CAPTURING THE ENVIRONMENTAL IMPACT OF LEATHER CHEMICALS

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Abstract. Product Environmental Footprint Category Rules (PEFCRs) for calculating the environmental impact of leather manufacturing were approved by the European Commission in 2018. Chemicals are key input data for this methodology, given leather's chemically intensive makeup. The increasing use of non-petrochemical materials represents an important part of industry-wide efforts to reduce overall environmental impact. Though still in its infancy, research and commercial use of renewable raw materials for leather chemicals is expected to accelerate in the coming years, especially with regard to understanding the environmental impact of bio-based products. Indeed, when decisions are made to substitute fossil fuel-derived products with alternative bio-based versions, a common assumption is that a reduction in environmental footprint will accompany that substitution. However, reports have been published that challenge this view[1,2,3]. The aim of this paper is to provide an overview of environmental impact data for bio-based polyurethanes and to interpret the data in order to make better decisions about further research and product design.

1 Introduction

Life Cycle Assessment Methodology (LCA) is widely recognized as the most effective way to calculate the environmental impact of a product, given that it tracks the impact of each element of the manufacture and transportation of that product from its origin to the end of life. The resulting data can be categorized and reported in an Environmental Product Declaration (EPD), which can be used by manufacturers to summarize the environmental impact of their products in a harmonized and standardized way.

The impact of chemicals is critical input when undertaking LCA methodology for leather manufacturing - a highly chemical-intensive process. This paper shows that the environmental impact data of different polyurethanes can vary within the same environmental category. It also suggests that the environmental impact of using renewable resources to reduce greenhouse gas emissions should not be evaluated in isolation.

2 Bio-based Polyurethane Dispersions

Polyurethane dispersions (also known as PUDs) are often used in the finishing step of leather manufacturing. They are typically formulated as the base resin for complex coatings formulations which are applied to the surface of the leather during in the final stages of its manufacture. These aqueous polyurethane coatings contribute to the long term durability, touch and aesthetic properties that characterize the finished leather that we know as consumers.

A typical PUD polymer is made up of many raw materials but in large part it is formed by the reaction of di-isocyanates with polyols to form a pre-polymer which is dispersed into water under controlled conditions. In recent years, new polyol raw materials have been made available that are derived from renewable resources instead of fossil fuels. These polyols are typically based on sugar, corn, rapeseed, soy, palm or other related plants which are processed by the biotechnology industry. Our research has developed to the point where the bio-based content of a PUD can reach levels of 40-60% of the solids of that polymer dispersion, while still maintaining the desired performance in the final coating. Several such bio-based polyurethanes have been developed based on this principle.

Several cradle-to-gate environmental impact studies comparing bio-based PUDs and fossil fuel based PUD equivalents have been performed based on accepted LCA methodology and guidelines in which the manufacturing of the product, and that of its raw materials, were taken into account, ie: not the end of life. The data overview presented here is indicative, not conclusive, and is based on several of the LCA studies observed.

3 Main Findings

Given that they are derived from a natural and renewable resource, it could be assumed that a bio-based PUD will automatically have a lower environmental footprint than a fossil fuel based PUD. However, the findings show that this is not necessarily the case. The impact of using bio-based polyurethanes depends on the environmental category chosen, and on the source of the bio-based material used.

For example, in Fig. 1, it can be seen that the impact on climate change is lower (ie: better) for the bio-based PUDs than for the fossil fuel based PUDs. As expected, the LCA database allocates the manufacturing of fossil fuel based polyols as having a higher greenhouse gas emissions factor than their bio-based equivalents, hence the higher climate change impact.

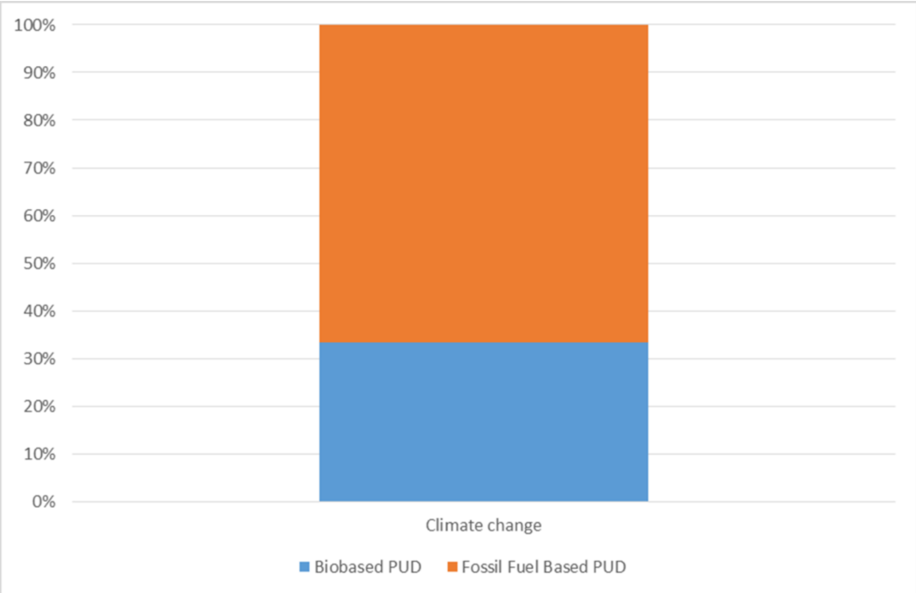

Fig. 1. Illustration of the relative impact on Climate Change of bio-based PUDs and fossil fuel based PUDs.

