be used in cricket gloves.

- British Standard BS 5993:1994[15] for cricket balls specifies use of leather defined according to standards for leather.[16] Notably, almost all of the over 87 biomaterials identified in the University of Cambridge[17] study as being leather alternatives could not be classed or referred to as 'leathers' so cannot currently be used for balls.
- However, BS 6183-4[18]for gloves does not specify that leather must be used. Therefore, leather alternatives could, in principle, be used if they meet performance and other criteria.
- The standards for 'soft' personal protective equipment (PPE), including gloves and pads, have not been updated to align with developments in safety standards, specifically British Safety Industry Federation (BSIF)[19] requirements for testing introduced in 2018. The British Standards Institute (BSI) is currently reviewing is reviewing the options for revision for cricket gear PPE standards.

Performance testing

The study found that comprehensive and accurate assessment of suitability of PBVLs and other leather alternative materials for cricket gear applications is not possible at this stage due to:

- The number of different materials available being significant and fast growing; and most being in the early stages of development with a lack of information.
- The majority of the alternative leather materials identified target the fashion sector. None of them appear to have looked into sporting gear applications, which have complex performance requirements.
- Testing of the 4 PBVL samples showed that PBVLs do not perform as well as bovine leather and are therefore currently not suited for cricket gear. However, the results of a player survey[20] indicated interest in the use of PBVLs in cricket gear as long as they match existing technical and functional properties .

Testing was nevertheless conducted as follows:

[15] https://www.en-standard.eu/bs-5993-1994-specification-for-cricket-balls/

[16] See Final Report: Leather Alternatives for Cricket Gear. Available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

[17] Ibid.

[18] https://www.en-standard.eu/bs-6183-4-2001-protective-equipment-for-cricketers-gloves-for-batsmen/

[19] See: https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023-1.pdf

[20] See https://cfsd.org.uk/wp-content/uploads/2023/04/Final_Players_Vegan_Cricket_Gear-27-04-23.pdf

- Two types of testing were conducted: tensile testing to measure strength and elongation in tension and contact angle analysis to measure wettability and absorption behaviour.
- For preliminary testing, two varieties each of four leather alternative materials were procured: Piñatex (Leaf-based, Ananas Anam), BarkTex (Other plant-based material, BarkTex), Bananatex (Leaf-based, QWSTION) and Hide Biotech leather (Fish scales-based, Hide Biotech).
- After considering various testing standards, a method was devised which could be altered to test the variety of failure mechanisms of the materials.
- The Hide Biotech material appears to behave more as a leather-like extendable material, whereas the other three materials have a failure typical of fibrous textiles.
- Only the Hide BioTech red leather was thick enough to withstand the stitching that would be required in the ball manufacturing process. However, the current material is not an appropriate substitute for bovine cricket ball leather. The lack of any alternative leathers of the large thickness required (3-5mm) is limiting but there may be more potential for use in gloves.

Disassembly exercise

Disassembly of a pair of batting gloves was undertaken to ascertain materials content. Findings and recommendations included:

- The size and shape of components/materials appear to be cut using precise moulds.
- No waste was identified as part of the manufacturing process.
- Focusing on alternatives to bovine leather used for the palm were identified as potential sustainability improvements.
- Based on the material properties required for the batting glove(s), the palm appears to be the component that is most likely to deteriorate during use. It is therefore also recommended to focus on design features that enable palm replacement.

R*efurbishing a 'right-hand' batting glove using 'vegan' chamois leather*

A study was carried out to assess the feasibility for refurbishing a pair of cricket batting gloves to extend the product's use phase using a 'vegan' chamois leather to replace bovine leather. This material was selected for pragmatic reasons. As highlighted in the study conducted by the University of Cambridge on Leather Alternatives for Cricket Gear[21], the vegan leather industry is at an early R&D stage, therefore, obtaining vegan leather samples represented a major challenge. As such, while the authors are aware that the composition of the selected 'vegan' chamois leather is made from 80% polyester and 20% viscose[22], and consequently, not deemed a sustainable plant-based alternative, the main goal was to produce and test a 'vegan' leather cricket batting glove as a proof of concept, within a limited time frame and

[21] Full report available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

[22] Viscose is derived from the "cellulose" or wood pulp from fast-growing, regenerative trees such as eucalyptus, beech, and pine, as well as plants such as bamboo, soy, and sugar cane. This cellulose material is then dissolved in a chemical solution to produce a pulpy viscous substance, which is then spun into fibres that can then be made into threads. See https://goodonyou.eco/material-guide-viscose-sustainability/

budget constraints. The final refurbished batting glove was tested by a high-standard league cricket player.

The refurbishment process included:

- Selecting a pair of used batting gloves and focusing on the right-hand glove (subject to most wear for a right-handed player).
- Identifying areas of wear and tear
- Refurbishing the palm and thumb by disassembling of the palm and thumb as a single component
- A prototype of a batting glove was made by a CfSD researcher/designer. Prototype development involved cutting, pattern making and stitching.
- The prototype was tested by a high standard league cricket player who provided the following feedback:
- The odour of the gloves remains problematic. The player indicated that this is one of the key issues related to refurbished gloves.

Player feedback indicated that:

- The gloves appeared to be 'a little too thick', compared to other gloves worn'. However, the player also indicated that this may be due to personal preference.
- Regarding thickness and breathability of the material, this was deemed as being a potential issue for the warmer months of the year.
- The player indicated that towards the end of the batting session (about an hour and 10 mins of wear) the gloves started to fray.
- Lastly, aligned to the testing feedback provide above, a cricket gear manufacturer indicated that chamois leather was too thick to produce a batting prototype. However, the manufacturer indicated that perhaps the chamois vegan leather would be better suited to for wicket-keeping 'inner' gloves. Therefore, a prototype of a pair of wicket-keeper 'inner' gloves was produced by the manufacturer using this material.
- Early feedback from testing of the chamois vegan leather wicket keeper 'inner' gloves by a professional wicket keeper did not report back anything 'adverse' regarding the material. Furthermore, he did not report back "a notable difference compared to his usual 'inner' gloves, which can be viewed as positive."[23]

Life Cycle Assessment (LCA) and Product Sustainability Framework

CfSD identified that there are no published on LCA studies on cricket gear. An LCA was not conducted on batting gloves due to logistical issues associated with procurement of appropriate software within the timescale of the project. In addition, a plan to use a protype Sustainability LCSA tool did not happen due to delays in software development within the Orienting project.[24] Nonetheless, an LCA was conducted on cricket pads within the CCG project which demonstrated the value of LCA in identifying the main areas of environmental concern related to a cricket product's lifecycle. However, a comparative assessment of a pair of cricket batting gloves was conducted using an early version of the Product Sustainability Framework (SPF) – a qualitative tool that has been development to think through

[23] Direct quote from the brand/manufacturer of the wicket keeper inner gloves prototype.
[24] https://orienting.eu

sustainability aspects of products.[25] The study compared a pair of batting pads using bovine leather against a pair using a PBVL across 3 sustainability areas: product performance, provenance in the supply chain and legacy of the products. Initial findings from the use of the PSF suggest that while the overall performance of the product under a PBVL scenario appears to be reduced when compared to the use of bovine leather, the products overall 'provenance in the supply chain' is substantially improved. Additionally, there appears to be an improvement in relation to the product's legacy[26], specifically in relation to the material's carbon footprint and overall waste. Lastly, the PSF highlighted some of the data required for conducting a quantitative assessment, e.g., existing LCA reports. However, due to the qualitative nature of the PSF, the findings should be considered as indicative rather than definitive and further research is required to quantitively assess the potential benefits of replacing bovine leather with PBVLs in cricket gear. Overall, the experience of applying the PSF to a practical example highlights that it is a useful framework that can be used as a 'thinking tool' to support 'quick and dirty' decision making related to product sustainability in the early stages of the early design and development (D&D). However, further work is required to fully develop the PSF process, user guidance and alignment with other standardised methodologies for it to be used in the D&D process.

1.1 Conclusions

Market for cricket gear

- The study confirmed the lack of market data for cricket gear and the difficulty in estimating the quantity of leather consumption and therefore potential for substitution with alternatives.
- Nevertheless, from estimates of use in matches at all levels of play in England and Wales, a figure of approximately 100 tonnes annual leather consumption for balls and gloves has been derived of which around 86% is for balls.

A review of cricket gear suppliers and manufacturers

A review of cricket gear suppliers and manufactures and subsequent expert input highlighted the following:

- There appear to be 200-250 cricket gear suppliers in E&W.
- Specific details of 83 suppliers were identified.
- Most of the cricket gear used in E&W is produced overseas, e.g., in India and Pakistan which means that cricket gear used in E&W has a significant embedded carbon footprint.
- Moreover, due to production being predominantly outsourced, it appears that the skills required to produce for example, cricket balls, has been lost in E&W.
- The research also shows that there appears to be an emerging number of 'bedroom brands' which are importing and placing gear onto E&W.
- A small number of suppliers are sustainability considerations on their websites and the issue appears to be a low priority for the cricket gear industry.

[25] The PSF is currently under development by Louis Brimacombe within the British Standards Institution (BSI).
[26] In this context, the term "legacy" refers to the longer-term impacts arising across the product life cycle including for example results from LCA studies and considering product durability, end-of-life/ circular economy/resource efficiency considerations.

- Therefore, further work needs to be undertaken to increase the cricket sector's sustainability awareness and understanding.

Player survey

- The players surveyed did not view the use of leather as a significant negative environmental impact compared to, for example, the carbon footprint of the supply chain of cricket gear more generally.
- There were overall positive attitudes to the use of vegan leather alternatives but presently, there is still a lack of trust in its performance for cricket gear. PBVLs would have to perform as well as leather.

PBVL and other leather alternatives market

- The PBVL industry is significant and fast growing but information is limited as most of the companies' materials are either in research and development stages or are being produced on a small scale.
- Most suppliers of alternative leathers are targeting applications in the fashion sector and are not intended for performance associated with sports e.g. cricket.

Standards

- The current combination of standards and norms currently restricts alternative leathers from being used officially for cricket balls. However, there is potential flexibility in use for batting and wicket-keeping gloves.

Testing and materials performance

Due to a lack of access to material samples, the materials testing completed by UoC was limited and the results not positive in terms of performance for cricket gear.

- Most of the alternatives could not be produced to the thickness (>3mm) desired for cricket balls.
- All materials showed limitations in physical properties and performance, especially for use in cricket balls, for which they are constrained by existing standards requirements.

Refurbishment

Overall, the refurbishment exercise demonstrated the technical feasibility of refurbishing a batting glove as well as providing insight into common product failures that lead to the disposal of cricket batting gloves. Testing of the refurbished batting glove using chamois vegan leather indicated that this material does not possess the technical properties required for cricket gear as the material started to fray after 2.5 hours of use and appeared to be too thick compared to the bovine leather batting glove. Furthermore, the 'feel' and breathability of the material was not equivalent to traditional bovine leather gloves.

Life Cycle Assessment (LCA) and Product Sustainability Framework (PSF)

Although the VLCG project did not include a Life Cycle Assessment (LCA), a separate study on cricket pads contributed to the identification of some of the main areas of concern related to a lifecycle of cricket gear. Additionally, the use of the Product Sustainability Framework (PSF) highlighted the relevance of qualitatively assessing the social, economic, and environmental trade-offs associated with replacing bovine leather in cricket batting gloves with a PBVL. Moreover, the PSF assisted in highlighting essential data gaps for conducting a quantitative assessment such as supply chain considerations. Overall, the PSF can be considered as a

valuable “thinking tool” for facilitating informed decision-making in the early design and development (D&D) stages, whilst acknowledging that further refinement of the tool is required.

1.2 Recommendations

The main recommendations from the various research activities conducted as part of the VLCG project are as follows:

Scope

Research indicated that leather is no longer used in the production of cricket pads. Under the current BS standard for cricket balls, animal hide leather is required for production which restricts to the use of leather alternatives. There is more flexibility to use vegan or alternative leather in batting or wicket-keeping gloves and inner gloves, as no restrictions are placed within the relevant BS standard.

Market research

Better market information is needed to assess the use of PBVL in cricket gear.

- This includes gaining better access to market information on cricket gear purchase and use to confirm quantities of leather used.
- Increased market information on PBVL materials and supply to further develop the existing materials database developed by UoC[27].

Cooperation between stakeholders in providing information which is not commercially sensitive would be beneficial.

