Vegan Leather Guide Part 1: Monomers

What exactly is vegan leather? Get to know all about mushroom leather, mycelium and other bio-based monomers

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Animal leather is one of the most ancient materials used by humans and was considered a social status symbol for a long time.[1] However, nowadays this material is no longer in line with the times. There has been a significant change in public opinion in relation to the production of traditional leather. This is due to a growing awareness of the cruelty of factory farming, the social conditions for workers during leather production and the consumption of resources. According to the HIGG Index, which compares different textile materials in terms of their environmental impact, animal leather is the third most harmful material in existence. Consumers are increasingly looking for alternatives, making it necessary for the fashion industry to rethink its approach.

As a result, alternatives to animal leather are increasingly conquering the market. Brands, including luxury brands like Gucci and sportswear manufacturers like Adidas, are launching a growing number of products made from non-animal leather, following in the footsteps of Stella McCartney, who has been using vegan leather since she founded her label in 2001. According to Infinium Global Research's February 2021 market report, the global vegan leather market is expected to reach a compound annual growth rate (CAGR) of 48,1 percent over the forecast period from 2020 to 2026.[2]

With the variety of new materials entering the market every year, it is difficult to keep track of them all. In addition, reporting on the various synthetic and so-called plant-based alternatives is often inaccurate, misleading or simply greenwashing. Not every

[1] Meyer et al., 2021, pp. 1-2.
[2] https://www.infiniumglobalresearch.com/consumer-goods-packaging/global-vegan-leather-market#tab-1

non-animal leather is also a vegan leather, as materials from animals – such as glue and dye – may also be used in the production process. Neither does every vegan leather have the same properties and environmental impact, as the production methods are quite different.

As a label that specializes in vegan leather, we of course keep a close eye on the market and are constantly testing new developments. The following article therefore aims to create order, to disentangle the prevailing confusion of definitions and to give an overview of the different types of leather. In Part 1 of our Vegan Leather Guide, we will first examine mono-materials (also called monomers), which include animal leather and new material developments made from mycelium or collagen.

Apple leather? Pineapple leather? But what does that mean? Learn more about coated materials in part 2 of our Vegan Leather Guide. At the very end of the article you will also find an overview table with the most important characteristics of the most well-known vegan leathers.

Animal leather

Production: Before we take a closer look at the various vegan leathers, let's briefly return to the original product: Animal leather is still referred to as a "natural product" in articles and vegan leather is praised for its ethical superiority, but criticized in terms of sustainability.

Animal leather ranks among the so-called mono-materials and is made from the skins of animals. The skin of the animals (usually cows, goats or sheep, but also exotic animals like crocodiles and snakes) is first preserved, then soaked to clean and rehydrated. After that, components such as hair or flesh are removed. Next, the animal skin is dehydrated, pickled and degreased. In a complex process, the hide is then tanned, further processed and later usually dyed. After about 20-40 process steps, the result is a robust, relatively flexible and water- and dirt-repellent material.[3]

Performance: The final product thus in fact has relatively little to do with the "natural product" of animal skin. Instead, each of these steps is designed to keep a biological

[3] Kumar at al., 2021, pp. 5-9.

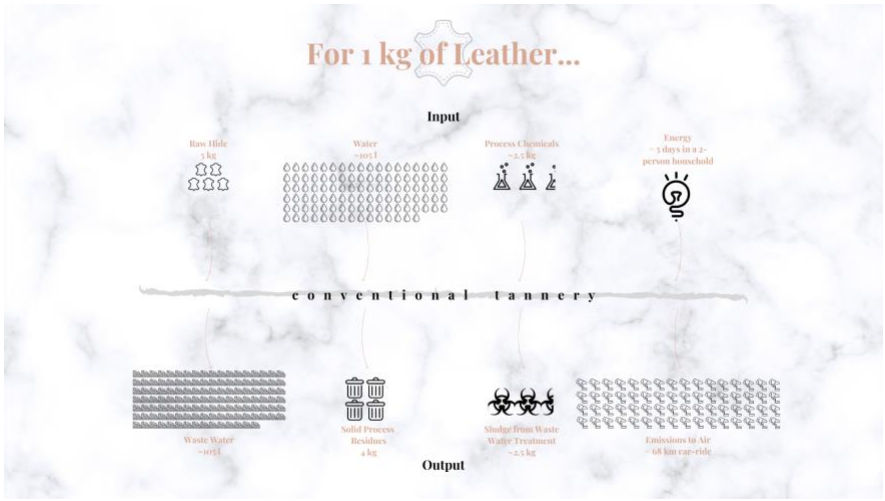
material from decomposing and to make it last as long as possible. In addition, animal leather is often, if not mostly, coated with polyurethane or other synthetic materials to even out imperfections in the structure and make it more durable against moisture and humidity.[4] Take a closer look at the leather when shopping: if the graining is identical and uniform at all parts of the product, it may well be that the material is coated. A coating up to 0.15 mm is not subject to declaration, so the material may still be called leather.