Conversely, Fig. 2 shows that the impact of manufacturing bio-based PUDs on land use is significantly higher than that of its fossil fuel equivalent. The likely reason for this is that most bio-based polyols are derived from plants which are grown for industrial use. This activity occupies areas of cropland that are farmed and irrigated - activities that have an impact on land use (and water quality). This latter point may also account for the relatively high impact on eutrophication of the bio-based PUDs shown in Fig. 3.

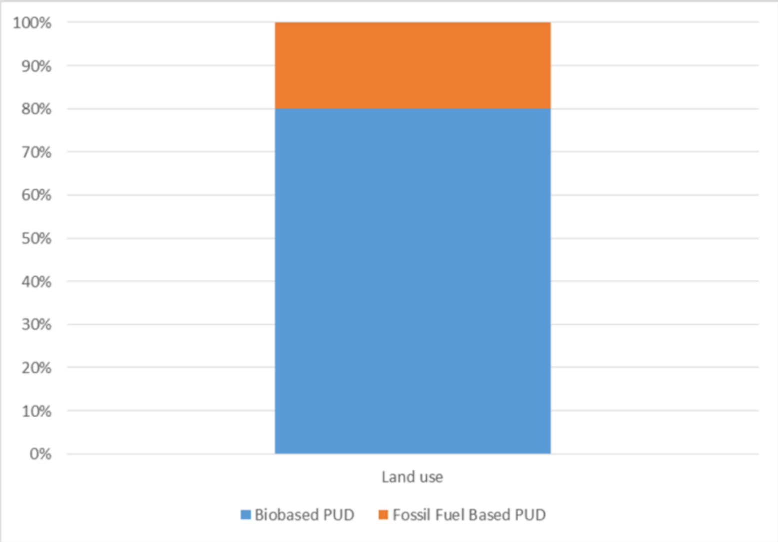

Fig. 2. Illustration of the relative impact on Land Use of bio-based PUDs and fossil fuel based PUDs.

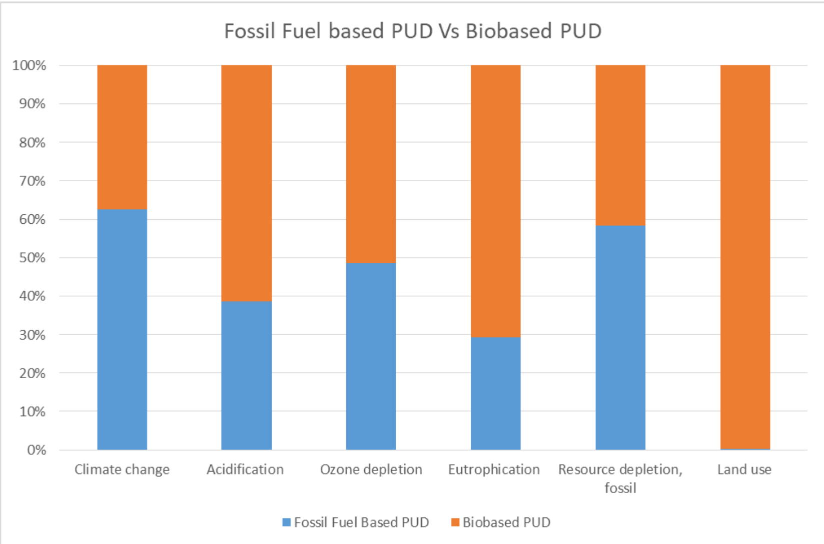

Fig. 3. Illustration of the environmental Impact comparison of fossil fuel based PUDs vs bio-based PUDs, for selected environmental categories.

Although the graphs are illustrations of indicative data, the impact of manufacturing bio-based polyurethanes is not consistently positive or negative across environmental categories. What is good for climate change is not necessarily good for land use, and so on.

Additional notes:

a) The origin of plant-based biomaterials (ie: chemical or geographical origin) is a variable in the determination of their environmental impact and was not included in these illustrations, ie: different plants require different extraction methods and process techniques in order to be able to use their derivatives industrially. Similarly, if a polyol or its raw material is sourced from the other side of the world to where the polyurethane is manufactured, then the environmental impact of its transportation is taken into account in the calculation.

b) Biotech industry processing: How renewable materials are processed (usually by the biotech industry) is also a determining factor in their environmental footprint, and much research is being done in areas like carbon capture and alternative energy use for this reason.

c) Waste streams: If a bio-based raw material were derived from a natural waste stream (eg: biomass), then its impact on land use will be significantly reduced when compared to that of a primary bio-based product that has been extracted from a plant that was exclusively cultivated for industrial use (as in this case). Research into waste stream technology like this has not yet reached a commercial stage in polyurethanes, but work has begun.

d) C-14 content: The bio-based content (also known as C-14 content) of the PUDs in the graphs is 20-25%. Higher C-14 content will increase bio-based impact on the chosen environmental categories proportionally. Bio-based content of above 40% can now be achieved for PUDs of this type and are also being studied for their environmental impact.

4. Conclusions

Choosing bio-based raw materials over fossil fuel-based products does not necessarily reduce the overall environment footprint of polyurethane dispersions (PUD) used in leather finishing. However, if climate change is considered in isolation, there is a marked advantage in using bio-based polyurethanes, especially if their C-14 content is high. Conversely, if an improvement in land use impact is desired, using bio-based materials derived from plants that are grown exclusively for industrial purpose does not appear to be the best choice.

Given the ever-increasing importance of measuring and reducing the environmental impact of chemicals and leather, the opportunity for further research on this topic is high. It is hoped that the introduction of LCA methodology will trigger more focussed innovation, now that the environmental impact can be predicted before decisions on product design are made.

The development of bio-based raw materials for leather chemicals, though still in its infancy, represents a critical step in the move away from fossil fuels and towards a more circular economy. Developing a generation of even lower impact alternatives, based on biomass or other waste streams, appears to be the next move.

References

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