- Addressing reasons for gap between lack of environmental concern in relation to bovine leather in cricket gear and interest in PBVL’s is needed.

Further research into players’ attitudes to PBVL.

- Also, researching the attitudes of younger and female players.

Further research into materials performance

Further research should focus primarily on the following:

- Potential use of PBVLs in batting and wicket-keeper gloves, since standards preclude use in balls, and also performance requirements for balls are more challenging. However, the development of a PBVL cricket ball might lead to other innovation and/or calls to change standards or laws as per the development of bamboo cricket bats that currently sit outside the MCC laws of cricket.[28]
- Further research into vegan chamois leathers as a separate category
- Improved data on materials and manufacturing processes to facilitate research and innovation in relation to the application of PBVL to cricket gear.

[27] For data base see: https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

[28] Tinkler-Davies B, Ramage MH, Shah DU. Replacing willow with bamboo in cricket bats. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*. 2022;236(4):255-265. doi:10.1177/17543371211016592

- Further investigation into the microstructure of the materials; and any links between the materials' microstructures and macroscopic properties should also be identified. In so doing, this will then inform the future development of new materials allowing for more streamlined innovation.
- Development of a testing method that can be applied consistently to all materials, despite the materials' variability. This testing method should then be applied to a wide range of materials, ideally at least one from each category in the classification (fungus-based, leaf-based, fruit/vegetable/flower-based, other plant-based, fish scales/shells-based, cell cultured, and other/varying composition). It should also be applied to a bovine leather sample which will provide benchmark results for comparison.
- This testing should attempt to mimic the use of the cricket gear in practice but in doing so should be informed by standard leather testing procedures where possible.
  LCAs on PBVLs should be conducted to assess the relative environmental benefits compared to animal hide leathers. This should include an assessment of their circularity and manufacturability. The cost and supply-chain of PBVLs needs further clarity, both of which impact the feasibility of manufacture.

Disassembly, refurbishment and prototyping

- The technical and economic feasibility of repair and refurbishment of cricket gear more broadly should be further researched to assess the sustainability benefits. Lessons should also be learnt from the disassembly of batting pads completed with the CCG project.[29]
- Prototyping may also reveal insights on the manufacturability with some of the alternative leathers (e.g., stitching, compatibility with lacquers for cricket balls).
- Further testing of refurbished cricket gear will also be useful to understand the technical and functional implications associated with refurbished gear and for example, to ensure that PPE standards are met.

Collaboration between cricket gear manufacturers and PBVL suppliers

Cricket gear manufacturers should explore potential collaboration with PBVL suppliers to accelerate learning, development and innovation.

- Currently, many companies are producing what seems to be very similar alternative leather materials and so it could potentially be beneficial to encourage collaboration between such companies.
- Combining resources and expertise of multiple companies could lead to rapid development of alternative leather materials that could be integrated into current manufacturing processes in the near future.

2. Introduction

2.1 This report

This report summarises the results of a project led by The Centre for Sustainable Design ® (CfSD) at University for the Creative Arts (UCA) in partnership with the Centre for Natural Innovation at the University of Cambridge (UoC) that has explored opportunities for the use

[29] https://cfsd.org.uk/projects/ccg/

of PBVLs in cricket gear. It presents the main findings and recommendations on the way forward. Further details are provided in separate sub-task reports as stated below in Section 2.4.2.

This study is part of longer-term investigation by CfSD into the sustainability of cricket equipment, apparel, and clothing.

2.2 Background

The Centre for Sustainable Design ® (CfSD)[30] at the Business School for the Creative Industries[31] at the University for the Creative Arts (UCA)[32] is working on a range of projects related to cricket related to sustainability, cricket gear and clothing. Outcomes of these projects will be disseminated through the PASIC[33] platform. CfSD is a centre focusing on research and knowledge transfer related to sustainable innovation and product sustainability that was established in 1995.

Research to date has found that considerable quantities of cricket gear (bats, balls and protective equipment), clothing and apparel, including footwear, are being used (consumed) and will be needed to meet growing global participation in cricket – current participation at all levels has been estimated to be over 300 million[34] people globally and nearly 300,000 in the UK[35]. However there has been little consideration of sustainability in the production, use and disposal cricket products and little information is available on supply chains as to what happens to products at end of life.

Leather is extensively used material in cricket gear being a critical element of cricket balls, and an important part of gloves, boots and shoes. CfSD at UCA initiated the Vegan Leather Cricket Gear (VLCG) project to consider opportunities for more sustainable alternatives and collaborated with UoC who provided research and technical support on materials issues. Gunn & Moore provided industry support and the cricket gear samples used for the disassembly and refurbishment study, as well as the production of a prototype pair of wicket keeper inner gloves using a vegan chamois leather. Ananas Anam provided PBVL expertise and the "Piñatex" sample used for the materials testing study conducted by the UoC. In addition, other input was provided by British Standards Institute (BSI), British Association for Sustainability in Sport (BASIS), Sports Labs and Joe Cooke ex-professional cricketer.

2.3 Purpose

The stated aims of the VLCG project were to analyse leather alternatives to replace the use of animal hide in cricket gear and evaluate the feasibility of the use of vegan leathers in the production of cricket gear.

[30] www.cfsd.org.uk
[31] www.uca.ac.uk/business-school
[32] www.uca.ac.uk
[33] https://cfsd.org.uk/projects/cricket/
[34] Source: International Cricket Council.
[35] Cricket participation England 2016-2020 | Statista

2.4 Scope

2.4.1 Overall project scope

This project focused on the use of vegan leathers for balls and gloves (batter and wicketkeeper). Pads, boots and shoes were initially included for the VLCG study. However, it was established early in the review of cricket gear that leather is no longer used in pads and cricket boots and shoes were excluded due to budget and time constraints. To understand the comparative environmental impact of bovine leather and 'vegan leather' in cricket balls and gloves, life cycle assessments (LCAs) were considered. However, no completed studies were found in the public domain and specific LCA analyses could not be completed on the above items - within the timescale of the project - due to internal challenges related to software procurement.

The following is a list of tasks completed under the VLCG project included a combination of desk and primary research methodologies that included technical materials testing and prototype development:

- Collation of data on market size for a) leather and PBVL and b) cricket balls (red, white and pink), and gloves (batter and wicket-keeper).
- Evaluation of BSI and MCC/other standards for cricket balls and gloves to understand the interpretation of the term 'leather' and other relevant criteria/aspects for the project.
- Reviewing manufacturer specifications for cricket balls and gloves.
- Researching the performance characteristics of PBVL in comparison to conventional leathers used in cricket balls and gloves (based on BSI, MCC and other standards, and manufacturers requirements).
    a) Producing a database of PBVLs that are commercially available and those in R&D, with a list of documented characteristics.
    b) Testing various samples of PBVL for surface and structural characteristics and evaluating against standards and specifications.
- Refurbishment and user testing of a pair of worn batting gloves using synthetic chamois leather.
- Production of prototype wicket-keeper inner gloves using synthetic chamois leather.
- Scenario based sustainability analysis using the Product Sustainability Framework[36] on a pair of cricket batting gloves to compare the trade-offs associated with replacing the use of bovine leather with a PBVL (Piñatex).

The focus was on England and Wales while considering the global context.

2.4.2 Scope of this report

This report provides summary information covering various tasks that were completed within the VLCG project which, as distinct tasks in most cases, are reported separately.
The following reports are available through the CfSD website and should be referred to for further details:

[36] The Product Sustainability Framework is currently in early stages of development and is not widely available. Therefore, it has not been possible to provide further details or reference to this methodology.

- Research on cricket gear market[37].
- Research into suppliers of cricket gear in England and Wales.[38]
- Market research on PBVL and a database on commercially available PBVL and other leather alternatives, and testing results on alternative PBVL.[39]
- A player survey on PBVL perceptions.[40]
- A report on the batting glove refurbishment.[41]
- A Product Sustainability Framework (PSF) study on a cricket batting glove palm.[42]

3. Market Research

3.1 Introduction

This section summarises the results of four market research exercises:

a) Market research into cricket gear was conducted to estimate consumption of leather-containing cricket gear in E&W and assess the feasibility of material substitution to replace the use of animal hide leather.
b) A review of cricket gear manufacturers and suppliers was conducted to identify e-commerce platforms, suppliers, or distributors of cricket gear in the UK.
c) A survey among players to gauge attitudes to PBVL.
d) Market research into PBVL and other leather alternatives was conducted to develop a database of materials and suppliers and a classification for use in testing and further research.

3.2 Market research[43] into cricket gear

3.2.1 Data availability

Obtaining data on cricket gear use (consumption) in England and Wales has proved to be challenging due to a general lack of availability[44] and transparency of information in the cricket sector:

- The England and Wales Cricket Board (ECB), the national governing body, was unable to provide data on cricket gear consumption, or detailed data on participation at club level from which to derive consumption estimates.
- There is no cricket gear or sports industry organisations compiling information on cricket sales in England and Wales (E&W). Cricket gear supply in England and Wales is

[37] https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023-1.pdf

[38] https://cfsd.org.uk/wp-content/uploads/2023/07/A-Review-of-Cricket-Gear-Manufacturers-Suppliers-July-2023.pdf

[39] See www.cfsd.org.uk

[40] https://cfsd.org.uk/wp-content/uploads/2023/04/Final_Players_Vegan_Cricket_Gear-27-04-23.pdf

[41] https://cfsd.org.uk/projects/vlcg/research/

[42] https://cfsd.org.uk/wp-content/uploads/2023/09/Product-Sustainability-Framework-Cricket-Batting-Gloves-Palm-July-2023.pdf

[43] The information contained in this section has been derived from Charter, M and Clark T (2022). Sustainability, Cricket Gear, Clothing and Apparel: Report on Cricket Gear. Available at: https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023-1.pdf

[44] There is some market data available online but this is expensive, costing up to 5000 USD for a global report and of uncertain quality and currency. 15 or more sites seem to be selling the same information from possibly the same source.

highly fragmented with many suppliers, but mostly importers and retailers and dominated by global sports goods suppliers for whom cricket is a small part of their business.

- The global producers of cricket gear may have data on the overall market, but they have not responded to requests for interviews and market information.
- Smaller bat manufacturers supplying other cricket gear have been helpful but had no data was provided on the national market.

3.2.2 Product classifications

Suppliers and distributors of cricket gear tend to use similar general product classifications as well as their own grading terms. Table 1 shows the main classifications for balls and gloves. There are corresponding classifications for bats and for pads, helmets and other PPE such as thigh, elbow guards but these are not shown as they are not relevant to or significant for leather.

3.2.3 Cricket gear supply chain

The cricket gear supply chain is complex and fragmented with many suppliers of different types.

Global brands

The market is dominated by global sporting goods brands e.g. Adidas, Puma, New Balance for which cricket gear is a small part of their business but has high marketing value in reaching many people through TV advertising and player sponsorship. Generally, these firms add their logos to sub-contracted manufactured goods. Some global brands are country-based. For example, Indian tyre manufacturer MRF is now a major cricket brand.

Product type	Categories
Balls	
Size/weight	Senior/junior Men/women
Colour	Red/white/pink
Material	Hard/soft (field, indoor, junior)
Purpose	Match/training/bowling machine *(balls)*
Grade	Suppliers grade
Batting and wicket keeping gloves	
Size/weight	Senior/junior Men/women Standard and lightweight
Material/Grade	Suppliers grade (many suppliers offer a range of their own brand quality grades for the various types of gear)

Table 1 Product classifications for balls and gloves

The dominance of branding and labelling by major brands/producers has contributed to the opacity of the sector and lack of information on the supply chain and conditions in manufacturing - an issue in sports goods generally.

Manufacturers

Most cricket gear manufacturing is now in India and Pakistan.

- In India, specialist cricket and sporting goods manufacturers supply the large home as well as export markets. The larger Indian manufacturers (there are many smaller firms) include SG, SS, BDM and BAS.
- In order to compete, most have become contract manufacturers for global brands. Some companies (e.g. Sanspareils-Greenlands (SG)) produce and market their own brands as well as providing outsourced production under contract to global firms – effectively in competition against their own brand products.
- Manufacture of gear, including balls, gloves, pads and footwear, has also spread to Bangladesh, China and elsewhere but no data has been obtained on the supply chain and volume compared to India.
- The production and supply chain of balls and 'soft' gear or personal protective equipment (PPE) resembles that of cricket clothing in some respects e.g. in involving cutting and stitching. Production processes in Asia appear to be labour intensive using basic production technologies e.g. sewing machines for clothing, pads, gloves, etc.