Sustainability: Animal leather also scores poorly in terms of environmental impact: The hides have to be tanned before they can be used as textile goods. If the hides were not treated with often toxic chemicals such as chromium, they would decompose and become unusable for further processing.[5] The manufacturing process consumes an enormous amount of water and causes high CO2 emissions. This results in environmentally harmful, non-biodegradable waste products[6], such as tannin-containing wastewater[7] or chemical containing solid wastes like raw hides or flesh.[8] Moreover, more than 70% of animal skins are processed in developing countries, where the lack of wastewater systems means that toxic waste ends up in the groundwater.[9]

Disposal: Biodegradation of most animal leather is also severely limited after use,[10] and recycling is not technologically feasible or economically viable.[11] So animal leather is currently either landfilled or incinerated.[12]

[4] European Commission, 2013, pp. 22-24; p. 54; p. 57.
[5] Notarnicola, 2011, pp. 172-174; Navarro et al., 2020, p. 4.
[6] European Commission, 2013, pp. 54-55.
[7] He, 2007, p. 1.
[8] Ferreira, 2020, p. 1091.
[9] Navarro et al., 2020, p. 4.
[10] He, 2007, p. 465; Priebe, 2016, p. 2; Guida et al., 2019, p. 1.
[11] Pringle, 2016, pp. 546-648.
[12] Pringle, 2016, p. 546.

Figure 1: Leather Production In- and Output per 1 kg of Leather



Source: own presentation.[13]

Read more about animal leather in our detailed article "The 5 most popular myths about animal leather".

Bio-based vegan leather made from a mono-material.

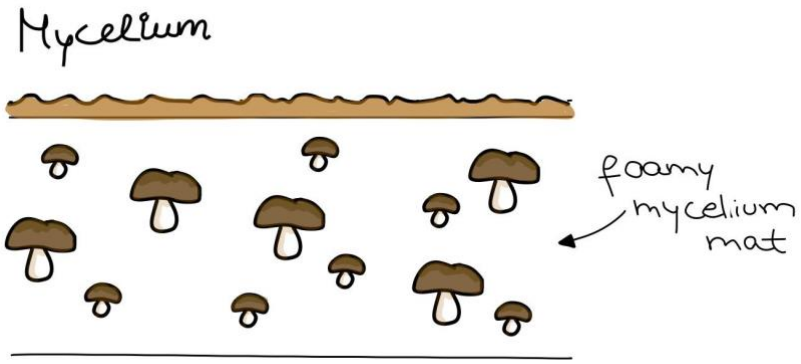
There are some companies developing materials that mimic animal skin as a raw material in the leather process. These materials can then be made durable and adapted in their physical properties by either mechanical or chemical processes. Cellulose-containing materials, collagen or fungal biomass are used for this purpose.[14] The main goal is to replace animal or synthetic raw materials with biological ones. In the following, we present some of these innovations in more detail.

Mycelium Leather

Production: In the making of "mushroom leather" from mycelium, mushroom cells are grown into mycelium, a net-like biological mass. Mycelia are structures of the fungus that usually grow underground and are therefore less well known than the superficial fungal body. The mycelium produces a foam-like mat that can then be processed in chemical and mechanical processes to produce a leather-like material.

[13] Flow diagram following European Commission, 2013, p. 47. Numbers calculated based on Notarnicola, 2011, pp. 172-174.
[14] Jones et al., 2020, p. 2.

Figure 2: Mycelium leather material cross-section



Source: own illustration.[15]

Performance: MycoWorks, which manufactures mycelium leather marketed under the product name Reishi, has commissioned extensive testing of material strength, durability and color fastness. The results show that the mycelium leather has similar properties to animal leather. The "Reishi High Strength" material even outperforms animal leather – in this case, a polyester carrier and coating were applied.