Various other types of manufacturers supply the market in England and Wales (E&W). These include:

- Major UK cricket gear manufacturers e.g. GM, Gray Nicolls.
- Major international general cricket specialists e.g. Kookaburra (Australia).
- Specialist ball makers e.g. Dukes.
- Smaller 'craft' bat manufacturers supplying other cricket gear (e.g. B3).

While retaining some domestic manufacturing in E&W, especially in bat making, most PPE and other gear manufacture is outsourced to Asia by these companies.

The larger specialist suppliers such as GM have retained an important niche, especially at the quality and upper echelon player end of the market.

Dukes is the leading supply of quality balls. Its leather is supplied from and prepared in the Scotland and England with final manufacturing is in India (see Section 4.2).

Smaller bat makers in England and Wales have retained a niche and sell gear as an extra source of income, branding imported goods.

Distribution and retailing

As with many products, there has been a shift to e-commerce. Specialist cricket retail stores are now rare, but in-store retailing continues to add value to customers for personal service, sizing, 'feel', customising and other purposes.

- In-store cricket gear retailing is mainly through cricket sections in large sports goods retailers, often national chains e.g. Lillywhites. These retailers sell multiple brands or 'white label' imported goods with their own brand labels.
- Independent sports retailers selling cricket gear serve niche local markets e.g. Berkeley Sports (Farnham).
- Club shops of county and other cricket clubs often supply cricket gear (merchandising is an important source of income).
- Major (e.g. GM) and smaller (e.g. Aldred) manufacturers usually have factory shops selling their own brands of bats and other gear.

Many of these retailers combine in-store with online retailing.

There are also suppliers in E&W which are wholly on-line:

- Ecommerce or portal e.g. CricketDirect
- Historically, mail order firms for cricket gear existed but there has now been a shift online e.g. Morrant Group.
- 'Bedroom brands': Small 'white labellers' badging imported gear and selling online e.g. Village Cricket. Aided by online selling and low overheads these firms have gained a significant market share.[45]

3.2.4 Participation and customer markets in England and Wales

Participation

Understanding the level of participation in cricket (i.e., number of players), globally as well as in E&W, provides important context for evaluating the demand for cricket gear and potential benefits of more sustainable alternatives.

- Global participation in cricket has shown major growth, especially through its popularity in the Indian sub-continent and promotion of the game in many other countries. The International Cricket Council (ICC) has estimated that 300 million people worldwide play cricket to at least some extent[46].
- In E&W there has been a significant decline in participation over the past 15-20 years. However there have been major efforts to promote the game, especially at junior level, through T20 and other new formats, as well as attracting women and girls. If successful, these will increase participation and demand for gear.
- In E&W a 2021 survey estimated that 294,000 adults played cricket at least once a month within the cricket season. The ECB has estimated that a third of these are of South Asian origin, cricket having a strong cultural affinity with this community.
- Research by CfSD has also estimated that around 200,000 juniors play cricket in independent schools in E&W where cricket remains strong.[47]
- While the game has been in decline in state schools, there are still substantial numbers playing and considerable efforts to increase interest and participation, especially at primary school level, and including girls.
- At all levels there has been increasing female participation and many clubs now have women's teams.

Customer markets

- The core market for personal cricket gear (bats, gloves, pads and other PPE) is individual recreational players in around 6500 ECB-affiliated clubs as well as non-affiliated clubs and teams. At the highest level are National County clubs and ECB

[45] For further details, see Charter, M., & Clark, T., (2022). Report: Sustainability, Cricket Gear, Clothing and Apparel. Available at: https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023.pdf

[46] International Cricket Council (2018) Media Release 759733 First global market research project unveils more than one billion cricket fans (icc-cricket.com)

[47] See Charter, M., & Clark, T., (2022). Report: Sustainability, Cricket Gear, Clothing and Apparel. Available at: https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023.pdf

Premier Leagues, and at the lower levels Sunday leagues and other friendly and social cricket.

- From discussions with suppliers and former players, most players are likely to own their own personal gear whereas in the past, gear was often shared through club bags particularly in social cricket. An exception is balls, which are usually purchased by clubs.
- A small but important part of the market is professional clubs and players, playing in First Class County, T20, international and other competitions.
- The research suggests that junior cricket contributes to 47% of consumption and waste, reflecting shorter equipment lives as young people grow.[48]

3.2.5 Estimate of market size and consumption

Market size and consumption of leather-containing cricket gear in E&W has been estimated to understand the potential for substituting animal hide leather with PBVL or other leather alternatives.

No data was readily available on production, consumption and product life from cricket gear, globally or in E&W, but the quantities can be roughly estimated from assumptions on ownership, usage, average product lives and replacement, including.

- In the case of PPE, numbers of players, ownership rates and average lives of gear for each main player type.
- In the case of balls, numbers of new balls per match and numbers of clubs, leagues and matches, with 2 new balls for most matches.

Other factors can be considered in relation to usage (and waste) such as level and frequency of play, teams changing colours and logos annually (relates to clothing primarily) and juniors outgrowing gear.

Some reuse of balls happens within clubs such as re-using balls for Sunday league games and for 'net' practice. Balls may be used many times until the seam splits.

For the stated assumptions in the original CfSD report in 2022[49] annual tonnages of leather-containing gear consumed for balls and gloves in E&W are shown in Table 2.

[48] See: https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023.pdf

[49] Charter, M., & Clark, T., (2022). Report: Sustainability, Cricket Gear, Clothing and Apparel. Available at: https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023.pdf

Gear type	Number of items	Total weight (tonnes)	Leather % by weight	Leather weight (tonnes)
Balls	1,800,000	284	30	85
Batting gloves	500,000 pairs	170	6	10
Wicket keeping gloves	50,000 pairs	59	6	3
Total		**508**		**c. 100**

Table 2 Estimated 2022 leather consumption in England and Wales (E&W) for cricket balls and gloves (Numbers are rounded. Consumption does not include production waste)

In the case of balls, these estimates are for all hard balls of any colour. White balls are mainly used at professional level for one day matches for greater visibility under floodlights.
Similar considerations apply to pink balls used in T20. Usage per match is higher than at recreational levels but they form a very small part of total usage – say 1%. Soft balls used in under 12, social and indoor cricket are considered to be a small part of the market and are mainly made of plastic.

Many assumptions have been used in these estimates and the total is especially sensitive to estimates of ownership and use at adult and junior levels, average lives of gear, and average weights. Nevertheless, these estimates provide indicative figures which can be refined with time.

3.2.6 Conclusions

The research conducted by CfSD at UCA confirmed the lack of market data for cricket gear and, in the present context, difficulty in estimating the quantity of leather consumption and therefore potential for substitution with alternatives.

- Obtaining data on cricket gear use (consumption) in E&W has proved to be challenging due to a general lack of availability and transparency of information in the cricket sector.
- The cricket gear supply chain is complex and fragmented with many suppliers of different types. However, the dominance of global sports brands and labelling, with most manufacturing in India, has contributed to the opacity of the sector and lack of information on the supply chain.
- There is no accessible data on sales of cricket gear and little data on cricket participation.
- Nevertheless, from estimates of use in matches at all levels of play in England and Wales, a figure of approximately 100 tonnes annual leather consumption for balls and gloves has been derived of which around 86% is for balls.

3.3 Review of cricket gear manufacturers and suppliers

3.3.1 Research methodology and background

A list of e-commerce platforms, suppliers, or distributors was collated by conducting a Google search using the following key words: cricket gear suppliers, cricket gear manufacturers,

cricket bats, cricket gloves, cricket clothing. The research was conducted between August 2022 and March 2023.[50]

No specific desk research into the number of e-commerce platforms, suppliers, or distributors of cricket gear in the E&W appears to have been completed to date. Previous research for 'Sustainability, Cricket Gear, Clothing and Apparel: Report on Cricket Gear'[51] indicated that there were approximately 200 cricket gear suppliers in the UK with an industry expert more recently estimating over 250 suppliers. Therefore, identifying the structure and breakdown of the sector is difficult. This is exacerbated by there being no industry association specifically covering suppliers of cricket gear that has an interest in compiling market data and representing the industry.

The Heritage Crafts report (2017)[52] identified 18 manufacturers of cricket bats in UK and has declared that the making of hand-stitched cricket balls with a cork core and leather covering as an extinct craft as of 2017. Issues affecting the viability of production of cricket bats and balls in the E&W include a shortage of skilled workers and cost of producing in the UK that has led to outsourcing production to India, Pakistan and other parts of Asia.

3.3.2 Findings

- Research highlighted 83 companies placing cricket gear on the market in E&W. 70% had a physical address, while the remaining 30% appear to only have an online presence. This could suggest that these companies operate at a very small scale with for local distribution and/or are operating as 'bedroom brands'[53] supplying 'white labelled' brands where suppliers add their logo on 'blank' imported products.
- Regarding geographical location, 90% appear to be based in the E&W and 10% abroad (India, Pakistan, Australia, etc).
- From the companies identified, it is generally the case that part of the production is outsourced to other countries e.g. India, Pakistan and other parts of Asia

Specifics

- From the 83 companies identified, 67 were classified as e-commerce platforms, suppliers, or distributors and 16 were manufacturers who also distributed cricket gear. This was determined by reviewing each companies' website description.
- From the 83 companies, 15 were identified as UK based bat manufacturers, 67 as bat suppliers and 1 as a ball manufacturer. 80 companies supplied batting gloves, 61 supplied wicket keeping gloves; with 61 companies supplied batting pads, and 79 supplied wicket keeping pads. Additionally, 67 companies were identified as suppliers of abdominal protection (boxes) and 58 as suppliers of helmets. A smaller number of suppliers were identified as supplying clothing: 49 companies supplied shirts, 46 trousers, 34 jumpers and 29 socks.

[50] Full report will be available at: https://cfsd.org.uk/projects/vlcg/research/
[51] https://cfsd.org.uk/wp-content/uploads/2023/06/Sustainability_Cricket-Gear-Final-July-2022-Updated-June-2023.pdf
[52] See: http://heritagecrafts.org.uk/?s=cricket+bats
[53] 'Bedroom brands' can be defined as 'white labellers' badging imported bats and other gear e.g., Retailers' own brands. Source: https://cfsd.org.uk/wp-content/uploads/2022/07/Sustainability_Cricket-Gear-Final-28-7-22.pdf

Sustainability

- Sustainability issues or achievements were not clear on most of the websites of the cricket gear suppliers. This suggests consumer facing sustainability considerations are not perceived as a priority. However, a few examples were identified. Bradbury Cricket, for example, have a section on sustainability and circular economy initiatives, indicating that "Off-cuts that can be considered a waste material from cutting the raw clefts to regulation width, are used to construct bird houses and shelters for native bees."[54] In addition, Millichamp and Hall has a 'green policy'[55] and Gray Nichols recently launched its 'Envyro' sustainability programme that will focus on sustainable production and packaging.[56]

Conclusions

Based on the findings from the cricket gear manufacturer and supplier research, the following conclusions were made:

- Most of the cricket gear used in the E&W is produced aboard, e.g. in India, Pakistan and to parts of Asia. This means that cricket gear used in the UK has a significant embedded carbon footprint.

Moreover, due to production being predominantly outsourced, it appears that the skills required to produce, for example, cricket balls, has been lost locally. Therefore, if an alternative material to replace the use of bovine leather was accepted by the BS 5993:1994[57] and MCC laws in the future, production of cricket balls would perhaps remain outsourced to India and Pakistan and thus remain with a significant embedded carbon footprint despite material innovation.

- The supplier research also shows that there appears to be an emerging market of bedroom brands' which import gear to then label in the UK.
- Lastly, sustainability considerations appear to be a low priority for the cricket gear industry in E&W. For example, it is unlikely that cricket gear industry will accept the use of PBVL to replace the use of bovine leather in cricket gear due to a) conservatism of the sector as indicated in the cricket gear standards research[58], b) perceived players technical issues with the PBVLs as indicated in the player survey[59] and c) lack of performance of PBVLs in relation to cricket gear. Therefore, further work needs to be undertaken to increase the cricket sector's sustainability awareness.

[54] https://bradburycricket.com/sustainability/
[55] https://millichampandhall.co.uk/pages/our-green-policy
[56] https://www.gray-nicolls.com.au/blogs/news/envyro-a-sustainability-initiative
[57] BS 5993 1994 https://www.en-standard.eu/bs-5993-1994-specification-for-cricket-balls/
[58] Taylor, B., & Shah, D.U (2023). Leather Alternatives for Cricket Gear. Available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf
[59] Sanchez-Moreno, L., & Charter, M., (2023). Specific Findings from a Survey of Cricket Players related to Cricket Gear ad Plant-based/'Vegan' Leather Alternatives. Available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final_Players_Vegan_Cricket_Gear-27-04-23.pdf

3.4 Player survey

3.4.1 Scope

An online survey was conducted in April 2023 as part of the ongoing Circular Cricket Gear (CCG) project.[60] However, the section below highlights the findings relevant to the VLCG project. A full analysis and report is available on CfSD website under the CCG project.[61] The survey was circulated to a list of 114 players at various levels and received 42 responses.[62] Findings, analysis and conclusions should be treated as indicative and not definitive due to the small size of the sample.

3.4.2 Results

Playing level

Based on the 42 responses received, the following is a percentage breakdown for each category:

- League: 48%
- Recreational: 38%
- Friendly Club/Friendlies: 9%
- Other: 5%

Demographics

The demographic breakdown of respondents was:

- 83% identified as male
- 41% aged over 55
- 26% aged 45-55.
- 12% aged 35-45
- 7% aged 25-35
- 14% aged 18-25

Games played and cricket gear life

The average number of cricket games played per year was 13, reflecting the number of respondents from recreational and friendly cricket. An initial analysis indicates that the number of games played does not correlate to age or gender.
The survey indicated that:

- Cricket gear and specifically, cricket gloves, appear to be kept for over 8 seasons by 38% of respondents and between 2-3 seasons[63] by 36%.
- Initially, it was hypothesised that older respondents (over 55), playing 'friendlies', would have kept their kit for over 8 seasons, while younger players (between 18-25) would perhaps change their kit every 2-3 seasons.

[60] CCG Project https://cfsd.org.uk/projects/ccg/
[61] Sanchez-Moreno, L., & Charter, M., (2023). Full Report: Findings from Online Survey: Cricket Gear Users/Players. Available at: https://cfsd.org.uk/wp-content/uploads/2023/09/Survey-of-Cricket-Gear-Users_Players_August-2023.pdf
[62] The findings from the player survey highlighted in this report are only relevant to player perceptions on the use of vegan leathers. Report is available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final_Players_Vegan_Cricket_Gear-27-04-23.pdf. /
[63] 1 season is equivalent to 1 year.

- The survey further indicated that there is no correlation between how many seasons cricket gear is kept and age, level of play, and gender.

Sustainability considerations and relevance for Vegan Leather Cricket Gear (VLCG) Project

- 57% of respondents indicated that they have considered the environmental impact of cricket gear in the past 6 months.
- However, when asked to elaborate further on their response, it appears that most respondents had not identified specific environmental issues.
- For those that had considered 'the environment', most focused primarily on the disposal of cricket gear at 'end of life' and the carbon footprint associated with the cricket gear supply chain.
- Respondents did not perceive the use of bovine leather to produce cricket batting gloves and cricket balls to be a significant contributor to the negative environmental impacts associated with the production of cricket gear. Only 1 respondent selected the use of bovine leather as the highest contributor to the environmental degradation in relation to the production of cricket gear.
- Conversely, the carbon emissions related to overseas manufacturing and transportation were perceived as the highest contributor.
- This was followed by concern over the use of materials derived from non-renewable sources such as high-density-foam for paddings and synthetic leather.
- Therefore, from a player (user) perspective, replacing the use of bovine leather is potentially not perceived as a priority for reducing the negative impacts associated to the production of cricket gear.
- However, when respondents were asked if they would consider replacing their existing cricket gear - specifically batting gloves and cricket balls - with a 'plant-based'/'vegan' leather alternative, 71% replied positively.
- The main reasons highlighted were related to the alignment with lifestyles such as veganism, or increased awareness of sustainability considerations.
- However, it was also highlighted that to consider switching to cricket gear incorporating 'plant-based'/vegan leather alternatives, new equipment using alternatives would be required to match existing products' durability, quality, and performance. Likewise, new products would have to be affordable.
- From the 29% that indicated they would not consider using cricket gear made from a 'plant-based'/'vegan' leather alternative, the main reasons appear to be player (user) perception related to potentially lower quality, durability, and performance of the material e.g., 'not as hard wearing' as 'true' leather.
- Further research should seek to address why there is a gap between lack of environmental concern in relation to bovine leather in cricket gear and interest in 'plant-based'/'vegan' leather alternatives.

3.4.3 Conclusions

Based on the preliminary analysis outlined above, key conclusions for the VLCG project are the following:

- Players (users) do not consider the use of bovine leather to be a high contributor to the negative environmental impact associated with the production of cricket gear.

- There appears to high market interest amongst players (users) for cricket gear incorporating 'plant-based'/'vegan' alternative leathers.
- The main reasons highlighted for the acceptance of cricket gear using 'plant-based'/'vegan' leather alternatives primarily relate to the potential improvement of product sustainability and alignment with specific lifestyles such as veganism.
- However, the survey also highlights that player (user) confidence in 'plant-based'/'vegan' leathers alternatives is low. This relates particularly to its quality, durability, and technical performance.
- Therefore, it can be concluded that if players (users) are to adopt cricket gear produced using a 'plant-based'/ 'vegan' leather alternatives, firstly, industry must address player (user) confidence in the material. This requires further research into player (user) behaviour and a wider demonstration of technical and functional properties of these materials for relevant cricket gear.
- In addition, based on findings of project on the refurbishment of cricket batting glove using a 'vegan' chamois leather[64], 'plant-based'/'vegan' leathers would also need to address some of the perceived failures of leather. For example, issues related to leather cracking or sweat and odour considerations, which in turn, result in loss to grip
- Lastly, it is important to highlight that the findings presented in this report are based on an older demographic of cricket players (over 55), and responses are primarily from a male perspective. As such, further research focusing on a younger demographic and perhaps from a female perspective is required to gain a better understanding of the requirements for the development of cricket gear incorporating 'plant-based'/ 'vegan' leather alternatives.

3.5 Market research into PBVL and other leather alternatives

3.5.1 Research methodology

The University of Cambridge (UoC) conducted market research unto PBVL and other leather alternatives during July and August 2022. The results are summarised here and details available in a separate report.[65]

An internet search was conducted into materials identified as sustainable, leather, alternative, vegan, material, bio-based or biomaterial. This method allowed identification of many materials. The materials identified were then assessed to determine whether they should be included or excluded in this review.

Within this market summary, materials were listed under their company name where possible. In the cases where the company name is unknown, the name of the leather is used.

The majority of companies summarised had missing data. This, alongside the number of companies discovered, suggests that this market is rapidly growing, with many companies in early production or research and development stages. A number of these companies were also reluctant to share data publicly for this reason. It should be noted that many of the applications are for bags and other fashion purposes.

[65] Taylor, B., & Shah, U.D., (2023). Leather Alternatives for Cricket Gear. Available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

3.5.2 Categorisation of leather alternatives

The market research revealed a distinct lack of publicly available data. Where possible, the following information was noted: natural component(s); plastic component(s); manufacturing process; properties and characteristics; locations(s); sustainability; compliance to relevant regulations. 87 companies producing 123 different leather alternative materials are included in the resulting database.

A simple classification system was derived to categorise the various materials.

- 8 categories were devised based on the key biological component of the leather alternative material: fungus-based, leaf-based, fruit/vegetable/flower-based, other plant-based, fish scales/shells-based, cell cultured, and other/varying composition.

Leaves				Trunk/Stem			
Waste	Grown	Harvested	Unknown	Waste	Grown	Harvested	Unknown
Leaf Leather		Pinatex Desserto + 1 other	Mulbtex + 3 others			Bananatex BarkTex + 4 others	Rewrap + 6 others
Fish scales/Shells				**Fungus**			
Waste	Grown	Harvested	Unknown	Waste	Grown	Harvested	Unknown
Hide BioTech + 7 others				Creation of Sustainable Materials (COSM)	Amadou Bolt Threads + 7 others	FUNGISKIN	AirMycelium + 3 others
Fruit/Vegetable/Flower				**Cell-cultured**			
Waste	Grown	Harvested	Unknown	Waste	Grown	Harvested	Unknown
Mirum Appleskin + 7 others			Curo Vegetal da Amazonia + 6 others			AirCarbon BioFabbrica + 10 others	
Other Plant-based				**Other/Varied Composition**			
Waste	Grown	Harvested	Unknown	Waste	Grown	Harvested	Unknown
Treekind LOVR + 6 others		Philippine-inspired plant leather	LaVeg BioVeg + 3 others	SOYA C(O)U(L)TURE + 6 other	Coopflora Fungi Line		Flex Tree + 29 others

Table 3: Classification of sustainable leather alternatives

The classification used to sort the sustainable leather alternatives found in the market research. The full report by UoC[74] includes a database of all the leather alternatives identified.

- Within each category, four sub-categories were identified: waste-based, grown, harvested, and unknown. A summary of this is shown in Table 3, with example companies operating in this space listed.

3.5.3 Sustainability and ethical considerations

Sustainability and ethical considerations are important aspects of the PBVL market and were therefore considered for the selection of materials for testing.

- When replacing leather with a 'sustainable' alternative material, acceptable indicators of environmental impact – such as embodied energy, carbon footprint, or water use – need to be quantified.

- A number of alternative leathers identified in the study claimed to be sustainable. Such claims need to be backed by certified life cycle assessment (LCA) studies. Only Piñatex provided LCA information.
- It is notable that many widely used leather alternatives are petroleum-derived plastics which, based on the impacts of their source, and any issues in disposal, limits their life cycle sustainability.
- An LCA comparison would be necessary to compare petroleum-based and non-petroleum-based alternatives against life cycle sustainability criteria. However, for this study petroleum-based materials were not judged to be suitable for further study since, even if they performed well in testing, they would not provide an alternative to leather which could claim to be sustainable.
- Ethical reasons and personal motivation (e.g. vegan lifestyle) may be the principal driver of the substitution of hide leathers for some people. Such motivations may or may not exclude leathers made from fossil fuel-based plastics.

3.5.4 Conclusions

The main conclusions from the PBVL market research are as follows.

- The PBVL and alternative leather industry mostly targets the fashion sector, which limited the scope for performance testing and comparison for potential use in cricket gear.
- Information is limited. There are few scientific articles covering the material properties of PBVL or other leather alternatives.
- Additionally, as most of the companies' materials are either in research and development stages or are being produced on a small scale, many of the firms are unwilling to share details about the material composition or the manufacturing process for IP reasons.
- In addition, as many of the companies are in phases of securing investment funding, they are wary of supplying samples for testing, as publication of any findings in poor light – however exploratory and preliminary - may have a negative bearing on their venture or brand.
- Based on the market research conducted, 4 materials were selected for testing (Piñatex, BarkTex, Bananatex and Hide Biotech). The selection criteria were based on the material's functional and technical properties, but also influenced by sample availability. Moreover, the material testing provided inconclusive results for cricket balls and batting gloves. For example, none of the materials were prime candidates for use in cricket gear and further testing that simulates the material in use if required. e.g. abrasion testing.
- LCA research and information will be necessary to verify the sustainability of materials.

4. Evaluation of Standards

4.1 Introduction

This section summarises the findings based on the evaluation of BSI and MCC/other standards for cricket balls and gloves to understand the interpretation of the term 'leather' and other relevant criteria/aspects for the project.

A key challenge for the VLCG project is the degree to which there is scope for innovation to achieve technical and performance standards with alternative materials which may be more sustainable.

4.2 Definition of leather

Sources and use for cricket gear.

In simple terms, leather is treated animal hide or skin. 87% of all leather produced and consumed in E&W is cow hide. Other leathers are produced from sheep and other animal hides. For cricket gear, leather used is also usually cow hide.

India is the largest exporter of cow hide leather and most cricket balls and gloves are produced in India. Around 80% of cricket balls and gloves produced in India use cow hide, with the remaining being produced from buffalo or ox hide, which are considered inferior[66].

For some manufacture of high-quality products, the leather is produced elsewhere, and final manufacture is in India. For example, Duke – a supplier of premium grade cricket balls - acquire their leather from farmers of Angus cows in Scotland as a by-product of meat production, have the leather tanned in Derbyshire, finished in East London and manufactured into cricket balls in India before being returned to the UK for packaging and distribution.