Sustainability: The companies MycoWorks and BoltThreads use sawdust, a waste product from forestry, to grow mycelium. Thereby, the foam-like mats can be produced in 4-9 days.[16] Since the mycelium grows in a naturally biological process and does not require light to grow, the environmental impact should be correspondingly low.[17] Mushrooms absorb and store CO_2 as they grow, so the process is CO_2-neutral.[18] The subsequent processing of the mats into leather consumes resources – which depend on the selected processes of the manufacturer. BoltThreads, for example, states that they work with leather tanneries that have to meet special requirements in terms of sustainability. However, more in-depth information is not publicly available.

Disposal: Mycelium is a natural, biodegradable material.[19] In order to determine the biodegradability or recyclability of the end product, it is necessary to consider the

[15] Illustration of the material cross-section of Mycelium leather, based on Meyer et al., 2021, pp. 5-6.
[16] Kaplan-Bie, 2018.
[17] Jones et al., 2020, p. 2.
[18] Jones et al., 2020, p. 2.
[19] Jones et al., 2020, p. 2.

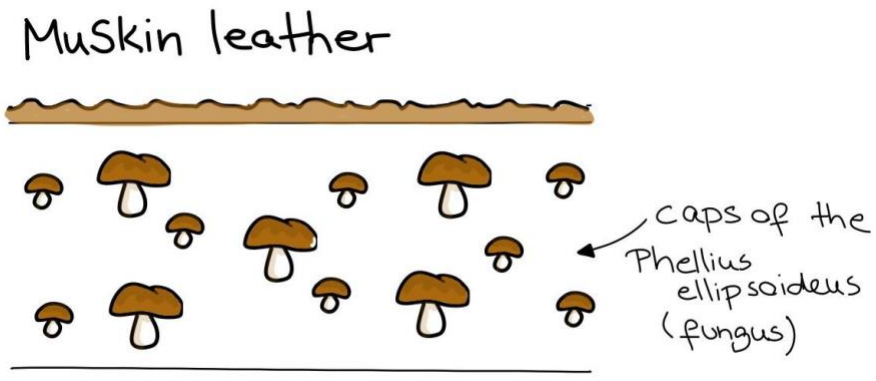
chemical processes used or, if applicable, the dyes and coatings selected. This is another area where information is still lacking.

Deployment in the fashion industry: Bolt Threads, the company developing the material Mylo, has raised approximately USD 218 million after 4 investment rounds. In addition, Mylo is part of a consortium with Adidas, Kering, Lululemon and Stella McCartney. At Paris Fashion Week, Stella McCartney showed a handbag made of Mylo on the runway for the first time. Initial products are expected to be launched "soon." Outside of the consortium, however, the material has not yet been made available. The company MycoWorks, which markets its mushroom leather under the name Reishi, is still in development and does not yet distribute its leather-like material. As exciting as these material sounds from an ethical and sustainable point of view, we still have to be patient until the market launches!

Muskin Mushroom Leather

Production: Muskin is a leather made from the caps of the Phellinus ellipsoideus. After extraction, the caps are cut into thin slices before being treated in chemical and mechanical processes similar to those used for animal leather. However, the leather can currently only be produced in small quantities, so it is not very suitable for industrial purposes.[20]

Figure 3: Muskin leather material cross-section



Source: own illustration.[21]

[20] Kumar at al., 2021, p. 51.
[21] Illustration of the material cross-section of Muskin leather, based on Meyer et al., 2021, pp. 5-6.

Performance: Muskin leather offers special properties such as antibacterial action and moisture management. Although the manufacturer states that the material does not have the mechanical properties of animal leather. However, it can be combined with carrier materials or waxes to improve the performance.

Sustainability: The fungus used to make Muskin is harvested from nature. According to the manufacturer, the material is treated without toxic substances and is plastic-free. Further information on the environmental impact of the manufacturing process has not been ascertainable.

Disposal: Since the material is completely natural in origin, it should be biologically degradable. However, this may change depending on whether and how it is bonded to textile backers or which waxes and dyes are used.

Deployment in the fashion industry: Muskin is manufactured in Italy by Grado Zero Innovation. At the moment, production is only possible in small quantities of 40-50 pieces per month, which is why it is not suitable for industrial purposes, but for special one-off pieces.[22] Besides, it is not produced in running meters, but only in individual pieces – so one is dependent on the size of the mushroom, similar to the hide size for animal leather.

Other vegan leathers in development

Modern Meadow, a biotech startup from the U.S., follows a different path: It develops collagen - the basic building block of animal skin - directly in the laboratory. In the early stages of development, skin cells were cultivated in the lab for this purpose. In the meantime, a specific yeast strain is fed with sugar in a fermentation process, which directly produces collagen.