There are many types and grades of leather according to source, quality, physical characteristics (such as thickness, softness and moisture absorption). In the present context, for example Pittards[67] leather and chamois leather, both made from sheepskin, are often used for the palms of gloves because their softness and that provide porosity provide comfort, breathability and sweat absorption.

Characteristics and requirements for cricket gear

To understand typical characteristics and requirements of leathers in cricket gear – namely, balls and gloves – a standards body (BSI), a manufacturer (Gunn and Moore) and a test house (Sports Labs) were consulted.

The BS EN 15987:2022 ("Leather. Terminology. Key definitions for the leather trade") defines leather as:

- A protected term defined as "*hide or skin with its original fibrous structure more or less intact, tanned to be imputrescible, where the hair or wool may or may not have been removed… and where any surface coating or surface layer, however applied, is not thicker than 0.15 mm*".
- Stipulates that leather is of natural, animal origin, and that leather "*cannot be used in the denomination of man-made materials*".
- States that reconstituted leather also cannot be referred to as leather without qualification: '*if the tanned hide or skin is disintegrated mechanically and/or chemically into fibrous particles, small pieces or powders and then, with or without the*

[66] https://timesofindia.indiatimes.com/top-stories/howzat-cow-queers-pitch-for-cricket-balls/articleshow/53075463.cms

[67] As of September 2023, Pittards has filled for administration. See: https://www.bbc.co.uk/news/uk-england-somerset-66723600.

combination of a binding agent, is made into sheets or other forms, such sheets or forms are not leather'[68]

- States that these reconstituted materials may however be referred to as 'recycled fibre leather' if they have a minimum of 50% dry leather fibres.

These definitions are particularly important as the standards for cricket balls refer to 'leather' that meet these definitions. Notably, almost all of the over 100 biomaterials identified in this report 'self-identify' as being leather alternatives but cannot be classed or referred to as 'leathers' according to BS EN 15987:2022. 'Leather' is also a legally protected term in Belgium, France, Italy, Spain and Portugal, and the term 'vegan leather' has been banned in Portugal.[69]

Standard no.	Specification	Date published	Status
Balls			
BS 5993:1994	Specification for leather covered cricket balls. Specifies the construction details, quality and performance of cricket balls: Dimensions, mass, construction, manufacture, finish, marking, performance requirements and methods of test for four grades and three sizes of cricket balls.	15/01/1995	Current
Other protective equipment			
BS 6183-1:2000	Protective equipment for cricketers. General requirements.[70] Provides definitions, requirements and test procedures for cricketers' protective equipment. As well as marking requirements and information to be supplied with the equipment.	15/02/2000	Current
BS 6183-4:2001	Protective equipment for cricketers. Gloves for batsmen.	15/03/2001	Current

Table 4. British Standards for cricket gear

4.3 British Standards (BSI)

BSI in the UK has published a series of technical standards related to the production of cricket gear, specifically head protectors, gloves, pads and other protective equipment, and balls (there is no standard for bats which is regulated under the MCC laws of cricket).[71] The

[68] BS2780:2013 https://www.en-standard.eu/bs-2780-1983-a1-2013-glossary-of-leather-terms/
[69] https://www.thetimes.co.uk/article/portugal-bans-misleading-vegan-leather-term-p76njhb32
[70] This standard covers specifications for batting gloves, leg guards and boxes. See: https://knowledge.bsigroup.com/products/protective-equipment-for-cricketers-general-requirements?version=standard
[71] https://www.lords.org/mcc/the-laws-of-cricket

standards for 'soft' PPE have not been updated to align with developments in PPE regulations[72], specifically requirements for testing (see Section 4.4.2). However, BSI has initiated a revision process for cricket gear PPE, but this has currently stalled pending industry feedback. Table 4 shows current standards for cricket balls and protective gear relevant to gloves.

4.3.1 Balls

BS 5993:1994 ("Specification for cricket balls") specifies the construction and manufacture for the different grades of cricket balls. It requires the cover of the ball to be constructed from "*two or four pieces of alum-tanned leather enclosing a core*", where 'leather' is defined as per BS EN 15987:2022.

In terms of performance characteristics, the BSI standard specifies mass and dimensions/shape of the ball – the latter of which is actively regulated by umpires (and match referees in the professional game) in deciding whether a ball change is necessary during a game – as well as hardness, impact and wear resistance. However, these are measured for the product (i.e. ball), rather than component material.

Discussions with manufacturers (Gunn & Moore) and test houses (Sports Labs) has offered more insight into the key performance indices important for the selection of the leather cover material for balls:

Thickness

- Ball manufacturers normally receive leather at 4-4.5 mm thickness. During the processing it is then dried and compressed to ~3-3.5 mm thick, a thickness that is required for stitching with linen, wool or nylon yarn. This large thickness is an important criterion. The study by the University of Cambridge[73] found that procuring alternative leathers in such thickness is exceptionally difficult.

Density and mass per unit area

- Apart from thickness, the density and 'mass per unit area' of the leather are also typically recorded as key physical properties in a technical datasheet. Uniformity in these is important for a standardised product.

Mechanical properties

- A range of mechanical properties have been identified as being important for ball leather, including strength and elongation in tension, and abrasion behaviour (through a taber abraser[74] measuring mass of material lost over time). The tensile strength and elongation in particular are an important indicator of durability.

[72] https://www.bsigroup.com/en-GB/our-services/product-certification/industry-sector-schemes/personal-protective-equipment-ppe/

[73] https://cfsd.org.uk/wp-content/uploads/2023/04/Final_Players_Vegan_Cricket_Gear-27-04-23.pdf

[74] A taber abraser is an instrument that performs accelerated abrasion/wear testing using a standard test procedure. See https://www.taberindustries.com/taber-rotary-abraser

Other physical properties

- Water absorption, dimensional stability (contraction and expansion when exposed to different levels of humidity), and UV-stability (tested through changes in tensile strength after UV exposure) are other important tests to ascertain durability and environmental resistance.

Suitability for manufacturing processes

- Alternative leathers need to replicate leather's machinability, including flexibility, cutability and tear strength.
- The ability to be stitched is also important for the manufacture of the ball.
- Compatibility with lacquers that are already used is particularly important.

Acceptability to players

- In order to be accepted by the cricket community, the material needs to appear and feel like real (bovine) leather, as well as having an appropriate deterioration rate, scuffing properties and the ability to be polished.

Product- scale testing

The performance indices discussed above relate to the property of the leather material in isolation. Leather is only a part of the product and product-scale testing is even more critical than material-scale testing for product certification (e.g. CE marking)[75] purposes, such as in the case of balls and gloves.

- In particular, the compatibility of the leather casing with the core material (typically cork, rubber or cork-rubber composites[76]) is important.
- To determine the synergy between the two materials – the casing and the core materials – a vertical rebound test is used to determine energy restitution (by dropping the ball from a certain height and measuring rebound height). While not typically employed for cricket balls, repeat impact tests to measure evolution in shape and sphericity may also be informative.
- As the principal target applications for the identified PBVLs has been for fashion products, such a wide range of testing is not normally conducted. Typically, PBVLs are tested for strength and elongation in tension, water absorption and thickness.

4.3.2 Gloves

While BS 6183-4:2011 ("Protective equipment for cricketers —Part 4: Gloves for batsmen") does not specify that leather needs to be used for any part of the gloves, the palms of batting gloves are typically made from Pittards[77] leather, a specialist 'premium' performance leather made from sheep hide. For similar reasons, chamois leather, also made from sheep hide, is often used for wicket-keeper gloves.

Batting gloves

Features of batting gloves are as follows:

[75] CE marking – obtaining the certificate, EU requirements - Your Europe (europa.eu)

[76] https://onlinelibrary.wiley.com/doi/full/10.1002/jst.8

[77] However, it appears that cricket gear manufacturers are switching to the use of standard sheep and/or cow leather for gloves due to the high cost of Pittards leather and additional issues related to shipping.

- Gloves are multi-material products, and the Pittards leather palm is stitched to the other materials.
- The leather is treated with special water repellent[78] to protect the fibre structure against perspiration and maintain softness of leather over time[79], whilst also enabling a comfortable grip of the bat handle.
- Pittards leather is characterised with high tensile strength (and durability). Colour fastness, the pH, and the innocuousness and chromium VI content of the leather are expected to be defined, as per BS 6183-4:2011.

Wicket-keeping inner[80] gloves

While Pittards leather palms are commonly used for batting gloves, there appears to be a preference for chamois leather for wicket-keeper's inner gloves. This was confirmed by Gunn & Moore.

- Chamois leather is a highly porous leather with incredible water absorbency properties – it can absorb over 4 times its weight in water. It also has almost no abrasive properties. Therefore, a wicket-keeper can repeatedly handle the ball with the glove without damaging the ball surface.
- Chamois leather is also used in the palm of some wicket-keeping inners for added palm protection. Inners also contain cotton, mesh or other materials for cooling and other purposes.
- Chamois leather is commonly used in the automotive industry, including for cleaning and drying cars. While chamois leather was traditionally produced from the skin of the European chamois goat, today it is produced from sheepskin.
- The British Standard BS 6715:1991 defines chamois leather as, "leather made from the flesh split of sheepskin or lambskin, or from sheepskin or lambskin from which the grain (the top split) has been removed by frizzing, and tanned by processes involving oxidation of marine oils in the skin."

4.4 Other standards

4.4.1 MCC Laws

Professional cricket and high-level recreational club cricket is governed by the MCC Laws and Appendices to the Laws. However, while leagues sign up to the Laws of the game, 'friendly' games can be played outside of the Laws if this is agreed by captains on both sides. With respect to cricket gear, the Laws influence product design, manufacture, availability and use at all levels of the game.

The Laws include requirements for cricket gear as follows:

Law 4: The ball.

This law specifies sizes, weight and materials for hard balls made from leather, cork and twine. In this sense, the ball, when new, shall weigh no less than 5.5 ounces/155.9 g, and no more

[78] For further details, see: https://www.signature-leather.com/index.php/en/our-leather/about-our-leather
[79] https://www.pryzmcricket.co.uk/blogs/news/tagged/what-is-pittards-leather
[80] Wicket keeper 'inner' gloves are worn under the main wicket-keeping gloves to improve protection and performance.

than 5.75 ounces/163 g. Likewise, it shall measure no less than 8.81 in/22.4 cm, nor more than 9 in/22.9 cm in circumference.[81] The main aspects of the specifications are shown in Table 5.

As noted above, the use of white and pink balls is a small part of the total. These types of ball are not referenced in MCC Laws but are included in ICC Regulations in applying to international one day and T20 matches.

Standard practice in use varies with the level e.g.

- Recreational league cricket: 1 ball per innings
- The Hundred: One ball per 'end', so 2 balls per innings and 4 in total.

- The size and weight of the cricket ball in men's cricket.
- A slightly smaller and lighter ball is specified in women's cricket. (Weight: from 4.94 ounces/140 g to 5.31 ounces/151 g and circumference: from 8.25 in/21.0 cm to 8.88 in/22.5 cm.)[82]
- A slightly smaller and lighter ball is also used in junior cricket (Law 4.6).
- Only one ball is used at a time, unless it is lost, when it is replaced with a ball of similar wear.
- It is also replaced at the start of each innings, and may, at the request of the fielding side, be replaced with a new ball, after a minimum number of overs have been bowled as prescribed by the regulations under which the match is taking place. The gradual degradation of the ball through the innings is an important aspect of the game.

General

- External protective equipment is any visible item of apparel worn for protection against external blows.
- For a batsman, items permitted are a protective helmet, external leg guards (batting pads), batting gloves and, if visible, forearm guards.
- For a fielder, only a protective helmet is permitted, except in the case of a wicket keeper, for whom wicket-keeping pads and gloves are also permitted.
- A protective helmet is headwear made of hard material and designed to protect the head or the face or both. For the purposes of interpreting these Laws of Cricket, such a description will include faceguards.
- Equipment - a batsman's equipment is his/her bat as defined above, together with any external protective equipment he/she is wearing. A fielder's equipment is any external protective equipment that he/she is wearing.

Wicket-keeping gloves.

Restrictions on the size and design of the gloves worn by the wicket-keeper are stated in Appendix E, including specifications on permitted webbing, including a diagram showing requirements.

Table 5. Aspects of Law 4 on cricket balls and MCC requirements of protective equipment

[81] https://www.lords.org/mcc/the-laws-of-cricket/the-ball
[82] Ibid.

Protective equipment

Appendix 2 of the Laws defines protective equipment (Table 5). Appendix E of the Laws specifies restrictions on the size and design of the gloves used by the wicket-keeper, especially relating to webbing. The Laws do not specify the use of leather or other materials.

4.4.2 British Safety Industry Federation

BSIF is responsible for specifying regulations applying to Personal Protective Equipment (PPE) of any type. EU Regulation 2016/425 on Personal Protective Equipment (PPE) was directly applicable in the UK from 21 April 2018.[83]

- The enforcement system was implemented into UK law by the Personal Protective Equipment (Enforcement) Regulations 2018 (SI 2018 No. 390). The EU Withdrawal Act 2018 preserves these regulations and enables them to be amended so as to continue to function effectively now that the UK has left the EU.
- The Regulations state classifications and requirements according to risk. Under previous regulations, cricket gear 'softs' were classed as Category 1 and subject to self-declaration on testing and other requirements.
- The Regulations are enforced through local authority trading standards bodies.

BSIF has stated (and confirmed in 2021) that all PPE worn in cricket, including as leg pads (batting and wicket-keeping), gloves (batting and wicket-keeping), body protection as well as helmets, etc. falls within scope of the PPE Regulation and is classified as Category II PPE. This means that:

- All products need to be conformity assessed by an independent body (design and performance) in line with the Category II rules detailed within the Regulation.
- All economic operators within the supply chain must ensure that PPE placed on, and made available to the market, meets the essential safety requirements of the Regulation.
- Products also need to be appropriately labelled, including the CE mark (or relevant UK Conformity Assessment for UK and Northern Ireland (UKCA)/UKNI mark) and be accompanied by the required documentation, such as a Declaration of Conformity and Instructions for Use in a language likely to be understood by a wearer. All suppliers of PPE, whether they are a manufacturer or brand owner, importer or retailer (distributor), must be aware of the legal obligations applicable to their role in the supply chain and ensure they comply with the Regulation.
- Products must be retested for chemical safety if there is a change in the use of colour.
- Helmets must not be used if they have been compromised.

There has been wide objection by the cricket gear sector in E&W to this classification for PPE other than for helmets, on the grounds that requiring it for 'softs' is imposing high costs with minimal safety benefits, and that Category 1 is more appropriate.

[83] British Safety Industry Federation (2021) Cricket PPE Cricket PPE | BSIF. Accessed 4 June 2022.

4.5 Conclusions on standards

The current combination of standards and norms currently restricts PBVL and other alternative leathers from being used officially for cricket balls but do not restrict their use in batting or wicket-keeping gloves and 'inner' gloves.

5. Research into Performance Characteristics

5.1 Introduction

This section summarises research conducted by UoC into performance characteristics. A summary of the results is presented here. Detailed results are presented in the report by UoC[84] (see Section 2.4.2).

In conducting materials testing, the limitations of PBVL and other alternatives were recognised. This reinforced the findings from a 2021 research paper - entitled '*Comparison of the Technical Performance of Leather, Artificial Leather, and Trendy Alternatives'*[85] - that examined nine leather alternatives, that found that none of the PBVL or other alternatives matched the universal performance of bovine leather regarding 5 key properties: tensile strength, tear resistance, flex resistance, water vapour permeability and water vapour absorption[86].

5.2 Preliminary materials testing

Over the course of the project, two types of testing were conducted:

- Tensile testing to measure strength and elongation in tension, and
- Contact angle analysis to measure wettability and absorption behaviour.

Discussions with Sports Labs revealed that tensile testing is an important standard test conducted to determine the performance of a material, and a key piece of information in a technical datasheet for the material.

For preliminary testing, two varieties each of four leather alternative materials were procured:

- Piñatex (Pineapple leaf based, Ananas Anam),
- BarkTex (Other plant-based material, BarkTex),
- Bananatex (Leaf-based, QWSTION) and
- Hide Biotech leather (Fish scales-based)

Piñatex was found to have the most publicly available information, including LCA and material datasheets. Hide Biotech leather was the only leather found to be sufficiently thick for cricket ball applications (>3.5mm thick). Piñatex, Bananatex and Hide Biotech leathers all had a backing material (for additional tear resistance). While Piñatex, BarkTex and Bananatex are fibrous materials with a textile appearance and feel, the Hide Biotech leathers are reconstituted materials, more uniform, and act more like an extendable material.

[84] Taylor, B., & Shah, D.U., (2023). Leather Alternatives for Cricket Gear. Available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

[85] https://www.mdpi.com/2079-6412/11/2/226

[86] Ibid.

5.3 Tensile testing method

The selection of the method for tensile testing can influence the findings and make comparison between literature or datasets difficult or invalid. For example, tests carried out at different loading (i.e. tensioning) speeds are likely to have different results and therefore are not readily comparable.

Various standard methods were considered by UoC when designing the tensile testing method. BS EN ISO 3376:2020 describes the tensile testing of leather and uses an elongation speed of 100 mm/min. However, 'textile' or fibre-based leather alternatives tend to use different tensile testing methods. Piñatex, one of the few leather alternative materials for which data is publicly available, uses the standard grab tensile test for nonwovens (based on BS EN ISO 9073-18:2008). This test involves pulling a 25mm wide and 100mm long strip to failure. It was noted that this method was likely to induce premature failure at or near the grip.

After considering these various standards, a method to conduct tensile testing was devised in the UoC's 's Department of Engineering. Tests were carried out using a 2kN load sensor, as no leather alternatives with publicly available data had maximum failure loads over 1kN (100 kg force). A slow 10 mm/min loading (i.e. elongation) speed was used to enable data collection at a reasonable rate. To prevent slippage of samples in the grip during testing, serrated grips were used to hold the fabric at the clamp. To prevent the materials from being damaged at the serrated grips, the material was held in paper card tabs. On a few of the less fibrous samples (e.g. Hide Biotech material), samples were cut into a dogbone shape to encourage failure at the middle of the sample, away from the grip.

5.4 Results and discussion

For each material, force was plotted against displacement and stress was plotted against strain. Appendix B of the UoC report (see Section 24.2) contains the graphs for all of the materials tested. This was used to determine failure loads (tensile strength), and elongation (failure strain).

The Hide Biotech samples had the highest elongation and toughness (ability to withstand fracture). The Bananatex samples were found to be the strongest (highest force at failure). BTX H919-100-002 was the thickest Banantex sample and had the highest breaking force (over 500N) of all the materials tested. BTX 0903-110-002 was a thinner Banantex sample and had the highest breaking stress for its mass (as opposed to breaking force).

Since the UoC testing method has not yet been applied to bovine leather it is not possible to comment on the meaning of these results in the context of the potential application to cricket gear. At present, as the type and parameters of a testing method influences the results, it is not possible to compare the findings with those in the literature. Therefore, the results can only be used to compare the leather alternatives tested.

The main point of interest is the variety of failure mechanisms that these materials exhibited. This is why the testing procedure had to be altered to each specific material.

- The Piñatex and BarkTex samples suffered permanent deformation at failure.
- The Bananatex did not extend very far but appears to have contracted back to its original length.

- The Hide BioTech material reached a very large extension and then, upon failure, contracted immediately back to its original length. The Hide Biotech material appears to behave more as an extendable material, whereas the other three materials have a failure typical of fibrous textiles.

The testing also revealed information about the integrity of all the material types:

- Upon cutting, the edges of the Bananatex samples frayed as individual fibres separated themselves from the woven structure.
- The BarkTex materials also frayed with fibres splintering off due to cutting.
- The Piñatex material was easier to cut as the backing material held the pineapple leaf fibres.
- The same was true for the Hide BioTech materials however the thickness of those samples meant the use of scissors or scalpels to create smooth lines was more difficult.
- Only the Hide BioTech red leather was thick enough to withstand the stitching that would be required in the ball manufacturing process. The effects of stitching on that material were not investigated and the material type is not substitutable for bovine leather in hard cricket balls.

5.5 Conclusions

The scope of the testing was limited by:

- Availability of materials for testing, given industry reluctance to provide samples.
- Availability of materials with potentially suitable properties, given the focus of the PBVL and other leather alternatives on the fashion market.
- The lack of information on materials.
- Time and funding availability.

Nevertheless, some conclusions can be drawn:

- Compared to bovine leather, the alternative materials tested showed limitations in absorption, deterioration and thickness. This highlighted the fact that a suitable material will not just need to demonstrate optimal properties in physical testing, but also to replicate the properties of animal leather as closely as possible.
- These limitations are especially the case for balls where performance requirements are demanding. Furthermore, even if performance requirements could be met PBVL cannot currently be used for cricket balls due to constraints within standards (as noted above).
- The test results do not preclude the use of PBVL for batting and wicket-keeping glove palms and inners where performance requirements are less demanding and where the standards also do not specify that leather must be used.
- Although cricket boots and shoes have not been included in this study, some similar conclusions can be drawn on potential suitability according to performance demands: Current PBVL may not be sufficiently robust for bowlers' boots but might be acceptable for batters' shoes and boots.

6. Disassembly, Life Cycle Assessment and Refurbishment

6.1 Disassembly

As noted above, it was not possible to obtain a manufacturer's specification of cricket batting gloves and so a disassembly exercise was conducted to ascertain material content. The components for a pair of batting gloves are shown in Image 1 and Table 7.

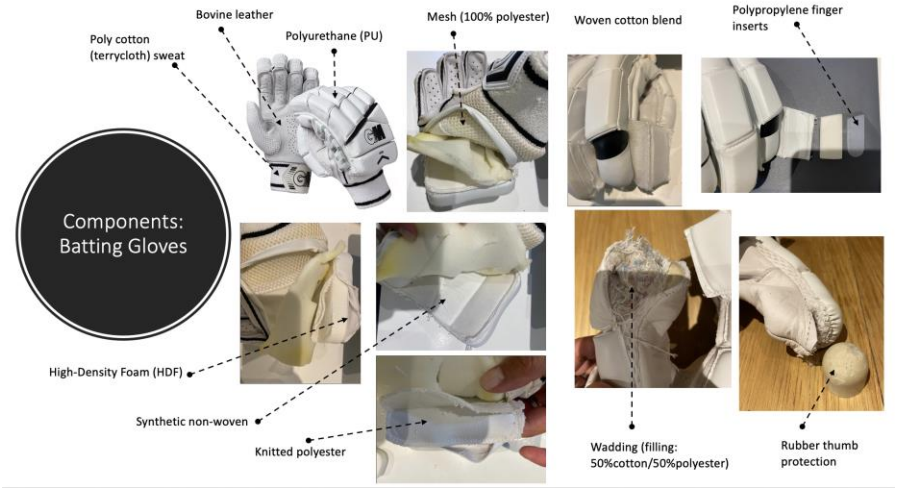

Image 1: Disassembly of cricket batting gloves

Components	Materials	Quantities	Performance/functional requirements
Palm	• Leather • Plastics- based fixings such as Velcro	2g leather	Durable/lightweight/flexible
Back	• Polyurethane (PU) • Mesh: 100% polyester • Woven cotton blend lining • Knitted polyester		Breathable/flexible
Padding	• High density foam (HDF)		Impact protection
Fingers	• Poron XRD (Performance PU)	<1g	Impact protection/ integrity/ lightweight/flexible
	• Rubber thumb protector	12g	
	• Polypropylene finger inserts	<1g	
	• Wadding (finger/filling protection) 50% cotton, 50% polyester	<1g	

Table 7 Batting gloves: Materials

The preliminary findings for batting gloves are:

- The size and shape of components/materials appear to be cut using precise moulds.
- No waste was identified within the product.

- Based on the material properties required for the batting glove, the palm appears to be the component that is most likely to deteriorate during use.

6.2 Life Cycle Assessment and Product Sustainability Framework

The VLCG project aimed to conduct a life cycle assessment (LCA) for gloves, but this was postponed due to internal/organisational challenges and timescales which meant that the software licence was only available at the end of the project. In a separate project, a streamlined LCA was conducted for a pair of batting pads[87] which provided lessons for future LCAs of batting gloves:

- Focus on strategies to extend the life of the product so that the average duration (e.g. years) of use can be extended, or parts/components can be replaced, while evaluating the trade-offs between life extension and the use of more resource-intensive materials.
- Focus on strategies to extend the life of the high-density foam (HDF) used for the internal protective padding, and polyester used for lining and mesh, through reuse, repair or refurbishment.
- Conduct further streamlined LCAs on different product scenarios to evaluate if the recommendations presented above lead to a reduction in the product's environmental impact.