The benefit: Whereas traditional leather production processes are designed to remove all substances that do not consist of collagen from the animal skin, Modern Meadow produces the collagen directly. The raw material can then be used in the same way known for cow hides in the leather industry – which is why it is possible to revert to

[22] Kumar at al., 2021, p. 51; https://www.gzinnovation.eu/files/Upload/5a0ebc70269c4-MuSkin-en-1711.pdf.

previous processing techniques – only without animals.[23] In April, the company closed its third round of financing with an investment volume of USD 130 million. The material is still in the development phase and is not yet available to designers or end consumers.

Along with the mono-materials discussed in more detail in this article, there are a variety of coated materials that are used instead of animal leather. These are materials that consist of a carrier such as cotton and one or more coatings. You can find all the information about materials such as apple leather, cactus leather or pineapple leather in our second part of the Vegan Leather Guide.

[23] Kansara, 2017, https://www.businessoffashion.com/articles/technology/bof-exclusive-with-lab-grown-leather-modern-meadow-is-bio-engineering-a-fashion-revolution.

Comparison table *

	Animal leather	Mycelium leather (Mycelium)	Muskin mushroom leather	Synthetic leather (PU)	Plant Synthetic Hybrid	Mirum
Production/ Technology	Animal skin is processed into leather in chemical and mechanical processes	Net-like biological mass (mycelium) is processed into leather-like material in a chemical + mechanical process	Caps of the phelli-nus ellipsoideus are treated in a chemical + mechanical process similar to animal leather	Textile backing (cotton / polyester) + synthetic poly layer	Textile backing (cotton / polyester) + polymer layer Part of the base material or coating is replaced by plant fibers.	Textile backing (organic cotton) + coating Coating and adhesives of 100% of plant and organic origin
Performance	Good performance due to coating + coloring Otherwise not durable against moisture and water	Similar properties as animal leather Material "Reishi High Strength" surpasses animal leather in mechanical measurements	Antibacterial effect, moisture-regulating Must be combined with textile backer/waxes to increase resistance	Quality and properties can be configured almost freely	Similar to the visual and haptic properties of leather Little to no scientific data on mechanical measurements	Haptic and visual properties comparable to animal leather Few to no scientific data on mechanical measured values
Sustainability of raw material extraction	- High environmental impact in the rearing and slaughter of animals	+ Mycelium grows in CO_2-neutral process. + Mycelium growth low requirements (grows on waste products, no light required).	+ Mushroom is harvested in nature + cannot be cultivated according to the manufacturer	- Resource-intensive crude oil production	+ Part of fossil raw materials replaced by agricultural waste	+ Raw materials partly waste materials from other industries (e.g. cork)
Sustainability of the manu-facturing process	- Enormous consumption of resources in production (chemicals, water, CO2) - Harmful waste products (e.g. chromium) - In developing countries (approx. 70% of production volume) insufficient waste management	- Processing into leather consumes resources depending on manufacturing process	+ Treated without toxic substances + plastic-free - Processing into leather consumes resources depending on manufacturing process	- Depending on textile carrier (polyester / cotton / ...) + type of coating. + Production on average more resource-efficient than animal leather production	- Depending on textile carrier (polyester / cotton / ...) + type of coating	+ CO2 emissions and energy consumption lower than animal and synthetic leather (manufacturer's specification) + No water consumption during production
Environ-mental impact based on LCA data?	According to HIGG Index approx. 5x as high environmental impact as synthetic leather; third most damaging textile material ever Other scientific studies: 2-5x as high environmental impact as synthetic leather	Insufficient data on the overall process to date	Insufficient data on the overall process to date	According to HIGG index approx. 5x lower environmental impact as animal leather Other scientific studies: 2-5x lower environmental impact as animal leather	Insufficient data on the overall process to date	Insufficient data on the overall process to date
Disposal	Limited biodegradability Enormous waste volume, partly difficult / not bio-logically degradable Recycling not technically / economically feasible	Biodegradability and recyclability depend on the processes, inks and coatings used. hardly any information from the manufacturer	Biodegradability and recyclability depend on the processes, inks and coatings used.	Limited biodegradability No recycling in practice	Limited biodegradability No recycling in practice Recycling of mixed materials (plant + PU) generally more difficult	Developed for the circular economy: technical cycle and compostable
Deployment in the Fashion industry	Established on the market	So far only used in pilot projects, currently not available on the market	Currently not applicable for industrial purposes	Established on the market	In the process of establishing itself on the market	First prototypes, no products on the market

* Disclaimer for table: Partially no values available for comparison, as there are rarely reliable studies.

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