In the absence of the ability to complete an LCA within the VLCG project, a Product Sustainability Framework (PSF) assessment was conducted on a pair of batting gloves.[88] The PSF is a framework methodology that aims to provide guidance for assessing product sustainability. The PSF assesses social, economic, and environmental aspects of a product in relation to three focus areas outlined below:

- Product performance: what does the product/functionality contribute to society and the well-being of society and individuals.
- Provenance in the supply chain: production and component history including, for example, responsible sourcing/employment across the supply chain.
- Legacy of the product: the longer-term impacts arising from the product stages including results from LCA studies and/or circular economy/resource efficiency considerations.

Furthermore, the PSF aims to stimulate product life cycle thinking and consider what aspects and/or attributes of a product add positive social value (improves quality of life/benefit to society), and which aspects may have negative impacts or trade-offs of impacts perhaps in different categories or at different stages of the product life cycle.

The PSF is publicly unavailable as it is currently under development by Dr Louis Brimacombe. However, the framework has proven useful to qualitatively evaluate some of the trades-offs associated with replacing the bovine leather used for the palms in cricket batting gloves with a PBVL. More specifically, for the purpose of the VLCG project, the use of the PSF focused on

[87] https://cfsd.org.uk/wp-content/uploads/2023/05/Final-Streamlined-LCA_batting-pads.pdf
[88] The full report is available at: https://cfsd.org.uk/wp-content/uploads/2023/09/Product-Sustainability-Framework-Cricket-Batting-Gloves-Palm-July-2023.pdf

a scenario-based analysis in which bovine leather was replaced specifically with Piñatex pineapple leather.

Due to the qualitative nature of the PSF, the findings should be considered as indicative rather than definitive. Nonetheless, the assessment highlighted that while the overall performance of the product under a PBVL scenario appears to be reduced when compared to the use of bovine leather, the products overall 'provenance in the supply chain' is substantially improved. Additionally, there appears to be an improvement in relation to the product's legacy, specifically in relation to the material's carbon footprint and overall waste. Lastly, the PSF highlighted some of the data required to conducting a further qualitative assessment.

The tables below highlight the topics that were considered across the 3 areas of the PSF (product performance, provenance in the supply chain and legacy of the product). The relevant topics for each area described above, were selected based on a qualitative evaluation of their relevance in relation to a pair of cricket batting gloves. After identifying the various subtopics, these were subsequently evaluated in terms of importance to the user and sustainability considerations. The column next to 'importance' indicates how well the current and proposed products comply with each sub-topic, the following column provides a score for data reliability. For example, if the level of confidence in the data is low, this in turn suggests that further research into quantitative data is required.

Table 8 indicates that the main product performance considerations for a pair of batting gloves are: protection, user comfort, grip, weight, breathability and sweat absorption, with the least important being appearance. Within this context, material substitution on the palm is unlikely to affect protection. Therefore, the level of protection provided by the glove is thought to be the same for palms using bovine leather and palms using Piñatex. Likewise, the product's appearance using Piñatex is expected to remain similar to the bovine leather gloves. However, due to the Piñatex's material composition[89], it is anticipated that breathability, sweat absorption, and grip characteristics will be significantly reduced. Therefore, this could potentially be considered as a deal breaker for the application of this material to replace the use of bovine leather on the palms of cricket batting gloves. Lastly, it is important to highlight that due to the evaluation being speculative or a scenario-based study, the findings presented here are primarily based on assumptions and should therefore be treated as indicative rather than definitive.

[89] Further details on the material composition of Piñatex can be found in the final report on leather alternatives for cricket gear. Available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

				Case A: Bovine leather		Case B: Vegan leather (piñatex)	
Performance: what does the product/functionality contribute to society and the well-being of society and individuals? Social value to the user		**Topic**	**Importance**	**Score** **10=good** **1=poor**	**Confidence:** This is related to existing/available documentation to support score **10= high** **1=low**	**Score** **10=good** **1=poor**	**Confidence** **10= high** **1=low**
	1	Comfort/user	10	9	8	8	Unknown
	2	Functionality (e.g., grip, weight)	10	9/10	9	7	Unknown
	3	Breathability/sweat absorption	10	7	7	5	Unknown
	4	Safety/protection of hands	9	9	8	9	Unknown
	5	Convenience/straps	9	8	8	8	Unknown
	6	Product brand/appearance	7	8/9	9	8/9	Unknown
	7	Affordability/cost	9	7/8	8	6/7	Unknown

Table 8: Product Sustainability Framework-Performance

Table 9 indicates that the main considerations for provenance in the supply chain for a pair of cricket batting gloves are employer rights, worker conditions, and human rights amongst producers and material suppliers across the supply chain. Particularly within this context, it was identified that the material proposed for the palm of the batting gloves (Piñatex) appears to perform better in relation to employer rights, worker conditions and human rights consideration.

				Case A: Bovine leather		Case B: Vegan leather	
Provenance in the supply chain: Production and component history including, for example, responsible sourcing/employment across the supply chain.		**Topic**	**Importance**	**Score** **10=good** **1=poor**	**Confidence** **10= high** **1=low**	**Score** **10=good** **1=poor**	**Confidence** **10= high** **1=low**
	1	Employee rights (fair wages)	8	5 (unknown)	5 (U)	8	8
	2	ESG report	5	6 (unknown)	6 (U)	Unknown	9
	3	Supply chain	8	6 (unknown)	6 (U)	8	9
	4	Human rights	8 (DB-Deal breaker)	6 (unknown)	6 (U)	8	9
	5	Education/training records	4	6 (unknown)	6 (U)	8	8
	6	Animal welfare	6	6 (unknown)	6 (U)	10	10
	7	Accreditation Responsible sourcing	7	Unknown	6 (u)	10	8

Table 9: Product Sustainability Framework-Provenance in the supply chain

The main reason for this is that Ananas Anam[90], the company that produces Piñatex, provides public access to data pertaining to its manufacturing process and supply chain. Accessing data related to the manufacturing process and supply chain for traditional cricket gear, has been a challenge not only for implementing the PSF methodology, but throughout the overall VLCG project. As such, based on the lack of supply chain data for traditional cricket gear using bovine leather, Case A has been assigned a low score for provenance in the supply chain.

Table 10 highlights the main considerations for the cricket batting gloves' legacy, which are: durability and carbon footprint as well as water footprint. In this regard, the bovine leather gloves were assigned a higher durability score compared to the Piñatex scenario. Aligned to this, the player survey conducted as part of the VLCG project indicated that based on 42 respondents, 38% of players kept their gear for more than 8 seasons, followed by 36% keeping it for 2-3 seasons, which indicates that traditional gear appears to be highly durable.[91] Furthermore, the same survey indicated that the reliability and durability of PBVLs was perceived to be low by users. Early studies conducted by the University of Cambridge on alternative leathers for cricket gear concluded that in its current state, the PBVL (Piñatex) proposed for this study is not suitable for replacing bovine leather in gloves. Hence the low score assigned for durability (see Table 3) as part of this PSF study. However, the carbon and water footprint of gloves using the proposed PBVL scored significantly higher compared to traditional gloves utilising bovine leather; as the proposed PBVL is made from a by-product from the pineapple industry which requires less water and chemical usage for processing, compared to the leather industry.[92] Lastly, neither of the options presented in this analysis appear to be recyclable, thus receiving an equally low score for this category.

[90] https://www.ananas-anam.com/about-us/

[91] Player survey report available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final_Players_Vegan_Cricket_Gear-27-04-23.pdf

[92] It is worth mentioning here that the pineapple fibres used to produce Piñatex are sourced in the Philippines and then shipped by boat to Italy or Spain for a specialised finishing. Thus, indicating that the material potentially contains a high embedded carbon. However, according to Ananas Anam's latest Impact Report, preventing pineapple waste from being landfilled and incinerated prevents 2794 tons of CO2 emissions which suggest that the overall embedded carbon from material sourcing could be offset by the CO2 emission saving from recovering pineapple waste. Source: https://www.ananas-anam.com/about-us/#:~:text=The%20Manufacturing%20Process%20of%20Pi%C3%B1atex&text=After%20pineapple%20harvest%2C%20the%20suitable,rainy%20season%20in%20drying%20ovens

				Case A: Bovine leather		Case B: Vegan leather	
Legacy of the product: The longer-term impacts arising from the product stages including results from LCA studies and/or circular economy/resource efficiency considerations.			**Importance**	**Score** **10=good** **1=poor**	**Confidence** **10= high** **1=low**	**Score** **10=good** **1=poor**	**Confidence** **10= high** **1=low**
	1	Durability/how long the product is kept in use	9	7	8	3	5
	2	Recyclable/reuse	8	1	10	3	5
	3	Carbon footprint	9	5	8	8	8
	4	Transport impact in supply chain	6	3	9	3	5
	5	Water footprint	9	3	8	8	5
	6	Total waste	9	5	8	8	5
	7	Plastic to ocean	8	4	8	8	5

Table 10: Product Sustainability Framework-Legacy of the product

6.3 Refurbishing a 'right-hand' batting glove using 'vegan' chamois leather

6.3.1 Introduction

A study was carried out to assess the feasibility refurbishing[93] a pair of cricket batting gloves to extend the product's use phase using a 'vegan' leather to replace bovine leather. The 'vegan' chamois leather chosen for the refurbishment study based on a discussion of desktop batting pad prototype developed with by a vegan cricketer, Gary Shacklady from Earley Cricket Club. The 'chamois' leather was sourced from Halfords where the application was for cleaning windows. There is little information on the material, but Halford's website previously indicated that it was composed of 80% polyester and 20% viscose; however, this information was later removed from the website. This material was not identified and/or tested by UoC within testing as it emerged after UoC had completed their supplier research and it is not a PBVL; and, PBVL 'chamois' leathers had not emerged as a specific materials category. The material was used for prototype due to its commercial availability, and the difficulties of identifying and accessing other appropriate plant-based samples to produce a prototype.

The prototype development of a refurbished batting glove palm provided:

- Insight into the most common product related faults that result in the disposal of cricket batting gloves
- An overview of the challenges faced when attempting to refurbish a pair of cricket batting gloves
- Initial recommendations for potential design improvements to enable the extension of the product's lifecycle.

There are batting gloves designed for left-handed and right-handed players. The exercise was completed on a pair of right-handed gloves. It was decided that the study would be based

[93] Refurbished as indicated in the 10Rs in Cramer, J. 2017. The Raw Materials Transition in the Amsterdam Metropolitan Area: Added Value for the Economy, Well-Being and the Environment, Environment. 59, 3: 14-21

solely on the refurbishment of a right-hand glove, as this is the one that showed more signs of wear and tear due to the gloves being previously owned by a right-handed player.

A detailed report has been prepared separately.[94] This section summarises the conduct, results, and key learnings.

6.3.2 The refurbishment process

The following section highlights the process for refurbishing the cricket batting glove palm:

Product in use

- A pair of used batting gloves were donated by a male recreational club cricket player who plays high standard league cricket.
- The player was asked to provide details on the use phase e.g. playing using the prototype batting gloves, which included how many seasons the gloves were used, how they were looked after and stored.

Identified areas of wear and tear

- While the study focused mainly on the refurbishment of the right-hand glove (for a right-handed player), for comparative purposes, areas of wear and tear were identified for both right- and left-hand gloves. Wear and tear include discolouration, holes, tearing of stitching and exposure of padding (see Image 1 below).
- A further wear and tear consideration is the odour resulting from repeated sweating/drying while in use (playing). This mainly affects the back of the palm (polyester) and the protective padding (HDF), which come into direct contact with the player for extended periods of time.

Disassembly Process

- Based on the product related failures/signs of wear and tear identified, the palm and thumb were refurbished by:
    a) Disassembling of the palm and thumb as a single component using a seam ripper.
    b) Separating the thumb from the palm.
    c) Separating the thumb into individual components (leather and rubber thumb protector)
- The rubber thumb protector was intact and therefore was reutilised within the refurbished thumb.

Refurbishment

- The pattern for the palm was produced using the silhouette of the existing palm, leaving a 0.5 cm seam allowance.
- Likewise, a pattern was used for tracing the thumb section to be replaced with the synthetic chamois leather.
- The palm and thumb sections were sewn by hand, as using an industrial sewing machine was not viable due to the limited space in between the fingers.
- The palm was then attached to overall glove structure.

[94] https://cfsd.org.uk/projects/vlcg/research/

Image 2: Wear and tear analysis of a pair of cricket batting gloves

Image 3: Final refurbished gloves using a vegan chamois leather.

6.3.3 Key learnings and recommendations

- The total time for producing the refurbished prototype of one right-hand glove was 3 hours. This included de-stitching, cutting the patterns and sewing the various components. The estimated time for refurbishing of the left-hand glove is similar.
- De-stitching/unpicking the palm was surprisingly easy due to the thinning of the material after use. Timewise, this process was relatively fast, as after a few cuts through the thread, the palm could be torn off.
- Regarding the level of wear and tear of the various components, the thumb protector remained intact. Therefore, it is recommended to explore further strategies for recovering and reusing this component, either for product

refurbishment or for manufacturing new gloves. However, further research into implementing a collection/recovery/harvesting of components is required. For example, based on the disassembly of cricket pads, plastic knee protectors were identified as a similar opportunity for the recovery of components.[95]

- The batting glove thumb was reconstructed partially, by replacing only the leather with holes. An initial concept proposal might be to design the cricket gloves for disassembly and make components available to users.
- Whilst removing the palm from the overall batting glove was straightforward and time efficient (3-5 minutes), sewing on the other hand, took approximately 2.5 hours. Therefore, for refurbishment to be viable, further research on alternatives to sewing or speeding up the sewing process is required.
- The protection on the back of the palm also showed significant deterioration. It is thus recommended for the textile (polyester) to be replaced and/or identify a solution to avoid sweat related decolouration and odour. Nonetheless, this deterioration does not appear to affect the product's performance.
- A further suggestion for tackling sweat related stains and odour is to perhaps use Polygiene[96] technology and implement design solutions that facilitate product maintenance such as drying and washing the product. Additionally, further research into alternative textiles that have deodorisation properties such as bamboo fibres is recommended.

6.3.4 Refurbished glove: player/user feedback

The refurbished glove was then returned to the original user (player) for testing (See Image 3 below). The player provided the following feedback:

- The odour of the gloves remains problematic. The player indicated that this is probably one of the main key issues related to refurbished gloves.
- The gloves using the alternative 'chamois' leather is "a little too thick, compared to other gloves I've worn". However, the player indicated that this may be due to personal preference, more than anything else.
- Furthermore, it was highlighted that thickness and breathability of the material may be an issue for the warmer months of the year.
- The feel and comfort of the gloves were not as good as conventional batting gloves e.g. they "don't feel quite right in the hand".
- Towards the end of the batting session (about an hour and 10 mins of wear) the gloves started to fray, which indicated that the material does not possess the required mechanical properties.

[95] See report: Sanchez-Moreno & Charter (2023), "Streamlined Life cycle Assessment: Pair of Cricket Batting Pads". Available at: https://cfsd.org.uk/wp-content/uploads/2023/05/Final-Streamlined-LCA_batting-pads.pdf

[96] https://polygiene.com

Image 4: feedback/testing the refurbished gloves.

6.3.5 Wicket-Keeper Inner Gloves Prototype

A prototype for a pair of wicket-keeping 'inner gloves' using the same synthetic vegan chamois leather as the refurbished batting gloves was produced to manufacturing standards (see image below). This pair of 'inner gloves' was tested by a professional player and the brand/manufacturer reported that there was "no real feedback as such, certainly nothing adverse anyway". Furthermore, the player did not report any notable differences compared his usual 'inner gloves', which can be viewed as positive feedback. However, gaining more specific feedback from the brand/manufacturer was not achieved.

Image 5: vegan chamois leather wicket keeper 'inner' gloves produced by cricket gear manufacturer.

6.3.6 Visual Concepts for Further Prototype Development using PBVL

The table below provides 4 visual concepts for further prototype development of batting gloves using PBVL. The first column highlights some of the technical and functional requirements for batting gloves, which are currently met by gloves using bovine leather. Subsequently, each of the materials selected for the visual concepts (i.e., synthetic chamois leather, Piñatex, Bannatex and BarkTex) are qualitatively evaluated against each requirement based on expert knowledge.[97] For requirements indicated as unknown, specific material testing is recommended to assess further the viability of substituting the use of bovine leather

[97] "Y" has been used to indicate that the technical requirement is met and "N" to indicate that the material does not satisfy the relevant requirement.

with the selected material. It is important to highlight here, that in the case of Piñatex, as indicated in the visual, the PBVL has been implemented on the back of the glove to replace the current use of PU leather. The study conducted by the UoC identified that Pinatex is currently not suitable for the palm due to its composition which does not offer efficient absorption, breathability, or flexibility.[98] Overall, the table below indicates that the selected PBVL do not match existing bovine leather breathability and absorption properties. Likewise, the table shows that both Banantex and Barktex do not match the aesthetics and feel of bovine leather which could hinder their potential use.

	Bovine leather	**Synthetic chamois leather**	**Piñatex**	**Bananatex**	**BarkTex**
					
					
Technical requirements	Y	Unknown	Unknown	Unknown	Unknown
Aesthetics	Y	Y	Y	N	N
Touch	Y	Y	Y	N	N
Durability	Y	Starts to fray after 3-4 hours of use	Unknown	Unknown	Unknown
Absorption	Y	Y	N	Y	Unknown
Breathability	Y	Feedback suggests that the material is too thick	N	Unknown	Unknown
Flexibility	Y	Y	Y	Y	Unknown
Protection	Y	Y	Y	Unknown	Unknown
Grip	Y	Y	Unknown	Unknown	Unknown
Overall performance	Y	Not equivalent to traditional bovine leather gloves	Unknown	Unknown	Unknown

Table 11: visual concepts for cricket batting gloves using a PBVL

[98] https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

7. Main Conclusions and Recommendations

7.1 Main conclusions

The main conclusions are as follows:

Market for cricket gear

- The study confirmed the lack of market data for cricket gear and the difficulty in estimating the quantity of leather consumption and therefore potential for substitution with alternatives.
- Nevertheless, a figure of approximately 100 tonnes of annual leather consumption for balls and gloves has been derived from estimates of use in matches at all levels of play in E&W, of which around 86% is for balls.

Player survey

- The players surveyed did not view the use of leather as a significant negative environmental impact compared to, for example, the carbon footprint of the supply chain.
- There were overall positive attitudes to the use of PBVL but presently there is a lack of trust in its performance for cricket gear. It would have to perform as well as leather.

PBVL alternatives market

- The PBVL industry is significant and fast growing but information is limited as most of the companies' materials are either in research and development stages or are being produced on a small scale.
- Available alternative materials for cricket gear are limited, with most targeting the fashion sector and not intended for comparable use ad performance.

Standards

- The current combination of standards currently restricts alternative leathers from being used officially for cricket balls. As currently, BS EN 15987:2022 defines leather as being composed of natural, animal origin, and "*cannot be used in the denomination of man-made materials*". However, there is potential flexibility in use of the materials for batting and wicket-keeping gloves.

Testing and materials performance

Due to a lack of access to material samples, the materials testing completed by UoC were limited to 4 materials. The findings from the materials testing are outlined below:

- Other than strength and elongation, most of the alternatives could not be produced to the thickness (>3mm) desired for cricket balls.
- All showed limitations in physical properties and performance, especially for use in cricket balls, which are also constrained by standards requirements.
- The materials testing results (and standards requirements) did not preclude the possible use of PBVLs in batting and wicket-keeping gloves and 'inner' gloves.

Refurbishment

A study was set up to refurbish a 'right-handed' batting gloves using a 'vegan' chamois leather to replace the use of bovine leather on the palm. A 'vegan' chamois leather composed of 80% polyester and 20% viscose was chosen due to practical considerations such as availability and

other the challenges associated with obtaining PBVL samples.[99] Overall, the exercise demonstrated the technical feasibility for refurbishing a batting glove as well as providing insight into common product failures that lead to the disposal of cricket batting gloves. The refurbished glove was tested by a high-standard league player who indicated that after 1.5 hours of use (play), the vegan chamois leather started to fray. This indicated that the vegan 'chamois' leather does not possess the technical and functional performance requirements for cricket batting gloves. Further research is required to identify more suitable materials, optimise the refurbishment process, explore component recovery strategies, and improve the durability and maintenance of gloves.

Life Cycle Assessment (LCA) and Product Sustainability Framework (PSF)

While an LCA was not included in the study due to challenges associated with gaining access to software and a delay in the development of ORIENTING LCSA[100] beta software, a streamlined LCA on cricket pads provided an overview of the main areas of environmental concern related to a cricket product's lifecycle. Typically, the highest impact is the manufacturing stage as most of the materials used are from virgin non-renewable sources. Sustainability strategies should, therefore, focus on extending product life of batting gloves while simultaneously evaluating the trade-offs between life extension and the use of less resource-intensive materials. The use of PSF delivered useful insights into some of the trade-offs associated with the replacement of bovine leather in cricket gloves with a PBVL: providing broader sustainability perspective. The PSF assessment was based on a comparative scenario in which Piñatex pineapple leather was used for the palm of the glove. While the overall performance of the gloves using Piñatex appears to be reduced compared to bovine leather, the assessment emphasises the importance of considering the product's contribution to society and individual well-being. For example, the analysis indicated that the use of Piñatex significantly improves the supply chain provenance of the batting gloves. This includes responsible sourcing and employment practices that are employed by Ananas Anam throughout production. Moreover, the assessment highlighted that the use of Piñatex could potentially lead to an improved environmental impact in terms of the material's carbon footprint. Further research is required to quantitively assess the potential benefits of replacing bovine leather with PBVLs in cricket gear.

7.2 Recommendations

The VLCG project consisted of a series of research activities to inform improved understanding of the potential use of vegan leather for the development of cricket gear, which later progressed to primarily the use of PBVL in cricket gear. The main recommendations from the research outputs are as follows:

Market research

Better market information is needed to assess potential markets.

- Market information on cricket gear consumption to enable the confirmation of the quantities of leather used.

[99] The challenges associated with obtaining PBVL samples were also raised in the study conducted by UoC on Leather Alternatives for Cricket Gear. Available at: https://cfsd.org.uk/wp-content/uploads/2023/04/Final-Vegan-leather-alternatives-22-4-23.pdf

[100] https://orienting.eu

- Market information on PBVL materials and supply to increase the understanding of existing producers.

Cooperation between stakeholders in providing information which is not commercially sensitive will be beneficial.

Further research into players' attitudes to PBVL will be beneficial. A follow-up survey should:

- Address why there is a gap between lack of environmental concern in relation to bovine leather in cricket gear and interest in PBVL alternatives.
- Research the attitudes of younger and female cohorts of players.

Further research into materials performance

Further research should focus primarily on the following:

- Potential use in gloves, since standards preclude use in balls, and performance requirements for balls are more challenging.
- Improved data on materials and manufacturing process to research and foster innovation in manufacturing processes for PBVL.
- Further investigations should be conducted into the microstructure of the materials; any links between the materials' microstructures and macroscopic properties should then be identified. These links will then inform future development of new materials allowing for more streamlined innovation.
- Development of a tensile testing method that can be applied consistently to all materials, despite the materials' variability. This testing method should then be applied to a wide range of materials, ideally at least one from each category in the classification. It should also be applied to a bovine leather sample which will provide benchmark results for comparison.
- This testing should attempt to mimic the use of the cricket gear in practice but in doing so should be informed by standard leather testing procedures where possible.
- LCAs should be conducted to compare the relative sustainability benefits of any materials identified as potential leather substitutes. This should include an assessment of their circularity and manufacturability. The cost and supply-chain of PBVLs needs further clarity, both of which impact the feasibility of manufacture.

Life Cycle Assessment and the Product Sustainability Framework

- Further LCA's and sustainability assessments should be conducted to firstly, benchmark the environmental impact of current cricket batting gloves and secondly, to gain an in-depth understanding of the trade-offs associated with the replacement of bovine leather with various PBVL options.

Disassembly, refurbishment, and prototyping

- The disassembly and analysis of current cricket gear will also be useful to help quantify how much material is used in various components. This would inform estimates of the quantity of various sustainable materials that would be required to replace these different components.
- The technical and economic feasibility of refurbishment should be further researched to assess the sustainability benefits.

- Prototyping may also reveal insights on the manufacturability with some of the alternative leathers (e.g. stitching).

Collaboration by cricket gear manufacturers

Cricket gear manufacturers should look to collaborate with and support PBVL companies to accelerate their growth.

- Currently, many companies are producing what seem to be very similar materials and so it could potentially be beneficial to encourage collaboration between such companies.
- Combining resources and expertise of multiple companies could lead to rapid development of materials that could be integrated into current manufacturing processes in the near future.

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